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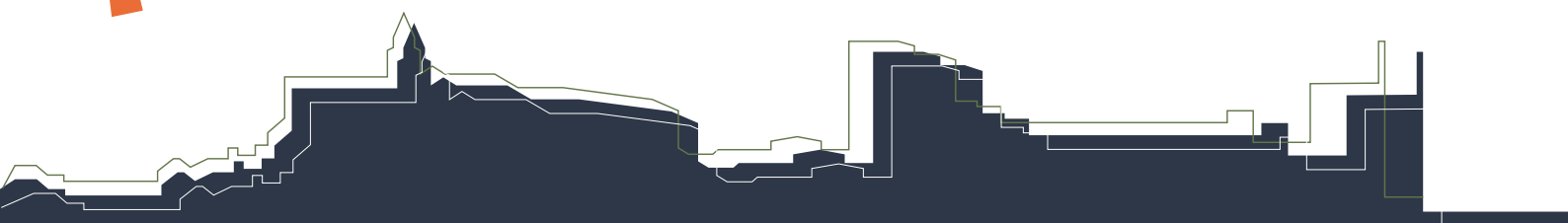
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! PROGRAM



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TOPICS

CONFERENCE TOPICS

- T1. Colloid and Interface Science for Biomedical Applications and Biomaterials
- T2. Colloid and Interface Science in Industry, Environment, Sustainability, Cosmetics and Food
- T3. Colloids at Interfaces, Membranes, Films, Emulsions, and Foams
- T4. Micro-, Nano-, Optofluidics, and Rheology of Complex Fluids
- T5. Wetting Phenomena, Superhydrophobicity, Capillary, and Surface Interactions
- T6. Active and Bioinspired Soft Materials
- T7. Polymers, Polyelectrolytes, Gels, Micro/Hydrogels, Glasses, and Liquid Crystals
- T8. Dynamics, Stability, Self-Assembly, and Phase Behavior of Complex Fluids
- T9. Individual and Collective Behaviors of Colloids under External Fields

SPECIAL SESSIONS

- S1. Machine Learning and AI-Based Methods for Colloids and Interfaces
- S2. Scattering, Imaging, and Other Analytical Techniques Applied to Colloids and Interfaces

DAY 1 - MONDAY 07/09/2026

Time	Main Auditorium (Paraninfo)	Lecture Hall (Salón de Actos)	Room 1	Room 2
08:00 - 08:20	Registration			
08:20 - 08:40	Welcome reception			
08:40 - 09:30	PLENARY TALK PL1 Eleonora Secchi (ETH Zurich, Switzerland) <i>Nonlinear rheology and mass transport in bacterial biofilms: a polymer-network perspective</i> CHAIR: Irene Adroher-Benitez (University of Granada, Spain)			
09:30 - 10:00	COFFEE BREAK			
	CHAIR: Jordi Faraudo (ICMAB-CSIC, Barcelona, Spain)	CHAIR: Dorota Matyszcwka (University of Warsaw, Poland)	CHAIR: Kai Sothewes (University of Twente, Netherlands)	CHAIR: Eduardo Marques (University of Porto, Portugal)
10:00 - 10:15	KEYNOTE T3-K1 Monika Österberg (Aalto University, Finland) <i>Role of interfacial interactions in unlocking the full potential of plant-based nanomaterials</i>	T1-O1 Agata Michalska (University of Warsaw, Poland) <i>Towards drug delivery systems triggered by ion-selective interactions</i>	T2-O1 Biganska Olga (L'Oréal Research and Innovation, France) <i>Multiscale engineering of green oregano essential oil delivery: From interfacial control to deep skin imaging and clinical efficacy</i>	T6-O1 Quinn Besford (Leibniz-Institut für Polymerforschung Dresden e.V., Germany) <i>The sweetest polymer nanoparticles: Opportunities ahead for glycogen in nanomedicine</i>
10:15 - 10:30		T1-O2 Fatemeh Soleimani (The Institute for Advanced Chemistry of Catalonia (IQAC-CSIC), Spain) <i>Hexosomes and cubosomes from PDMS-PEG block copolymers as potential drug carriers</i>	T2-O2 Arunitha Koodaliedathil Sreepakash (University of Twente, Netherlands) <i>Coalescence of droplets stabilized by potato protease inhibitor: Microfluidic investigation on the effect of temperature and adsorption time on protein functionality</i>	T6-O2 Isabelle Feller (ETH Zurich, Switzerland) <i>Programmable fabrication of biohybrid microswimmers: Templated spore outgrowth using polar-localized membrane-nanobody fusion proteins</i>
10:30 - 10:45	T3-O1 Gijs Konings (Wageningen University, Netherlands) <i>Adhesive nanoparticles control emulsion properties via tuneable interdroplet linking</i>	KEYNOTE T1-K1 Costanza Montis (University of Florence, Italy) <i>Multiphase lipid nanoparticles: Exploiting topological frustration for enhanced nucleic acid delivery</i>	T2-O3 Anna Tarrats-Duran (Universitat Ramon Llull - Institut Químic de Sarrià, Spain) <i>Sustainable, microplastic-free encapsulation of lipophilic fragrances using sodium alginate for cosmetic formulations</i>	T6-O3 Haichao Wu (Shanghai Jiao Tong University, China) <i>Anomalous transport phenomena of active particles in porous media</i>
10:45 - 11:00	T3-O2 Joao Victor Mattioni (University of Sao Paulo, Brazil) <i>Towards active bijels: Prussian-blue stabilized bicontinuous emulsions as electrode modifiers</i>		T2-O4 Kosuke Sano (Tohoku University, Japan) <i>Controlled self-organization of gold nanorods in aqueous dispersion via surface modification with oligo(ethylene glycol)-based ligands</i>	T6-O4 Miriam Martinez (Universitat de Barcelona, Spain) <i>Insect dynamics: Motion and fluctuations</i>
11:00 - 11:15	T3-O3 Jesse Steenhoff (Van 't Hoff Laboratory for Physical and Colloid Chemistry, Netherlands) <i>Understanding the structure of bicontinuous, particle-stabilised emulsions</i>	T1-O3 Roncin Hugo (CEA Paris-Saclay, France) <i>Fate of self-assembled squalene non-lamellar liquid crystalline nanoparticles acting as painkillers in a biomimetic medium assessed by scattering techniques</i>	KEYNOTE T2-K1 Amanda Ellis (The University of Melbourne, Australia) <i>Metal phenolic network nanolayer coatings on cathode active materials for lithium ion battery performance</i>	T6-O5 Salvatore Lombardo (Universidad de Girona, Spain) <i>Decoupling interfacial and bulk stabilization in natural wax Pickering emulgels using cellulose nanofibers</i>
11:15 - 11:30	T3-O4 Véronique Schmitt (Centre de Recherche Paul Pascal CNRS U-Bordeaux, France) <i>Control of partial coalescence in solid-oil-in-water emulsions as a tool to tune the texture</i>	T1-O4 Marina Ayala (Universidad de Valladolid, Spain) <i>Bioinspired engineering of surface coatings for protein corona control</i>		T6-O6 Eleftheria Diamanti (National Hellenic Research Foundation, Greece) <i>Enzyme-activated polymeric composite hydrogels for enhanced transdermal delivery of encapsulated phycocyanin</i>
11:30 - 11:45	T3-O5 Steven Armes (University of Sheffield, United Kingdom) <i>Where colloid science meets space science: Synthetic mimics for nitrogen-based polycyclic aromatic hydrocarbon cosmic dust</i>	T1-O5 Aaron Elbourne (RMIT University, Australia) <i>Ultra-small gold nanoparticle adsorption and uptake is directed by bio-membrane composition</i>	T2-O5 Margarida Esteves (University of Coimbra, Portugal) <i>From waste to interface: Tuning amino acid surfactants derived from used cooking oils</i>	KEYNOTE T6-K1 Andrij Pich (DWI Leibniz Institute for Interactive Materials, Germany) <i>Functional compartmentalized anisotropic colloidal gels</i>
11:45 - 12:00	T3-O6 Minke Yang (Bioproducts Institute, Canada) <i>Dual jamming of bio-based CNC-stabilized bijel fibers via continuous solvent transfer induced phase separation</i>	T1-O6 Mingrui Liao (The University of Manchester, United Kingdom) <i>The role of supramolecular aggregation for cationic peptide in fast bacterial killing</i>	T2-O6 Rondepierre Gaelle (L'Oréal Research and Innovation, France) <i>Diffusion kinetics of dyes out of hair fibre: Link with fibre properties and impact on cosmetic performances</i>	
12:00 - 12:15	T3-O7 Adeline Perro (ISM, France) <i>Stimuli-responsive microgels-based capsules constructed from all-aqueous coacervate droplets</i>	T1-O7 Marta Gallo (Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU), Germany) <i>pH dependence of the structure of drug-free lipid nanoparticle dispersions (LNPs)</i>	T2-O7 Christin Krämer (Institut de Chimie Séparative de Marcoule, France) <i>U(VI)-Si colloids: Metastable phases that should not be overlooked in the environment</i>	T6-O7 Jaime Gabriel Trazo (Laboratoire de Physique des Solides (LPS) / Université Paris-Saclay, France) <i>Photoswitchable and valence-free plasmonic superstructures by depletion-induced self-assembly</i>

12:15 - 13:45	LUNCH BREAK			
	CHAIR: Minghan Hu (ETH Zurich, Switzerland)	CHAIR: Eleonora Secchi (ETH Zurich, Switzerland)	CHAIR: Monika Österberg (Aalto University, Finland)	CHAIR: Ilaria Clemente (University of Siena, Italy)
13:45 - 14:00	T3-08 Gerhard Nägele (Forschungszentrum Jülich GmbH, Germany) <i>Modeling crossflow filtration: Effect of shear on particles-enriched polarization and cake layers</i>	KEYNOTE T1-K2 Dorota Matyszewska (University of Warsaw, Poland) <i>The effect of antiviral drugs on the surface properties and stability of model lipid viral envelopes.</i>	T2-08 Thomas Willers (KRÜSS GmbH, Germany) <i>Viscosity and dynamic surface tension measurement: A guideline for appropriate measurement</i>	T4-01 Mingjie Li (University of Melbourne, Australia) <i>A 3D-printed microfluidic approach for fabricating microcapsules in aqueous one-phase systems (AOPS)</i>
14:00 - 14:15	T3-09 Maria Clara Dos Santos Oliveira (Brazilian Center for Research in Energy and Materials (CNPEN), Brazil) <i>Understanding interfacial stabilization in one-step W/O/W Pickering double emulsions using cellulose nanofibrils and oleic acid</i>		T2-09 Bing Qin (SINOPEC Research Institute of Petroleum Processing Co., China) <i>Oligomeric surfactant-enhanced leaching coupled with bioremediation for petroleum-contaminated soils</i>	T4-02 Matilde Tancredi (University of Naples Federico II, Italy) <i>Rhamnolipid coacervate microdroplets via microfluidics: Generation, morphology, and interfacial properties</i>
14:15 - 14:30	T3-010 Bradley Green (Lund University, Sweden) <i>Emulsions of hydrophobic deep eutectic solvents stabilised with poloxamer surfactants and stearate salts</i>		KEYNOTE T2-K2 Antara Pal (Malmö University, Sweden) <i>Unravelling structural changes of pea globulins during heat treatment as studied using atomistic model-based SAXS</i>	T4-03 Marek Bekir (University of Potsdam, Germany) <i>Light induced motion manipulation of micro-sized colloids in external flow - aggregation, fractioning and analysis</i>
14:30 - 14:45	T3-011 Nicole Galenkamp (Lund University, Sweden) <i>When membranes get crowded: Interfacial constraints on protein binding and remodeling</i>	T1-09 Vincenzo Taresco (University of Nottingham, United Kingdom) <i>Exploiting the mechano-responsiveness of polydiacetylene nanoparticles to track polymeric nanoparticle blends during cellular uptake</i>		T4-04 Yevgeniya Karibjanova (University of Toulouse, France) <i>Rapid microfluidic osmotic compression of proteins to establish equations of state and phase diagrams</i>
14:45 - 15:00	T3-012 Felix Abik (University of Helsinki, Finland) <i>Pickering or not Pickering? Deformation of lignin nanoparticles at the air-water and oil-water interfaces</i>	T1-010 Debora Briganti (University of Florence, Italy) <i>Engineering size-controlled amorphous magnesium calcium phosphate nanoparticles via molecular and polymeric stabilization for drug delivery applications</i>	T2-010 Damiano Bandelli (University of Florence, Italy) <i>Elucidating surfactant-solvent interactions in dilute regimes to control nanostructured fluids features</i>	KEYNOTE T4-K1 Erin Koos (KU Leuven, Belgium) <i>Connecting recovery rheology to structural rearrangement in capillary suspensions</i>
15:00 - 15:15	T3-013 Benjamin Oliva (CNRS, France) <i>Dynamics and controlled assembly of solid lipid domains at interfaces</i>	T1-011 Piotr Kuich (Wrocław University of Science and Technology, Poland) <i>Layer-by-layer approach as a tool for enhanced functionality: Surface engineering of vesicular-type nanocarriers co-loaded with persistent luminescence nanoparticles and photosensitizers</i>	T2-011 Eva Theresia Müller (Institute of Physical and Theoretical Chemistry, Germany) <i>Hydrotrope-controlled pKa shifts and supramolecular reorganization in glycyrrhizic acid hydrogels for advanced solubilization</i>	
15:15 - 15:30	KEYNOTE T3-K2 Valérie Ravaine (University of Bordeaux, France) <i>When nano-ions bind to microgels: From intra- to inter-cross-linking in suspension and at interfaces</i>	T1-012 Hongye Li (University of Bristol, United Kingdom) <i>Understanding molecular interactions between dengue virus capsid protein and lipid droplets</i>	T2-012 Joshua Tyler (University of Sheffield, United Kingdom) <i>A highly anisotropic and hydrolytically degradable Pickering emulsifier for oil-in-water emulsions</i>	T4-05 Ana Jiménez Amaya (BCMaterials, Spain) <i>Optothermophoresis-induced patterning of gold nanoparticles on solid substrates</i>
15:30 - 15:45		T1-013 Paolo Di Gianvincenzo (CICbiomaGUNE, Spain) <i>Preparation, characterization and anticancer activity of β-cyclodextrin nanosponges formulated with two chemotherapeutic drugs</i>	T2-013 Céline Adamo (University of Florence / CSGI, Italy) <i>Modulating fibrin self-assembly in green consolidants for fragile silk artifacts</i>	T4-06 Anna Pajor-Świerzy (Jerzy Haber Institute of Catalysis and Surface Chemistry, Poland) <i>Core@shell nanomaterials as conductive inks for flexible printed electronics</i>
15:45 - 16:00	T3-014 Gökçe Tıdım (RWTH Aachen University, Germany) <i>From solution to interface: Structural evolution of pH-responsive O-carboxymethyl chitosan microgels with varying cross linking</i>	T1-014 Rashad Kariuki (RMIT University, Australia) <i>Interactions of gold nanoparticles and model membranes</i>	T2-014 Nasim Fadaie (Queen's University, Canada) <i>Amyloid-chitosan aerogels for efficient removal of pharmaceutical contaminants and heavy metals</i>	T4-07 Shunsuke Sato (University of Tsukuba, Japan) <i>Temporal decoupling of viscosity growth and particle aggregation in shear-induced gelation</i>
16:00 - 16:30	COFFEE BREAK			
	CHAIR: Valérie Ravaine (University of Bordeaux, France)	CHAIR: Constanza Montis (University of Florence, Italy)	CHAIR: Amanda Ellis (University of Melbourne, Australia)	CHAIR: Andrij Pich (RWTH Aachen University, Germany)
16:30 - 16:45	T3-015 Manaswini Gowtham V (Eindhoven University of Technology, Netherlands) <i>Foam films stabilized by microgel particles: Insights from the dynamic thin film balance</i>	T1-015 Nizar Alsharif (Lund University, Sweden) <i>Polymer-coated TiO₂ nanoparticles: Mechanistic insights into antimicrobial activity via particle-membrane interactions</i>	KEYNOTE T2-K3 Joseph Keddie (University of Surrey, United Kingdom) <i>Colloidal coatings on cellulose fiber bottles for the sustainable packaging of liquids</i>	T4-08 Kazue Kurihara (Tohoku University, Japan) <i>Resonance shear measurements reveal a new perspective on boundary lubrication</i>
16:45 - 17:00	T3-016 Stefan Wellert (Technische Universität Berlin, Germany) <i>From bulk to confinement: Slowing dynamics in bicontinuous microemulsions</i>	T1-016 Tommy Nylander (Lund University, Sweden) <i>Sponge phase lipid nanoparticles interacting with biomimetic membranes: Lipid exchange and delivery of proteins</i>		T4-09 Francisco J. Vazquez-Perez (Institut de Physique de Nice, France) <i>Rheological and microstructural characterization of non-brownian hydrogel suspensions</i>
17:00 - 17:15	T3-017 Oya Korkut (Eindhoven University of Technology, Netherlands) <i>Foam films stabilized by microgel particles: Insights from the dynamic thin film balance</i>	T1-017 Giulia Gabbricci (University of Siena, Italy) <i>Semisolid lipid nanoparticles with thermoresponsive properties: Structural and rheological characterization</i>	T2-015 Anyi Carolina Ropero Barrera (University of Bristol, United Kingdom) <i>Nanostructured complex polymer films with long-lasting antimicrobial efficacy</i>	KEYNOTE T4-K2 Yunpeng Zhang (Forschungszentrum Juelich, Germany) <i>An optofluidic microplatform for quantifying structure-stress-flow coupling in complex fluids under extensional microflow</i>
17:15 - 17:30	T3-018 Diat Olivier (CNRS, France) <i>Facetted liquid foam under free and force drainage</i>	T1-018 Elena Del Favero (University of Milan, Italy) <i>Camouflaging lipid particles with cell membranes for effective gene delivery to cancer cells</i>	T2-016 Hoang Yen Nguyenova (Palacký University in Olomouc, Czech Republic) <i>Magneto-plasmonic nanocomposites as selective and sensitive sensors for water remediation</i>	
17:30 - 17:45	KEYNOTE T3-K3 Regine Von Klitzing (TU Darmstadt, Germany) <i>Long-range interfacial repulsion across aqueous solutions of high ionic strength</i>	T1-019 Paula Antelo-Riveiro (University of Santiago de Compostela, Spain) <i>PRISM: a phase-resolved surface equation of state enabling automated analysis of Langmuir isotherms</i>	T2-017 Sofia Rogers-Ruiz (University of Bristol, United Kingdom) <i>Functionalized cotton fibres for sustainable antimicrobial textiles</i>	T4-010 Camille Brigodiot (University of Amsterdam, Netherlands) <i>Enhanced adsorption-limited process for model surfactants in the EDGE microfluidic device</i>
17:45 - 18:00		T1-020 Simona Sennato (National Research Council (CNR), Italy) <i>Triphenylphosphonium bolaamphiphile-liposomes loaded with resveratrol and Trolox: Mitochondriotropic formulations with therapeutic potential in neurodegeneration and cancer</i>	T2-018 Joyce Lemmer (University of Bath, United Kingdom) <i>Predicting the size of surfactant micelles incorporating hydrophobic additives – Quantitative model vs experimental data</i>	T4-011 Agnes Åhl (KTH Royal Institute of Technology, Sweden) <i>Hierarchical structuring and rheology of lignin-poly(lactic acid) blends for additive manufacturing</i>
18:00 - 18:15	T3-019 Nissa Nurfajrin Solihat (Aalto University, Finland) <i>Engineering lignocellulosic nanomaterials: From Pickering emulsions to air dried high performance foams</i>	KEYNOTE T1-K3 Eduardo Marques (University of Porto, Portugal) <i>Stimuli-responsive bio-inspired catanionic vesicles: From molecular design to tunable biocargo delivery</i>	T2-019 Nadia Flarup Laursen (Aarhus University, Denmark) <i>Characterization and structural analysis of egg yolk plasma</i>	T4-012 Diego Díaz (KTH Royal Institute of Technology, Sweden) <i>Droplet elasticity reduces the contact time on superhydrophobic surfaces</i>
18:15 - 18:30	T3-020 Mariam Arif (The University of Edinburgh, United Kingdom) <i>Impact of particle-size polydispersity on colloidal crystallization and thin-film structures</i>		T2-020 Nicole Rosik (Innospec, United Kingdom) <i>Investigating physicochemical characteristics of artificial sebum for sustainable cleansing.</i>	T4-013 Ana Sánchez-Iglesias (Centro de Física de Materiales (CFM-MPC) CSIC-UPV/EHU, Donostia-San Sebastián, Spain) <i>Tailoring gold bipyramids for photothermal applications</i>
18:30 - 20:00	POSTER SESSION 1 (Topics 1, 2 & 3) + DRINKS			

DAY 2 - TUESDAY 08/09/2026

Time	Main Auditorium (Paraninfo)	Lecture Hall (Salón de Actos)	Room 1	Room 2
08:00 - 08:30	Registration			
08:30 - 08:40	Updates			
08:40 - 09:30	PLENARY TALK PL2 Alberto Fernández-Nieves (University of Barcelona, Spain) <i>Points, disclinations and walls - Defects in confined passive and active nematics</i> CHAIR: Miguel Ángel Fernandez-Rodríguez (University of Granada, Spain)			
09:30 - 10:00	COFFEE BREAK			
	CHAIR: Eva Noya (Instituto de Química-Física Blas Cabrera, CSIC, Spain)	CHAIR: Daniel Harries (Hebrew University, Israel)	CHAIR: Antara Pal (Malmö University, Sweden)	CHAIR: Yunpeng Zhang (Forschungszentrum Juelich, Germany)
10:00 - 10:15	KEYNOTE T1-K4 Federica Sebastiani (University of Copenhagen, Denmark) <i>mRNA-lipid nanoparticles as a vaccine platform: Structural effect of cholesterol substitution with an adjuvant lipid</i>	T3-021 Klemen Bohinc (University of Ljubljana, Slovenia) <i>Influence of lipid shape and headgroup charge on bilayer behavior</i>	T8-01 Alberto Scacchi (University of Turku, Finland) <i>Data-driven density functional theory for phase coexistence & partitioning in multicomponent colloid-polymer mixtures</i>	T9-01 Ueli Töpfer (Laboratory for Soft Materials and Interfaces, Switzerland) <i>Directed transport and current reversal of active colloids under traveling wave illumination</i>
10:15 - 10:30		T3-022 Bastien Rousseau (ICMPE / UPEC, France) <i>Stabilization of water-in-water emulsions by macromolecular complexation at the interface</i>	T8-02 Keita Saito (RIKEN, Japan) <i>Direct measurement of osmotic pressure and a pair potential in colloidal dispersions</i>	T9-02 Carlo Rigoni (Institute of Science and Technology of Austria, Austria) <i>Photoconductive nonpolar liquids based on azobenzene</i>
10:30 - 10:45	T1-021 Michalina Zaborowska-Mazurkiewicz (University of Warsaw, Poland) <i>Molecular Insights into Janus Kinase Inhibitor Interactions with Model Intestinal Epithelial Membranes: From Langmuir Monolayers to Asymmetric Bilayers</i>	KEYNOTE T3-K4 Valeria Castelletto (University of Reading, United Kingdom) <i>Minimal peptide sequences that undergo liquid-liquid phase separation via self-coacervation or complex coacervation with ATP</i>	T8-03 Constantina Sofroniou (Loughborough University, United Kingdom) <i>Self-assembly and network formation in difunctional and monofunctional associative rheology modifiers</i>	T9-03 Gianluca Mazzotta (University of Fribourg, Switzerland) <i>Lyotropic liquid crystals alignment using magnetite NPs for production of anisotropic mesoporous materials</i>
10:45 - 11:00	T1-022 Aliséa Vignal (Université de technologie de Compiègne, France) <i>Towards a mechanistic understanding of water-in-water emulsion stabilization by bio-based polymers</i>		T8-04 Megumi Suyama (Tohoku University, Japan) <i>Tuning solid-state photoluminescence of AuCu₁₄ nanoclusters: Influence of dendron-shell spacing and dynamics</i>	T9-04 Abhimanyu Nowbagh (Heinrich Heine University, Germany) <i>Clustering of active colloids in crowded environments</i>
11:00 - 11:15	T1-023 Jaime García Concejo (Universidad de Valladolid, Spain) <i>Multinanostructured gold-silica nanoparticles for dual cancer therapy</i>	T3-023 Hayden Robertson (Technical University of Darmstadt, Germany) <i>Nanoscale landscapes: Unveiling the lateral and vertical architecture of microgels at fluid interfaces</i>	KEYNOTE T8-K1 Fatima Hassouna (University of Chemistry and Technology, Prague, Czech Republic) <i>Colloidal and interfacial properties of silicon nanocrystals and their impact on lithium ion battery performance</i>	T9-05 Tommaso Gentili (Sapienza University of Rome, Italy) <i>From light to motion: IR-driven actuation in adaptive lanthanide MOF crystals</i>
11:15 - 11:30	T1-024 Javier Reguera (University of Valladolid) <i>Synthesis of sub-10 nm gold nanostars for applications in sensing, catalysis, and hyperthermia</i>	T3-024 Jonathan Martín-González (Friedrich-Alexander University Erlangen-Nuremberg (FAU), Germany) <i>Universal double emulsions made simple</i>		T9-06 Indira Barros (Birla Institute of Technology and Science, India) <i>Electric and magnetic field-driven assembly of patchy and DNA-linked anisotropic colloids</i>
11:30 - 11:45	T1-025 Björn Braunschweig (University of Münster, Germany) <i>Light-induced drug release to interfaces with lipid monolayers</i>	T3-025 Birgit Felderer (Biofisika Institute, Spain) <i>MicroRNA-induced structural changes in reconstituted HDL probed by synchrotron SAXS</i>	T8-05 Akari Yoshida (Tohoku University, Japan) <i>Synthesis of oligothiophene dendron-modified Au nanoparticles and their effects on optical properties and self-assembled structures</i>	KEYNOTE T9-K1 Erica Pensini (University of Guelph, Canada) <i>Shear-direction-sensitive mechanoelectric transduction in a soft ionic paste under anisotropic interfacial boundary conditions</i>
11:45 - 12:00	T1-026 Francesca Baldelli Bombelli (Politecnico di Milano, Italy) <i>Decoding bio-nano interactions: From protein corona formation to cellular and membrane responses.</i>	T3-026 Geert Schulpen (Utrecht University, Netherlands) <i>Influence of supramolecular structure on hydrogel strength</i>	T8-06 Johanna Mirande-Ney (Laboratoire de Génie Chimique, France) <i>Self-segregation of polymer and salt along hydration gradients in evaporating aqueous solutions</i>	
12:00 - 12:15	T1-027 Juan José Valle-Delgado (Aalto University, Finland) <i>Nanocellulose hydrogels for biomedical applications: Using atomic force microscopy techniques to understand and control cell adhesion and spheroid formation</i>	T3-027 Tuukka Levä (VTT Technical Research Centre, Finland) <i>Thin nanocellulose coatings as tunable selective layers for membrane separation</i>	T8-07 Ofer Manor (Technion - Israel Institute of Technology, Israel) <i>Using wetting, capillary forces, and ultrasonic waves to extract oil from a drop containing oil/water mixtures</i>	T9-07 Matthew Roniger (Delft University of Technology, Netherlands) <i>Bubble dynamics-driven control of local microstructure in colloidal gels using ultrasound</i>
12:15 - 13:45	LUNCH BREAK			
	CHAIR: Juliana Carvalho (Brazilian Center for Research in Energy and Materials, São Paulo)	CHAIR: Klemen Bohinc (University of Ljubljana, Slovenia)	CHAIR: Serena Cozzolino (Uppsala University, Sweden)	CHAIR: Jennifer Gilbert (Chalmers University of Technology, Sweden)
13:45 - 14:00	T1-028 Maxime Guichonnet (Laboratoire de Génie Chimique de Toulouse, France) <i>Single-polymer lipid nanoparticles: Ultrafast assembly and multiscale structure</i>	KEYNOTE T3-K5 Kai Sothewes (University of Twente, Netherlands) <i>When grains generate power: Electro-active colloidal interfaces for triboelectric energy harvesting</i>	T7-01 Michael Gradzielski (Institute for Chemistry, Germany) <i>Water-soluble interpolyelectrolyte complexes (IPECs) - Effect of hydrophobic modification on structure and solubilisation</i>	T52-01 Andrea De Marco (University of Padova, Italy) <i>Differential dynamic microscopy as an alternative to dynamic light scattering for turbid nanoemulsions</i>
14:00 - 14:15	T1-029 Noemi Gallucci (University of Naples Federico II, Italy) <i>Making endotoxins visible with engineered F/ZnO nano-bio-interfaces</i>		T7-02 Nika Kutalia (Laboratoire de Physique des Solides/Université Paris-Saclay, France) <i>Reconfigurable liquid crystals of plasmonic nanorods</i>	T52-02 Zhibin Guo (Bettersize Instruments, China) <i>Photoactivated modulation of lipid nanoparticles via advanced light scattering techniques</i>
14:15 - 14:30	T1-030 Sourov Chandra (Aalto University, Finland) <i>Synergistic opto-electrochemical dual transduction for advanced biosensing</i>	T3-028 Luis Fernando Jiménez-Hernández (Institut de Ciència dels Materials (ICMUV), Spain) <i>Colloidal routes to thermoregulating coatings from phase change materials polymer nanocapsules</i>	KEYNOTE T7-K1 Marco Laurati (University of Florence, Italy) <i>Block-like monomer distribution and heterogeneous collapse of thermoresponsive copolymer microgels</i>	T52-03 Luigi Talarico (Università di Siena, Italy) <i>Photoactivated modulation of lipid nanosystems: A structural and kinetic study</i>
14:30 - 14:45	T1-031 Gerardo Odriozola (Universidad Autónoma Metropolitana-Azcapotzalco, Mexico) <i>When a disk becomes a square: Three-step melting of hard superdisks in two dimensions</i>	T3-029 Juan Pablo Fuenzalida Werner (University of Navarra, Spain) <i>Engineering protein-based colloids</i>		T52-04 Sergey Filippov (DWI, Germany) <i>The crosstalk between DOSY NMR and neutron spin echo spectroscopy: What can we learn about the chain dynamics of block and gradient poly(copoly-2-oxazoline) micelles and relative unimer population?</i>
14:45 - 15:00	T1-032 Marco Fornasier (KTH Royal Institute of Technology, Sweden) <i>Understanding response of lipid nanoparticles' structure to phospholipase D activity</i>	T3-030 Sylvain Faure (CEA, France) <i>Contaminated phyllosilicates colloids separation by particulate flotation foams for excavated or in-situ soils decontamination</i>	T7-03 Evelyn Gettinger (Bielefeld University, Germany) <i>Super-resolution imaging of nanoscale monomer distribution in copolymer microgels</i>	KEYNOTE T52-K1 Ilaria Clemente (University of Siena & CSGI, Italy) <i>Unraveling the microfluidic assembly kinetics of lipid nanoparticles under laminar flow conditions: An in situ time-resolved SAXS study</i>
15:00 - 15:15	T1-033 Margherita Recanatini (Centre National de la Recherche Scientifique, France) <i>Investigating the interaction between microbial glycolipids and bio-mimetic membranes</i>	T3-031 Kevin Roger (CNRS, France) <i>How phospholipids stabilize macro and nanoemulsions?</i>	T7-04 Omar A. Abdelaziz (Max Planck Institute for Intelligent Systems, Germany) <i>Gelatin-based hydrogel materials for controlled sorption and release of metoprolol</i>	
15:15 - 15:30	KEYNOTE T1-K5 Jordi Faraudo (ICMAB-CSIC, Spain) <i>How a few help all: Cooperative crossing of lipid membranes by COSAN anions</i>	T3-032 Dominik Horinek (University of Regensburg, Germany) <i>Dissecting the interactions of superchaotropic ions</i>	T7-05 Raffaele Mezzenga (ETH Zurich, Switzerland) <i>Resolving the liquid-to-glass transition(s) of water under soft nanoconfinement</i>	T52-05 Marcos Lopez Hernandez (Aarhus University, Denmark) <i>Isolating interfacial scattering in emulsions: A SAXS-based bulk subtraction approach for pro-teins-stabilized emulsion systems</i>
15:30 - 15:45		T3-033 Sandrine Delpoux - Ouldiane (CNRS - ICMN, France) <i>Hybrid alginate beads embedding lipid mesophase nanoparticles: Pollutant trapping validation</i>	T7-06 Julian Thiele (Otto von Guericke University Magdeburg, Germany) <i>Polymer microgels as synthetic mimics of cellular compartments and nucleoprotein condensates</i>	T52-06 Yi-Cheng Lai (National Synchrotron Radiation Research Center, Taiwan) <i>Probing the nucleation and growth of high-entropy alloy nanoparticles in dropwise synthesis by small-angle X-ray scattering</i>

15:45 - 16:00	T1-034 Elio Cinar San Segundo (Universidad de Granada, Spain) <i>Closed-loop control and spatiotemporal tracking of hydrogel extrusion and cell morphology</i>	T3-034 Elisa Silva Ferreira (Brazilian Center for Research in Energy and Materials (CNPEM), Brazil) <i>Highly stable aqueous foams with nanocelluloses and pectins</i>	T7-07 Oliver Mcdowell (Laboratoire Léon Brillouin (LLB), France) <i>Counterion-mediated growth of ruthenium nanoparticles stabilised by polymerized ionic liquids for future catalysis applications</i>	TS2-07 Max Allen (University of Sheffield, United Kingdom) <i>Morphology evolution during the drying of polyurethane dispersions for high-performance coatings</i>
16:00 - 16:30	COFFEE BREAK			
16:30 - 16:45	CHAIR: Anna Salvati (University of Groningen, Netherlands)	CHAIR: Aurora Pérez-Gramatges (Pontifical Catholic University of Rio de Janeiro, Brazil)	CHAIR: Marco Laurati (University of Florence, Italy)	CHAIR: Sofia Magkiriadou (University of Fribourg, Switzerland)
	TS2-020 Luc Girard (CNRS, France) <i>Solvent extraction for metal recovery: Composition and distribution of organic and ionic species at the water/oil interface</i>	T3-035 Saule Aidarova (Kazakh-British Technical University, Kazakhstan) <i>Application of nanoparticle-surfactant composites for the foam and emulsion stabilization</i>	KEYNOTE T7-K2 Wuge Briscoe (University of Bristol, United Kingdom) <i>LipoGels: Robust self-lubricating physically cross-linked alginate hydrogels embedded with liposomes</i>	TS2-08 Isabella Scarpa (Brazilian Center for Research in Energy and Materials (CNPEM), Brazil) <i>Dose and cell division drive intracellular nanoparticle redistribution revealed by correlative synchrotron imaging</i>
16:45 - 17:00	T1-036 Antonio Luis Medina-Castillo (Department of Applied Physics, University of Granada) <i>Design of Stimuli-Responsive Functional Materials for Optical Sensing Applications</i>	T3-036 Irene Russo Krauss (University of Naples Federico II, Italy) <i>Controlling assembly at the air-water interface through protein-nanoparticle pairing: The effects of protein structure, flexibility and NP interaction.</i>		TS2-09 Markus Retsch (University of Bayreuth, Germany) <i>Gradient particle dispersions: A versatile platform for polymeric colloids, photonic materials, and responsive assemblies</i>
17:00 - 17:15	T1-037 Urs Gasser (PSI Center for Neutron and Muon Sciences, Paul Scherrer Institute, Switzerland) <i>Phase separation of a microtubule plus-end tracking protein into a fluid fractal network</i>	T3-037 Giovanni Li Destri (University of Catania, Italy) <i>Macro- and nano-scale electrostatics govern self-assembly, interactions, and self-healing at charged aqueous surfaces</i>		KEYNOTE TS2-K2 Juliana Carvalho (Brazilian Synchrotron Light Laboratory (LNLS), Brazil) <i>Fractionation-free quantification of nanoparticle-protein interactions by synchrotron SAXS</i>
17:15 - 17:30	T1-038 Marc Jamin (Université Grenoble Alpes, France) <i>Deciphering electrostatic and allosteric determinants of thermoresponsive liquid-liquid phase separation in rabies virus phosphoprotein</i>	T3-038 Marina Rukhadze (I.Javakishvili Tbilisi State University, Georgia) <i>Temperature induced electrical percolation in mixed reverse microemulsions</i>	TS2-010 Jure Kovač (Faculty of Chemistry and Chemical Technology, Slovenia) <i>Angle-dependent absorption correction for reliable absolute-scale SAXS and SWAXS in Kratky-type geometry</i>	
17:30 - 17:45	KEYNOTE T1-K6 Armando Maestro (Materials Physics Center, Spain) <i>From spiral nanostructures to membrane fusion: Force-directed self-assembly of viral peptides at soft interfaces</i>	T3-039 Kang Wang (Cardiff University, United Kingdom) <i>A predictive hydrodynamic criterion for Pickering foam formation by hybrid eulerian multiphase population balance modeling</i>	T7-010 Emmanouela Filippidi (Max Planck Institute of Molecular Cell Biology and Genetics / IESL-FORTH, Germany) <i>Enrichment of higher charge density subspecies of random polyelectrolyte copolymer in complex coacervate</i>	TS2-011 Keishi Akada (Japan Synchrotron Radiation Research Institute, Japan) <i>Impact-induced millisecond clustering during shear melting of colloidal crystals</i>
17:45 - 18:00		T3-040 Ville Lovikka (University of Helsinki, Finland) <i>Disintegration of colloidal lignin in emulsion interfaces as monitored and triggered by atomic force microscopy</i>	T7-011 Miroslav Štěpánek (Charles University, Czech Republic) <i>Polyelectrolytes with guanidine structural motifs: From internal chain dynamics to the formation of interpolyelectrolyte complexes</i>	
18:00 - 18:15	T1-039 Vince Engelborghs (KU Leuven, Belgium) <i>Quantifying the structural evolution of Pseudomonas putida biofilms under flow</i>	KEYNOTE T3-K6 Daniel Harries (Hebrew University, Israel) <i>When alcohols break the rules: Nonmonotonic forces in soft membrane stacks</i>	T7-012 Ramón Rial (Universidade de Santiago de Compostela, Spain) <i>Cyclable photomodulation of supramolecular gels in deep eutectic solvents</i>	TS2-012 Wim Thielemans (KU Leuven, Belgium) <i>3D imaging and understanding the structure of the chiral nematic assembly of cellulose nanocrystals in suspension</i>
18:15 - 18:30	T1-040 Miriam Peña Figueroa (Centro de Física de Materiales (CFM-MPC), Spain) <i>Interaction and integration of amphiphilic single-chain nanoparticles into lipid model membranes</i>		T7-013 Andrea Scotti (Lund University, Sweden) <i>A neutron enters a bar and meets a microgel, a cubosome, and a spaghetti strand...three tales on small-angle neutron scattering with contrast variation</i>	TS2-013 Roberto Cerbino (University of Vienna, Austria) <i>ShearView: An open-source compact rheometer for integrated rheo-microscopy</i>
18:30 - 19:20	PLENARY TALK (María Miguel Prize) AW1 Adrián Sánchez-Fernández (University of Santiago de Compostela) <i>Solvation-by-design: Amphiphile self-assembly and biomolecular adaptation in deep eutectic solvents</i> CHAIR: Luciano Galantini (University of Rome, Italy)			

DAY 3 - WEDNESDAY 09/09/2026

Time	Main Auditorium (Paraninfo)	Lecture Hall (Salón de Actos)	Room 1	Room 2
08:00 - 08:30	Registration			
08:30 - 08:40	Updates			
08:40 - 09:30	PLENARY TALK PL3 Anna Salvati (University of Groningen, Netherlands) <i>Understanding how drug carrier physico-chemical properties shape their interactions in complex biological environments and with cells</i> CHAIR: Pierandrea Lo Nostro (University of Florence, Italy)			
09:30 - 11:00	COFFEE BREAK + POSTER SESSION 2 (Topics 4, 5, 6, 7, 8, 9, S1 & S2)			
	CHAIR: Alberto Striolo (University of Oklahoma, USA)	CHAIR: Adrián Sánchez-Fernández (Universidade de Santiago de Compostela, Spain)	CHAIR: Erica Pensini (University of Guelph, Canada)	CHAIR: Dominik Horinek (University of Regensburg, Germany)
11:00 - 11:15	KEYNOTE T8-K2 Eva Noya (Instituto de Química-Física Blas Cabrera (CSIC), Spain) <i>Design of colloidal particles to form 3-dimensional axial quasicrystals</i>	T6-O8 Tuuli Virkkala (VTT Technical Research Centre of Finland Ltd, Finland) <i>Interfacial hydrogel formation and entropic effects in adsorption of mixed-linkage glucans on cellulose surfaces</i>	T9-O8 Diane Rebiscoul (Institut de Chimie Séparative de Marcoule, France) <i>Interaction of protein-functionalized silica with f-block elements</i>	KEYNOTE TS1-K1 Duccio Tatini (University of Siena, Italy) <i>Data-driven approaches to investigate intermolecular interactions and self-assembly in complex fluids: From data fusion to 2D correlation analysis</i>
11:15 - 11:30		T6-O9 Efstathia Mantzari (Aalto University, Finland) <i>Towards bio-inspired underwater adhesives: Barnacle cement protein 19 structural ensembles via molecular modelling</i>	T9-O9 Amin Rahimzadeh (Technical University of Darmstadt, Germany) <i>Acousto-responsive microgels: A non-invasive approach for microgel dehydration</i>	
11:30 - 11:45	T8-O8 Reza Azizmalayeri (Leibniz Institute of Polymer Research Dresden, Germany) <i>Influence of ambient vapor composition on the stability and breakup of liquid jets</i>	KEYNOTE T6-K2 Minghan Hu (ETH Zurich, Switzerland) <i>Colloidal robots with physical intelligence</i>	T9-O10 Alexander Reinauer (University Stuttgart, Germany) <i>Mean-field calculation of the electrophoretic mobility of hard colloid and charged liquid droplets</i>	KEYNOTE TS1-K2 Steven Van Kesteren (ETH Zurich, Switzerland) <i>Programming ionic colloidal crystals into nanoelectronic architectures</i>
11:45 - 12:00	T8-O9 Léna Vincent (Soft Matter Science and Engineering Laboratory (SIMM), France) <i>Stabilization of water-in-water emulsions by complex coacervate core micelles</i>		T6-O17 Alvaro Domínguez (Universidad de Sevilla, Spain) <i>The mechanism of self-phoresis</i>	
12:00 - 12:15	T8-O10 Maximilian Theis (University of Bayreuth, Germany) <i>Double gradients, double control: Advancing core-shell particles</i>	T6-O10 Raj Kumar (Paul Pascal Research Center (CRPP), France) <i>Light-driven self-propulsion of rod-like fd-virus functionalized Janus particles</i>	KEYNOTE T9-K2 Darja Lisjak (Jozef Stefan Institute, Slovenia) <i>Surface-selective hybridization of magnetic nanoplatelets for the manipulation of ferrofluids with magnetic and electric fields</i>	TS1-O1 Tariq Muhammad (University of Toulouse, France) <i>Modified Poisson-Boltzmann models capturing ion correlations: a machine-learning approach using molecular dynamics data</i>
12:15 - 12:30	T8-O11 Manuela Walteros León (KU Leuven, Belgium) <i>Temperature-induced structural transitions of cationic vesicle dispersions</i>	T6-O11 Luigi Paduano (University of Naples Federico II, Italy) <i>Precision delivery of siRNA using human transferrin receptor-targeted lipid nanocarriers: Linking nanoscale structure to in vivo performance</i>		TS1-O2 Paul Großkopf (ILL/FAU, France/Germany) <i>Data fusion and machine learning for the particle sizing of lipid nanoparticles</i>
12:30 - 14:00	LUNCH BREAK			
	CHAIR: Thomas Zemb (INP-Toulouse, France)			
14:00 - 14:20	MEMORIAL TALK M1 Didier Roux (Académie des Sciences Paris, France) <i>From micro emulsion to fluctuating membranes: a tribute to Professor Pierre Bothorel</i>			
14:20 - 14:40	MEMORIAL TALK M2 Michael Gradzielski (Technische Universität Berlin, Germany) <i>Heinz Hoffmann - A life of passion for colloid science</i>			
14:40 - 15:30	PLENARY TALK ECIS (Overbeek Gold Medal) AW2 Roland Netz (Freie Universität Berlin, Germany) <i>The surface potential of water and electrolytes: Bridging experiments, theory and simulations</i> CHAIR: Tommy Nylander (Lund University, Sweden)			
15:30 - 16:00	CONFERENCE PICTURE. MEETING AT ASSEMBLY POINT FOR EXCURSION			
16:00 - 21:00	EXCURSION			

DAY 4 - THURSDAY 10/09/2026

Time	Main Auditorium (Paraninfo)	Lecture Hall (Salón de Actos)	Room 1	Room 2
08:00 - 08:30	Registration			
08:30 - 08:40	Updates			
08:40 - 09:30	PLENARY TALK PL4 Matej Kanduč (Jožef Stefan Institute, Slovenia) <i>Cavitation in water: a matter of the weakest link</i> CHAIR: Wuge Briscoe (University of Bristol, United Kingdom)			
09:30 - 10:00	COFFEE BREAK			
	CHAIR: Federica Sebastiani (University of Copenhagen, Denmark)	CHAIR: Emanuela Zaccarelli (CNR Institute of Complex Systems, Italy)	CHAIR: Hans-Jürgen Butt (Max Planck Institute for Polymer Research, Germany)	CHAIR: Epameinondas Leontidis (University of Cyprus, Greece)
10:00 - 10:15	KEYNOTE T2-K4 Bauduin Pierre (ICSM - CEA Marcoule, France) <i>Using foam to separate ions: Superchaotropic effects as a new route toward sustainable chemistry</i>	T7-014 Jacopo Vialetto (University of Florence, Italy) <i>Controlling the structure of star-like copolymer microgels through the monomer chain length to modulate softness and deswelling</i>	T5-01 Jantinus Wisman (University of Twente, Netherlands) <i>Humidity-sensitive mechanical properties of paper</i>	T8-012 Melanie Gettinger (Bielefeld University, Germany) <i>Impact of the sapogenin gypsogenin on the structure and phase behavior of DMPC vesicles</i>
10:15 - 10:30		T7-015 Matthias Karg (Martin Luther University Halle-Wittenberg, Germany) <i>Recent progress in studying the phase behavior of deformable colloids at fluid interfaces: Why in situ techniques are needed.</i>	T5-02 Xicheng Bao (Max Planck Institute for Polymer Research, Germany) <i>Contact line friction of bubbles</i>	T8-013 Christoph Haessig (Soft Matter, Belgium) <i>Using biology: How softness and shape anisotropy determine the percolation threshold of red blood cell networks</i>
10:30 - 10:45	T2-021 Giuseppe Vitiello (University of Naples Federico II, Italy) <i>Sustainable colloidal carbon nanodots: From green synthesis to physicochemical-functional insights</i>	KEYNOTE T7-K3 Serena Cozzolino (Uppsala University, Sweden) <i>Study of polymer pseudo-brushes by rheo-NR</i>	T5-03 Paola Brocca (University of Milano, Italy) <i>The role of ions in the first nanometer below the water-air interface detected by nanometric capillary waves as observed by the LFI interferometer.</i>	T8-014 Max Hohenschütz (RWTH Aachen University, Germany) <i>Hydration and water-mediated binding of superchaotropic clodo-dodecaborates</i>
10:45 - 11:00	T2-022 Sarah Verkempinck (Laboratory of Food Technology, Belgium) <i>Processing-induced structural changes in pea proteins and their impact on interfacial functionality and emulsion stability</i>		T5-04 Lea Delance (Max Planck Institute for Polymer Research - Germany, France) <i>Contact line instabilities in sliding viscoelastic drops</i>	T8-015 Luciano Galantini (Sapienza University of Rome, Italy) <i>On the self-assembly of porphyrins and bile salts: The supramolecular chiral induction by steroidal surfactants</i>
11:00 - 11:15	T2-023 Carolina Jesus (University of Coimbra, Portugal) <i>From biomass to interface: Carob pulp sugar extraction, synthesis, functional characterization of new cationic sugar-based surfactants</i>	T7-016 Izabella Leszczyńska (Jerzy Haber Institute of Catalysis and Surface Chemistry Polish Academy of Sciences, Poland) <i>Molecular level insight into behavior of ternary polyelectrolyte complexes</i>	KEYNOTE T5-K1 Luengo Gustavo S. (L'OREAL Research and Innovation, France) <i>Adsorption of a charged natural polysaccharide: Role of pH and counterion on surface forces and film thickness</i>	T8-016 Mert Acar (University of Florence, Italy) <i>The hidden solute: How dissolved atmospheric gases change liquid physicochemical properties</i>
11:15 - 11:30	T2-024 Mohit Agarwal (Swabian Instruments GmbH, Germany) <i>Exploring colloidal kinetics using dynamic light scattering</i>	T7-017 Saathana Ambikaibalan (University of Leeds, United Kingdom) <i>Influence of structure and processing on plant-based wax on physical properties of micro-oleogels</i>		T8-017 Hideki Sakai (Tokyo University of Science, Japan) <i>Non-aqueous emulsions with high dispersion stability prepared using a novel block-random-block type emulsifier</i>
11:30 - 11:45	T2-025 Teng Wang (Aarhus University, Denmark) <i>Foaming and emulsifying properties of commercial legume protein isolates as potential egg replacers: A comparative study</i>	T7-018 Francesco Brazili (Institute for Complex Systems, Italy) <i>Re-entrant plasmon coupling driven by phase behavior of microgel-nanoparticle systems</i>	T5-05 Jordi Esquena (Institute of Advanced Chemistry of Catalonia, CSIC, Spain) <i>New solvent-antisolvent nanoprecipitation method for the simple and low-cost production of polyethylene nanoparticles as nanoplastic models</i>	KEYNOTE T8-K3 Ryosuke Ohnuki (Tokyo University of Science, Japan) <i>Structural identification of photonic balls using structural color patterns</i>
11:45 - 12:00	T2-026 Dieke Groot Nibbelink (Wageningen University & Research, Netherlands) <i>Oleogelation using dried protein particles</i>	T7-019 Sonia Kudracik-Kramarczyk (Jerzy Haber Institute of Catalysis and Surface Chemistry, Poland) <i>Tailoring the physico-chemical and biological interface of gelatin-based hydrogels: The role of lactic acid in network stability and cell viability</i>	T5-06 Wei Song (Max Planck Institute for Polymer Research, Germany) <i>Electrotunable charge separation and its effect on dynamic wetting</i>	
12:00 - 12:15	T2-027 Michela Elena Pedretti (University of Genoa, Italy) <i>Foamed lunar regolith simulant slurries for the in-situ production of porous construction materials</i>	T7-020 Catalina Haro-Pérez (Universidad Autónoma Metropolitana-Azcapotzalco, Mexico) <i>Charge regulation in microgels across the volume phase transition under varying salt conditions</i>	T5-07 Lorene Champougny (CNRS / Chemical Engineering Institute, France) <i>Interfacial dripping faucet: Generating monodisperse liquid lenses</i>	T8-018 Anne Floor Den Ouden (Eindhoven University of Technology, Netherlands) <i>Beyond the effective solvent: How fractionation and solvent-solvent interactions drive micellization in binary solvents</i>
12:15 - 13:45	LUNCH BREAK			
	CHAIR: Paolo Samorì (ISIS, University of Strasbourg, France)	CHAIR: Rodrigo Sanches Pires (European Synchrotron Radiation Facility, France)	CHAIR: Matej Kanduč (Jožef Stefan Institute, Slovenia)	CHAIR: Alberto Fernández-Nieves (University of Barcelona, Spain)
13:45 - 14:00	T2-028 Antoine Simon (University of Lille, France) <i>Oil foams stabilized by polyglycerol fatty acid esters: Linking bulk self-assembly to interfacial and foaming properties</i>	KEYNOTE T7-K4 Remco Tuinier (Eindhoven University of Technology, Netherlands) <i>Associative and segregative liquid-liquid phase separation in macromolecular solutions</i>	T5-08 Khrystyna Rymsha (Leibniz-Institut für Polymerforschung e.V., Germany) <i>Can fluorescence anisotropy probe conformational transitions in polymer brushes?</i>	T8-019 Carlo Carandente Coscia (University of Naples - Federico II, Italy) <i>Supramolecular assembly and morphological control of lignin colloids via levulinic acid solvents</i>
14:00 - 14:15	T2-029 Muniba Shahzad Bhatti (INM-Leibniz Institute for New Materials, Germany) <i>Conductive polymer shell formation in gold-polythiophene hybrid nanoparticles for sinter-free printed conductors</i>		T5-09 Nikolaus Knorr (Max-Planck-Institut für Polymerforschung, Germany) <i>Charge patterns from water dewetting</i>	T8-020 Hilda Camila Nogueira (Paul Scherrer Institute, Switzerland) <i>Anisotropy under soft confinement: A new fate for gold nanoparticles?</i>
14:15 - 14:30	T2-030 Plamen Tchoukov (Institute of Physical Chemistry, Bulgaria) <i>Colloidal and interfacial effects of impurities in supercritical CO₂: Implications for corrosion in CO₂ dense phase pipelines (carbon capture and storage)</i>	T7-021 Lorenzo Riccio (University of Vienna, Austria) <i>Multifunctional p(NIPAM-co-NIPMAM)-Fe₃O₄ nanocubes hydrogel patches integrating antimicrobial activity and magnetic hyperthermia-controlled drug release</i>	KEYNOTE T5-K2 Hans-Jürgen Butt (Max Planck Institute for Polymer Research, Germany) <i>Water drops sliding over arrays of Janus micropillars: A new mechanism of drop charging</i>	T8-021 Laura Marty (Institut Charles Gerhardt Montpellier, France) <i>Aqueous supracolloidal assembly of gold nanoparticles guided by hydrophilic triblock copolymers</i>
14:30 - 14:45	T2-031 Tanisha Tanisha (University of Basque Country, Spain) <i>Microfluidic formation of lignin nanoparticles: Influence of processing parameters on colloidal properties for cosmetic applications</i>	T7-022 Nanami Hano (Kumamoto University, Japan) <i>Fluorescent chromic properties of polycyclic aromatic polymer colloidal particles</i>		T8-022 Luis Torquato (Paul Scherrer Institut, Switzerland) <i>Doing the dishes with neutrons: Milli-flow SANS-DLS of fat removal</i>
14:45 - 15:00	T2-032 Kate Alston (The University of Manchester, United Kingdom) <i>Development of interfacial models to understand preservation through neutron reflection</i>	T7-023 Kateryna Goloviznina (CNRS, France) <i>Probing free volume and gas solubility in silicon-functionalized ionic liquids</i>	T5-010 László Mérai (Leibniz-Institut für Polymerforschung Dresden e.V., Germany) <i>Polymer brush mobility revealed by integrated viscosity-sensitive fluorescent molecular rotors</i>	KEYNOTE T8-K4 Aurora Pérez-Gramatges (Pontifical Catholic University of Rio de Janeiro, Brazil) <i>Flow-dependent retention of zwitterionic surfactants in carbonates</i>
15:00 - 15:15	T2-033 Matteo Fois (University of Bristol, United Kingdom) <i>To gel or not to gel? A curious case of molecular self-assembly in deep eutectic solvents</i>	T7-024 Jose Manuel Ruiz Franco (University of Barcelona, Spain) <i>Liquid-like dynamics in ordered soft-particle systems</i>	T5-011 Yoonju Oh (Norwegian University of Science and Technology, Norway) <i>Adsorption and wetting behavior of epidote in hematite flotation: Insights from experiments and atomistic simulations</i>	
15:15 - 15:30		T7-025 Gerardo Campos-Villalobos (Consiglio Nazionale delle Ricerche-Istituto dei Sistemi Complessi, Italy) <i>From many-body interactions to collective behaviour in core-shell microgels</i>	T5-012 Kayleigh Davies (Malmö University, Sweden) <i>Electrification of water droplets for sustainable energy harvesting</i>	T8-023 Patrick Denk (RWTH Aachen University, Germany) <i>Using scattering to probe superchaotropic anion adsorption to nonionic polymers</i>
15:30 - 15:45	KEYNOTE T2-K5 Hideki Miwake (Research Institute, Japan) <i>Polyol-controlled self-assembly and removal of hydrophobic oil films in nanionic surfactant/polyol/water systems</i>	T7-026 Somashree Mondal (Paul Scherrer Institute, Switzerland) <i>Microstructural transformations in magnetic hydrogels under flow-magnetic field coupling</i>	T5-013 Naoyuki Ishida (Doshisha University, Japan) <i>Direct measurement of interactions forces between silica surfaces in organic solvents and mixtures by atomic force microscopy: Agreement with DLVO theory</i>	T8-024 Epameinondas Leontidis (University of Cyprus, Cyprus) <i>Phase transition in phosphocholine micellar solutions induced by lanthanide salts</i>

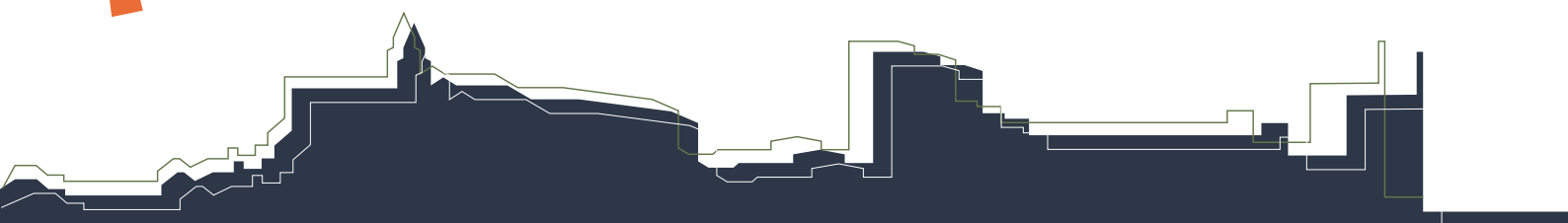
15:45 - 16:00	T2-034 Werner Kunz (Institute of Physical Chemistry, Germany) <i>New and original strategies for environmentally friendly solvent media without surfactants</i>	T7-027 Tim Günter (Uppsala University, Sweden) <i>Interactions of soft crystalline materials with solid-liquid interfaces studied by neutron scattering</i>	T5-014 Luca Stendardo (University of Milano - Bicocca, Italy) <i>A versatile method for controlling the wettability of stainless steel meshes for high-efficiency fog harvesting</i>	T8-025 Changhao Hu (Technical University of Berlin, Germany) <i>Thermo-responsive interpolyelectrolyte complexes (IPECs): Reversible colloidal structures governed by composition and temperature</i>
16:00 - 16:30	COFFEE BREAK			
	CHAIR: Armando Maestro (Materials Physics Center, Vizcaya, Spain)	CHAIR: Gerardo Odriozola Prego (UAM, México)	CHAIR: Roland Netz (Freie Universität Berlin, Germany)	CHAIR: Matthias Karg (Martin Luther University Halle-Wittenberg, Germany)
16:30 - 16:45	T2-035 Rafael Muñoz-Espí (University of Valencia, Spain) <i>Colloidal polymer nanoparticles for heterogeneous asymmetric organocatalysis and transition metal catalysis</i>	T7-028 Subrat Kumar Panigrahi (Indian Institute of Technology Hyderabad, India) <i>Formulation and in vitro assessment of a hybrid gel-microparticle composite for ocular delivery of dual-antiglaucoma drugs</i>	KEYNOTE T5-K3 Carlos Drummond (Université de Bordeaux, France) <i>Probing soft matter: Long-range forces and shear-induced phenomena in compliant systems</i>	T8-026 Harsha Namdeo (Friedrich-Alexander-Universität Erlangen-Nürnberg, Germany) <i>Coarse-grained contact-area dominated interaction for two-dimensional colloidal nanoparticles</i>
16:45 - 17:00	T2-036 Jean-Francois Dufreche (University of Montpellier, France) <i>Lateral equations of state of surfactants at interfaces: A multiscale perspective</i>	T7-029 Deborah Feller (Martin Luther University Halle-Wittenberg, Germany) <i>The structure of core-shell microgels: A light, X-ray and neutron scattering study</i>		T8-027 Gabriela Wojtan (Jerzy Haber Institute of Catalysis and Surface Chemistry Polish Academy of Sciences, Poland) <i>Surfactants as molecular switches in the formation of β structures in peptides.</i>
17:00 - 17:15	T2-037 Rubén Soria Martínez (Université Lorraine, France) <i>Stepwise self-assembly monolayer of sodium oleate on (111) fluorite: Insights from molecular dynamics simulations</i>	T7-030 Julian Oberdisse (Université de Montpellier, France) <i>Controlling the volume phase transition and structure of microgels by copolymerization</i>	T5-015 Ferdinand Fandrei (University Lund, Germany) <i>How protein droplets phase separate on lipid membranes</i>	KEYNOTE T8-K5 Elena Mileva (Institute of Physical Chemistry, Bulgaria) <i>Nanoarchitectonics in aqueous media containing antennary oligopeptides: General trends and specific phenomena</i>
17:15 - 17:30	T2-038 Tobias Roebroek (KU Leuven, Belgium) <i>Antifoam dynamics of oil droplets in protein-stabilized aqueous thin films</i>	T7-031 Paula Malo De Molina (Centro de Física de Materiales (CSIC-EHU), Spain) <i>Protein-mimetic heterograft polymers as model systems for controlled complexation with oppositely charged biomacromolecules</i>	T5-016 Xavier Banquy (Université de Montréal, Canada) <i>Resonance-controlled surface forces in confined aqueous films</i>	
17:30 - 17:45	KEYNOTE T2-K6 Alberto Striolo (University of Oklahoma, USA) <i>Synergistic and antagonistic effects experienced by surface-active compounds</i>	T7-032 David Tilve-Martinez (IMDEA Materials, Spain) <i>Silicon nanowire aqueous liquid crystal formation and processing into macromaterials</i>	T5-017 Keno Ky R. Studer (Laboratory for Soft Materials and Interfaces, Switzerland) <i>Probing capillary torque on multipolar particles at dynamically deformed liquid interfaces</i>	T8-028 Rahul Benani (The Pennsylvania State University, USA) <i>Modulating protein-protein interactions using osmolytes: Implications for protein stability and aggregation</i>
17:45 - 18:00		T7-033 Piotr Batys (Jerzy Haber Institute of Catalysis and Surface Chemistry PAS, Poland) <i>Tuning polypeptide multilayer growth and mechanics via solvent-mediated interactions</i>	T5-018 Frieder Mugele (University of Twente, Netherlands) <i>From wetting ridge formation to swelling-dependent solvent diffusivity in oil-infused polymer brushes</i>	T8-029 Anna Monclús-Rojo (Universitat de Barcelona, Spain) <i>Correlations in active nematic defects</i>
18:00 - 18:15	T2-039 Hao Li (INRAE, France) <i>On the calcium binding mechanisms of acacia gums (senegal and seyal): Importance of solvation in the binding process</i>	KEYNOTE T7-K5 Maria Sammalkorpi (Aalto University, Finland) <i>Solvent controlled plasticization and thermal response of polyelectrolyte assemblies</i>	T5-019 Laura Fieber (Aalto University, Finland) <i>Dynamics of wetting on submerged superhydrophobic surfaces</i>	T8-030 Xin Yin (Ludwig-Maximilian-Universität München, Germany) <i>Directed assembly of tetrahedral DNA-origami patchy colloids into diamond cubic, hexagonal diamond and S-II clathrates</i>
18:15 - 18:30	T2-040 Arshdeep Singh Bains (Technische Universität Berlin, Germany) <i>Investigations on the behavior of thermo-responsive block copolymers in natural deep eutectic solvents (NADES)</i>		T5-020 Takumi Sato (3-14-1, Japan) <i>Velocity dependency of ice melting at polymer interfaces: A molecular dynamics investigation</i>	T8-031 Makoto Takafuji (Kumamoto University, Japan) <i>Coordination-driven modulation of chiroptical properties in terpyridine-functionalized supramolecular gel assemblies</i>
18:30 - 19:45	ECIS Annual General Meeting			
20:00 - 23:00	GALA DINNER			

DAY 5 - FRIDAY 11/09/2026

Time	Main Auditorium (Paraninfo)	Lecture Hall (Salón de Actos)	Room 1	Room 2
08:00 - 08:30	Registration			
08:30 - 08:40	Updates			
08:40 - 09:30	PLENARY TALK (ECIS-SYENSQO AWARD) AW3 Paolo Samori (ISIS, University of Strasbourg, France) <i>Interfacing functions: Supramolecular chemistry enabling high-performance pressure sensors and neuromorphic computing</i> CHAIR: Regine von Klitzing (TU Darmstadt, Germany)			
09:30 - 10:00	COFFEE BREAK			
	CHAIR: Carlos Drummond (Université de Bordeaux, CNRS, France)	CHAIR: Fatima Hassouna (University of Chemistry and Technology, Prague, Czech Republic)	CHAIR: Gerhard Nägele (IBI - 4, Forschungszentrum Jülich GmbH, Germany)	CHAIR: Pablo Miguel Blanco Andrés (University of Lleida, Spain)
10:00 - 10:15	KEYNOTE T7-K6 Emanuela Zaccarelli (CNR Institute of Complex Systems, Italy) <i>Star-like thermoresponsive microgels: a new class of soft colloids with Gaussian effective interactions</i>	T8-O32 Inderdip Shere (ICSM-CNRS-CEA, France) <i>Molecular dynamics of choline chloride: Phase behavior, structural evolution, and transition mechanisms in deep eutectic solvents</i>	T6-O12 Mohammadjavad(Moja) Noohijooabani (University of Zaragoza, Spain) <i>Conductive active colloids propelled by releasing ions</i>	TS2-O14 Edward Stuckey (Uppsala University, Sweden) <i>Optimizing neutron reflectometry experiments for soft matter systems using HOBGEN</i>
10:15 - 10:30		T8-O33 Thomas Zemb (INP-Toulouse (FRANCE), France) <i>Is spontaneous emulsification in ternary solutions a common occurrence in nearly miscible solvents, or is it an urban legend caused by unavoidable impurities?</i>	T6-O13 Kai Yu (KU LEUVEN, Belgium) <i>Functional multiphase systems stabilized by protein–cellulose nanocomposites</i>	TS2-O15 Ariane Fournier (Lund University, Sweden) <i>Effect of selective deuteration on particle compressibility for SANS studies with contrast variation</i>
10:30 - 10:45	T7-O34 Ingi Hong (Konkuk University, South Korea) <i>Effects of internal emulsifier structure and concentration on dispersion properties and film performance of anionic waterborne polyurethanes</i>	KEYNOTE T8-K6 Rodrigo Sanches Pires (European Synchrotron Radiation Facility (ESRF), France) <i>Resolving hierarchical self-assembly pathways of oppositely charged surfactants using stopped-flow time-resolved (U)SAXS</i>	T6-O14 Brigida Romano (University of Perugia, Italy) <i>Phosphatidylserine lipids affect the location of chondroitin sulfate at the membrane surface</i>	TS2-O16 Bastian Mueller (Institut de Chimie Séparative de Marcoule, France) <i>Superchaotropic nano-ions control the phase behavior of lipid monolayers at the air/water interface</i>
10:45 - 11:00	T7-O35 Sadia Schülke (University of Vienna, Austria) <i>Training soft colloidal gels by shear flows</i>		T6-O15 Baptiste Chabaud (CNRS – UGA, France) <i>How interfacial chemistry controls macromolecular binding and responses to stimuli</i>	TS2-O17 Jenni Engstedt (Malmö University, Sweden) <i>Influence of Small Molecules on Hydration-Induced Phase Distribution in Lipid Liquid Crystalline Depots</i>
11:00 - 11:15	T7-O36 Hiroya Ishida (Ltd., Japan) <i>Influence of dispersants on graphite-polydimethylsiloxane composites and interfacial structures</i>	T8-O34 Anna Bratek-Skicki (Jerzy Haber Institute of Catalysis and Surface Chemistry, Poland) <i>Structural insights into liquid–liquid phase and aggregation of TDP-43 low complexity domain</i>	KEYNOTE T6-K3 Sofia Magkiriadou (University of Fribourg, Switzerland) <i>Structural colour in disordered media: From photon diffusion to colour</i>	TS2-O18 Asa Jerlhagen (KTH Royal Institute of Technology, Sweden) <i>Engineering X-ray visibility in soft colloids: Iodine-loaded PISA nanoparticles</i>
11:15 - 11:30	T7-O37 Luciana Buonaiuto (University of Twente, Netherlands) <i>Tuning semicrystalline polymer brush morphology and surface properties via solvent-mediated crystallization</i>	T8-O35 Angela Capocéfalo (Institute for Complex Systems, Italy) <i>Chirality-driven interparticle interactions in plasmonic colloids revealed by optical spectroscopy</i>		TS2-O19 Sophie Ray (University of Birmingham / Diamond Light Source, United Kingdom) <i>In-situ probing of ZIF-8 colloid self-assembly into photonic mesocrystals</i>
11:30 - 11:45	T7-O38 Barbara Lonetti (Université de Toulouse, France) <i>Clustering of gold nanoparticles in soft confined environments using pH responsive double hydrophilic block copolymers</i>	T8-O36 Nicolás Ariel García (Instituto de Física del Sur (IFISUR), Argentina) <i>Water models matter: From bulk solvent properties to casein macropeptide association and lipid vesicle stability</i>	T6-O16 Marcel Krzan (Jerzy Haber Institute of Catalysis and Surface Chemistry, Poland) <i>Hydrogen bonding versus electrostatic screening in saponin-stabilised interfaces: Molecular origins of foam stability</i>	KEYNOTE TS2-K3 Jennifer Gilbert (Chalmers University of Technology, Sweden) <i>Not-so-model systems: Quantification of multilamellar sub-populations in phospholipid vesicles with increasing cholesterol</i>
11:45 - 12:00	T7-O39 Manuel Kraus (University of Basel, Switzerland) <i>Tunable structural color in copolymer microgels through controlled synthesis and thermally induced assembly</i>	T8-O37 Firoz Malayil (Max IV Laboratory, Sweden) <i>From molecular nano-aggregates to microemulsions: A comprehensive description of the ternary phase diagram of water and mono-alcohols mixtures</i>	T9-O11 Peter Košován (Charles University, Prague) <i>Distribution of molecular solutes by phase-separating charged macromolecules</i>	
12:00 - 12:15	T7-O40 Andrei Zvelindovsky (University of Lincoln, United Kingdom) <i>Nanocolloids at block copolymer interfaces: Mesoscale modelling of self-assembly and morphology control</i>	T8-O38 Matteo Rutsch (University of Basel, Switzerland) <i>Confining geometry drives dynamics in lipidic mesophases</i>	T6-O18 Jianjun Wang Wang (Technical Institute of Physics & Chemistry, China) <i>Bio-inspired ice-control materials for cryopreservation of cells and tissues</i>	
12:15 - 12:30	T7-O41 Anindya Chowdhury (Institute of Physical Chemistry (IPC), Germany) <i>Mechanical degradation pathways of thermoresponsive microgels under ultrasonic cavitation</i>	T8-O39 Jyoti Pannu (Friedrich-Alexander-Universität Erlangen-Nürnberg, Germany) <i>Kinetic Monte Carlo simulations for twinned nanoparticles growth</i>	T6-O19 Shiho Tsutsumi (National Institute for Materials Sciences, Japan) <i>Design and production of lipid vesicles and nanoparticles with exosome-mimetic composition using a crossflow membrane mixing device</i>	TS2-O21 Thea Lykkegaard Møller (Aarhus University, Denmark) <i>Time-dependent structural evolution of casein micelles in reconstituted milk probed by SANS and SAXS</i>
12:30 - 13:00	CLOSING CEREMONY			
13:00 - 14:00	LUNCH			



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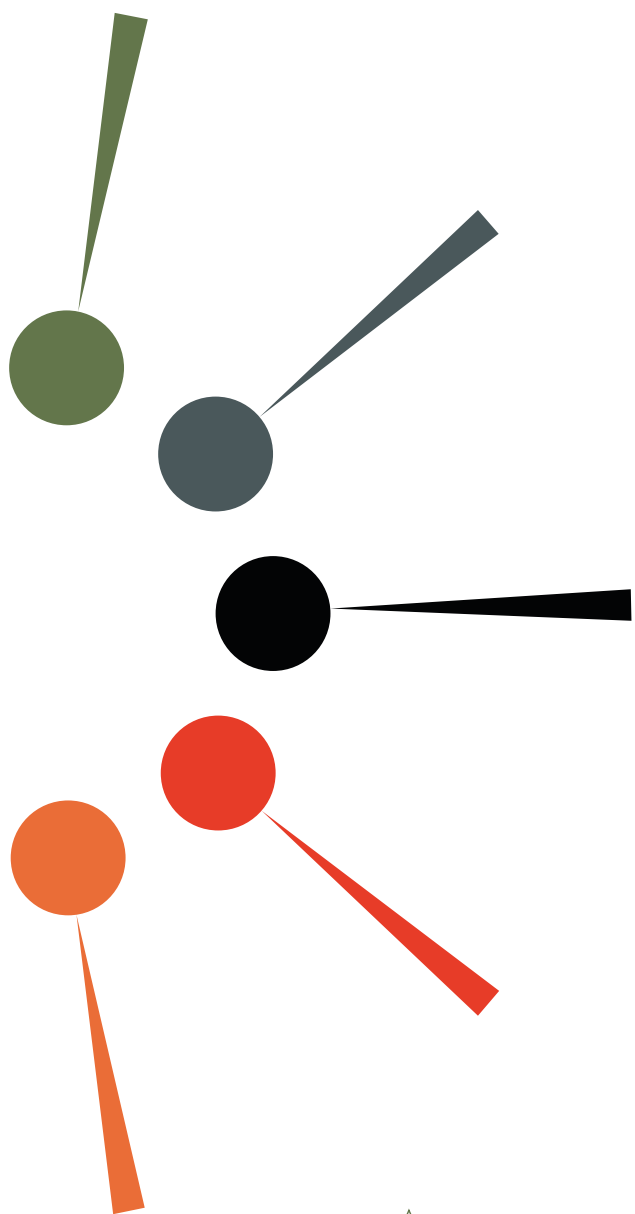
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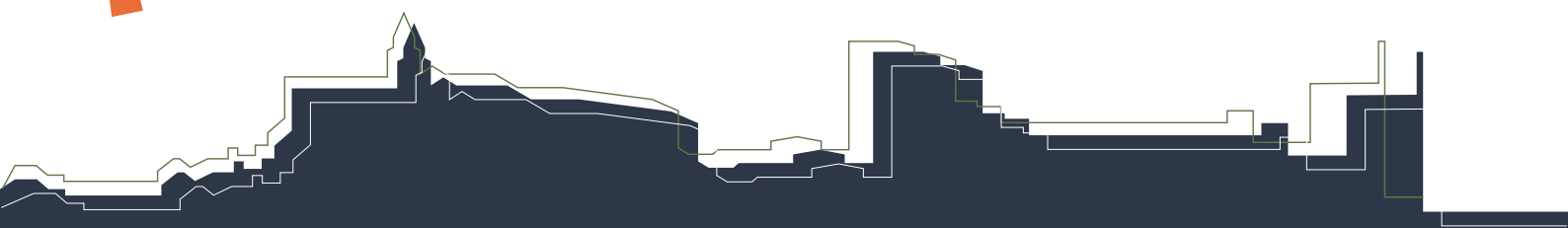
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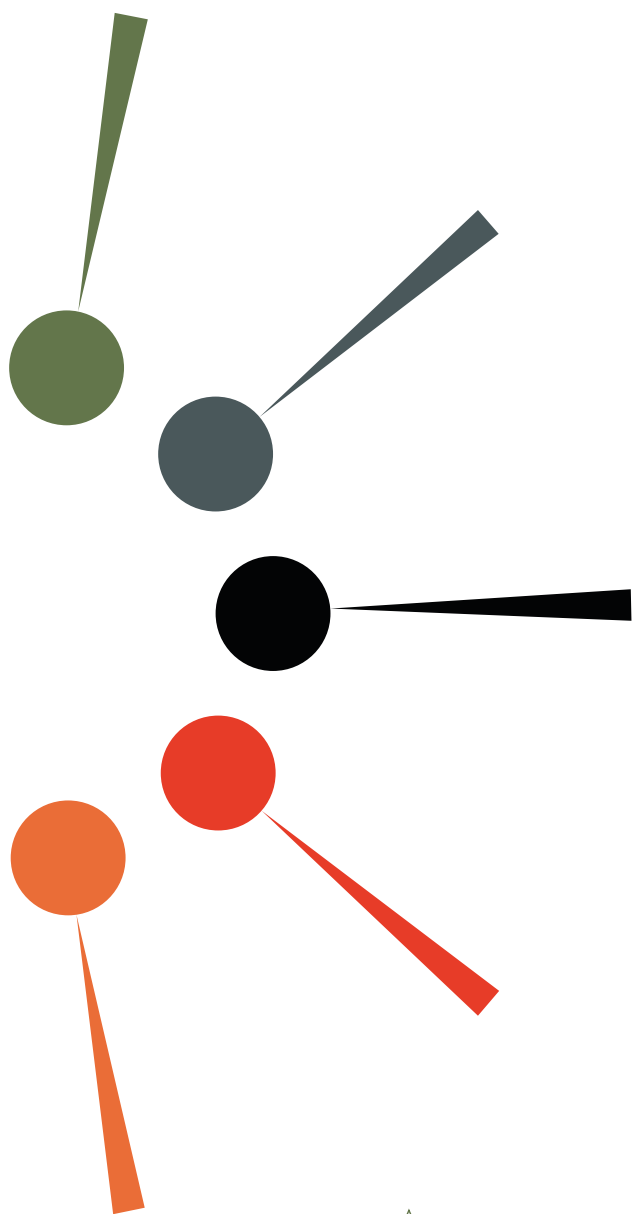
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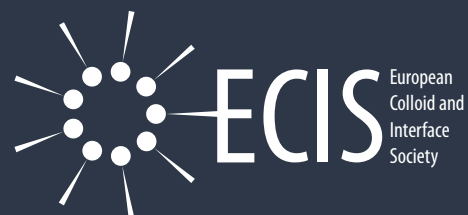
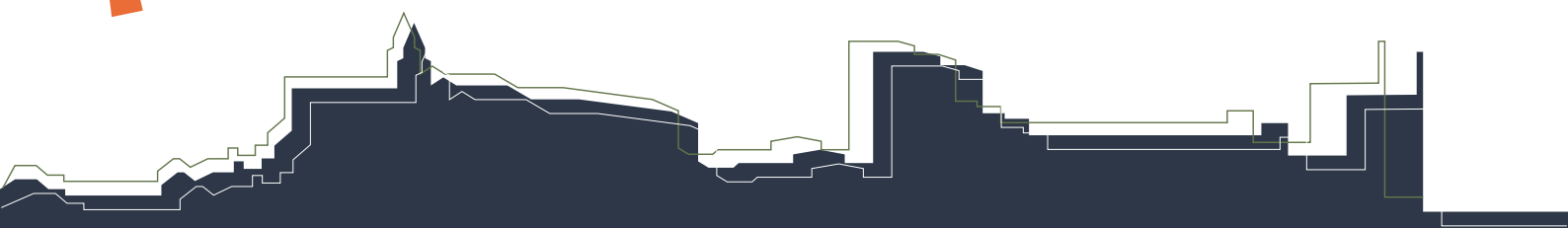
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PLENARY



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Nonlinear rheology and mass transport in bacterial biofilms: a polymer-network perspective.

Eleonora Secchi

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Biofilms are aggregates of bacteria embedded in a self-secreted extracellular polymeric substance (EPS) matrix [1]. From a physical perspective, they can be regarded as living complex fluids [2]: soft, heterogeneous polymer networks that undergo large deformations, display strongly nonlinear rheology, and simultaneously regulate the transport of chemical species. These coupled properties contribute to the remarkable persistence of biofilms across medical, industrial, and environmental settings, yet the physical mechanisms linking microstructure, mechanics, and transport remain poorly understood.

In this talk, I will present a physics-driven framework that treats biofilms as structured polymer networks whose macroscopic behaviour emerges from coupled nonlinear mechanics and hindered mass transport, operating alongside organism-specific biological regulation. Using microfluidic platforms combined with in situ imaging and numerical modelling, we probe biofilm responses under controlled mechanical deformation and chemical exposure, with the aim of identifying general physical principles that govern nonlinear rheology and transport in biofilms. On the rheological side, I will focus on the role of extracellular DNA (eDNA), a near-ubiquitous EPS component that acts as a load-bearing structural backbone. I will demonstrate how the eDNA network controls the assembly and nonlinear rheology of flow-suspended biofilms, enabling them to withstand flow fluctuations [3]. On the transport side, I will then show how the properties of eDNA–polysaccharide networks regulate permeability, mass transport, and chemical gradient formation, thereby directly shaping chemical protection, antimicrobial tolerance, and biofouling.

By linking nonlinear mechanics and transport through the physics of polymer networks, this work reframes biofilm resilience as an emergent property of a living complex fluid, modulated — but not fully dictated — by biology. This perspective opens new routes for predictive modelling of biofilm properties and for rational strategies to disrupt their integrity in real-world applications.

Keywords:

nonlinear rheology, mass transport, bacterial biofilms

References:

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Points, Disclinations and Walls – Defects in Confined Passive and Active Nematics

Alberto Fernandez-Nieves

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Nematics have orientational but not positional order, and often consist of elongated particles that align, on average, along a common axis or director. When confined within curved surfaces, the geometry and topology of the confining surface, together with the boundary conditions for the director field, all affect and often dictate how the material organizes. In this talk I will focus on the 3D confinement of nematics. In particular, I will discuss how we generate non-trivial confining spaces and how we quantify the order of the nematic inside them, paying special attention to the topological defects that we often observe. Inside tori with tangential anchoring, structures with broken reflection symmetry, as well as with pairs of point defects, are both observed. Applying magnetic fields results in the formation of inversion (Helfrich) walls, including splay-bend and twist walls, and a new wall type not previously classified before. Driving the nematic out-of-equilibrium results in spatio-temporal dynamics, where defects move, create and annihilate. These effects all conspire to result in anomalous number fluctuations, akin to hyperuniformity, in finite-size systems.

Keywords:

Topological defects, liquid crystals, active nematics, inversion walls

Understanding how drug carrier physico-chemical properties shape their interactions in complex biological environments and with cells

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Our research is focused on understanding at a fundamental level how the drug carriers used in nanomedicine interact with and are processed by cells. In this talk, we will show you how we combine optimization and physico-chemical characterization of drug delivery systems with different methods in cell biology to determine their interactions with cell receptors, mechanism of uptake and intracellular behavior. In addition, we will present novel methods to characterize cellular pathways, which we developed by taking advantage of nanoparticle properties. [1,2]

Particular attention is given to the modifications drug carriers encounter upon administration: once in contact with complex biological fluids, biomolecules adsorb on the drug carrier surface, forming a corona that strongly affects the subsequent interactions with cells. For instance, we previously showed that the adsorbed corona molecules can interact with specific cell receptors and affect the mechanisms cells use for internalizing the drug carrier.[3,4] Similarly, we found that the adsorbed corona can modulate the transfection efficiency of lipid nanoparticles for RNA delivery, such as those used for the RNA vaccines against COVID-19.[5]

Next, we focus on nanoparticle interactions with cells, and in particular the interaction with cell receptors, mechanisms of uptake and intracellular behavior, and study how these processes can be controlled by tuning nanoparticle physico-chemical properties. As an example of this, we used liposomes of different compositions in order to obtain nanoparticles with different rigidity and study how nanoparticle mechanical properties affect their cell behavior. Similarly, we modulated liposome charge to obtain positively charged nanoparticles that are stable in biological fluids and are not toxic to cells and used them to understand at a fundamental level why positively charged nanoparticles usually are internalized by cells more than negatively charged ones. [6]

Our findings highlight the importance of understanding how drug carrier physico-chemical properties shape their interactions in complex biological environments and with cells in order to be able to design nanomedicines with the desired outcomes at the cell level.

Keywords:

Drug delivery, nanomedicine, biomolecule corona, liposomes, lipid nanoparticles, cell uptake

References:

- [1] Garcia Romeu, H. et al., *Time-and Space-Resolved Flow-Cytometry of Cell Organelles to Quantify Nanoparticle Uptake and Intracellular Trafficking by Cells*, **Small** 2021, 17 (34), 2100887.
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- [3] Francia, V. et al. *Corona Composition Can Affect the Mechanisms Cells Use to Internalize Nanoparticles*. **ACS Nano** 2019, 13, 11107-11121.
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Cavitation in water: a matter of the weakest link

Matej Kanduč

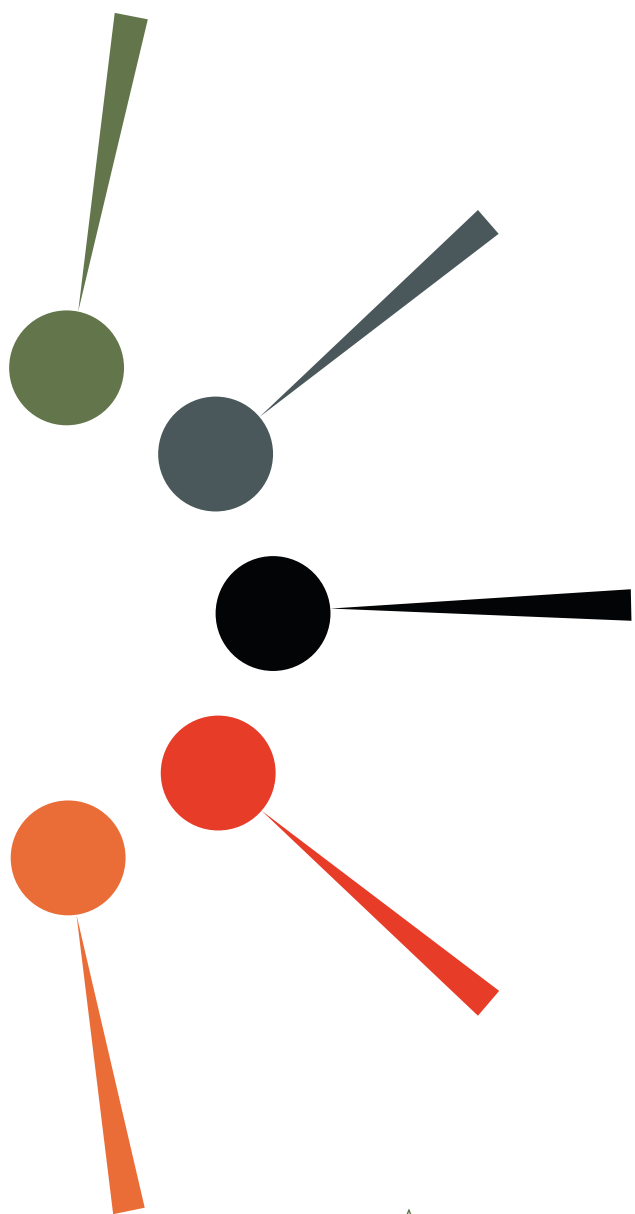
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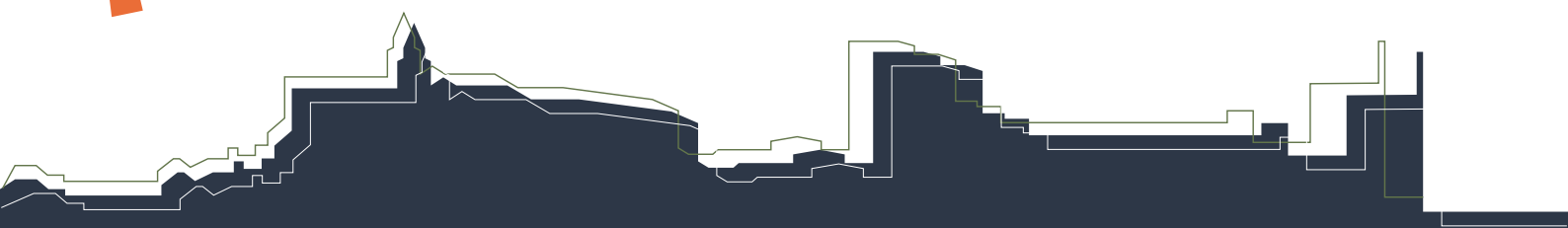
Liquids can sustain surprisingly large negative pressures before cavitation bubbles occur. In water, such deeply metastable states are typically observed when the liquid is exceptionally pure and free of nucleation sites. Yet in some cases, the opposite behavior is observed: the presence of amphiphilic molecules can significantly increase the resistance of water to cavitation. Even more strikingly, plants transport water at negative pressures approaching -100 atm without cavitation, even though xylem sap is far from pure water. How is this possible?

Cavitation in such systems is governed by the interplay of surfaces, impurities, nanobubbles, and amphiphilic molecules. These molecules can adsorb onto hydrophobic surface crevices—sites that would otherwise trap gas pockets and act as nucleation sites for cavitation. Once coated by amphiphiles, these nanoscale defects become effectively passivated and can no longer stabilize nanobubbles, allowing water to remain intact even under strong tension.

These mechanisms show how molecular organization at interfaces can fundamentally alter nucleation processes and the mechanical stability of liquids under tension.



! MEMORIAL



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From micro emulsion to fluctuating membranes : a tribute to Professor Pierre Bothorel

Didier Roux

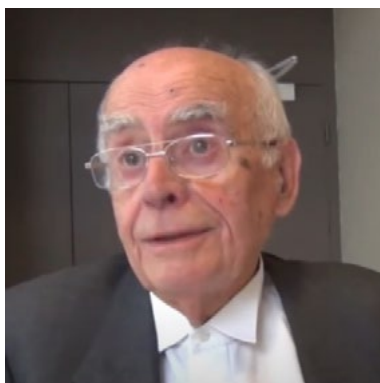
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Pierre Bothorel was one of the founders of the ECIS conferences, together with Mario Corti and Vittorio Degiorgio, in 1987. He was a highly entrepreneurial scientist and also my PhD advisor. When I began working with him, his main field of interest was microemulsions. In this presentation, we describe the motivations that led the scientific community to study microemulsions and how the subject evolved from applications in oil recovery to a deeply fundamental problem in statistical physics: the fluctuations of two-dimensional objects subjected to Brownian motion.

Keywords:

Macroemulsion, fluctuating surfaces, statistical physics



Pierre Bothorel 1930-1924

Heinz Hoffmann - A Life of Passion for Colloid Science

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Heinz Hoffmann was one of the “founding fathers” of ECIS, instrumental for bringing this organisation and conference into life in the second half of the 1980’s and dedicated to it until the end of his life. At the time of the foundation of ECIS, he had already established himself as an eminent scientist in the field of colloid science with a particular focus on surfactant science. Early on in his career he had realised that international cooperation is a central key in advancing science, especially in such a rather interdisciplinary field as colloid science, which was one of the driving motives for getting ECIS started.

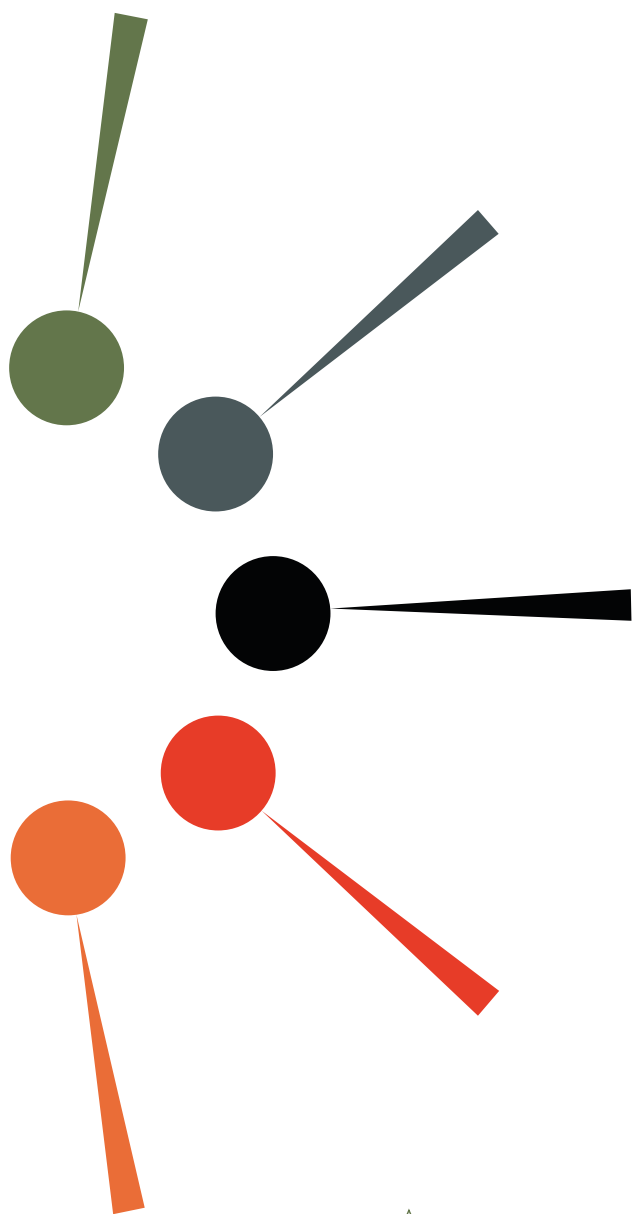
Heinz Hoffmann started his research career in the field of electrochemistry and then ventured into the newly developing field of studying fast reaction kinetics. Some time later he applied this methodology to the investigation of micellar systems and the interesting findings of these experiments brought him into the field of colloid science. Once he had arrived here, he discovered the multitude of interesting phenomena seen in colloidal systems and devoted the rest of his research life to the investigation of a large number of different questions from the field of colloid science. In his research he liked to focus on fundamental questions but then was also interested into bringing these fundamental insights to the more practical and applied aspects of colloid science. In this lecture we want to have a look at the personality of Heinz Hoffmann, which means on one side on the highlights of his research work and his contributions to our understanding of colloidal systems but on the other side also on the personality behind it, as almost always a good researcher is connected with being an interesting human being. This talk will not be able to cover all the various scientific exploits of Heinz Hoffmann in a comprehensive way but instead will focus on highlighting some of his most important findings, his contributions to ECIS and the personality behind it. In this way we will not only honour a well-deserving scientist from our community but hopefully also give some inspiration to the generations of scientist that come after him.

Keywords:

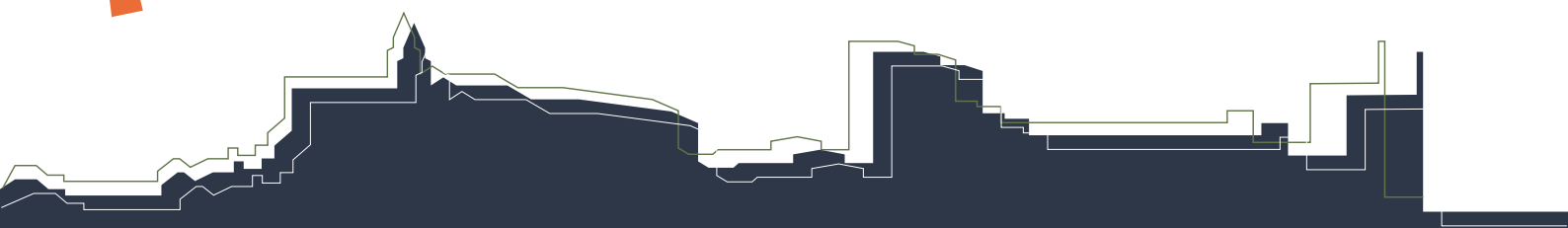
ECIS, surfactants, self-assembly, rheology



Photo of Heinz Hoffmann in his office



! AWARD



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Solvation-by-design: amphiphile self-assembly and biomolecular adaptation in deep eutectic solvents

Adrian Sanchez-Fernandez^a

^a*Centro Singular de Investigación en Química Biolóxica e Materiais Moleculares (CIQUS), Departamento de Enxeñaría Química, Universidade de Santiago de Compostela, Santiago de Compostela, Spain*

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Solvation has become a design principle, and deep eutectic solvents (DESs) perfectly exemplify this emerging paradigm. DESs are liquids formed through the mixture of simple molecular components (e.g. choline chloride and urea) in the absence of water or any other solvent [1]. In these, the intermolecular forces between the constituents elicit a marked depression in the melting point that stabilizes the fluid phase. Far from acting as passive media, DESs are increasingly recognized as task-specific ‘cocktails’ in which composition can be controlled to precisely modulate hydrogen-bonding networks, charge density, and solvophobicity. This allows to design DESs that can dictate solvation landscapes and specific solvent-solute interactions. This exceptional tunability makes DESs a unique framework in which we can interrogate phenomena ranging from self-assembly to biomolecular stability, adaptation and function, with implications spanning soft-matter science, biocatalysis and advanced biomedical formulation.

In our group *descaffold*, we exploit the design space to show that DESs can regulate matter across length scales. In amphiphile systems, they modulate self-assembly pathways by balancing the supramolecular interactions that define aggregate curvature and colloidal organization [2]. In proteins, they remodel folding and association landscapes [3], which can be induce gellation and expose new principles for biomolecular soft materials [4]. In nucleic-acid formulations, they create anhydrous environments that enhance stability, expanding the scope of transfecting systems beyond the constraints of aqueous media. If solvation can be engineered at will, then DESs may do more than expand formulation space—they may fundamentally redraw its boundaries.

Keywords:

Deep eutectic solvents, self-assembly, protein folding, gel formation

References:

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The Surface Potential of Water and Electrolytes: Bridging Experiments, Theory, and Simulations

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The electric surface potential of water and electrolyte interfaces plays a central role in colloid and interface science, governing surface interactions and electrokinetic phenomena. A wide range of experimental techniques — including vibrating-plate measurements, radioactive-probe methods, liquid-jet photoelectron spectroscopy, electrophoretic measurements, nonlinear optical spectroscopy, electron holography, and ion-scattering spectroscopy — have been interpreted in terms of surface potentials. However, these methods often yield conflicting results, even for the conceptually simple air–water interface. In this talk, I will explain the origins of these apparent discrepancies, show how the different measurements can be reconciled, and demonstrate how they provide complementary insights into the molecular structure of water and electrolytes at interfaces. In particular, I will show that the structural width of the pure air–water interface is only about 8 Å and is governed not only by dipolar ordering but also by biaxial molecular ordering.

Keywords:

Interfaces, Surface potential, Molecular structure, theory, simulations

Interfacing functions: supramolecular chemistry enabling high-performance pressure sensors and neuromorphic computing

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The remarkable characteristics of 2D materials can be further refined, expanded, and improved by integrating them with specifically designed molecules, utilizing principles of supramolecular chemistry. By leveraging the extensive range of molecules that can be tailored and synthesized with specific functionalities, it becomes possible to engineer 2D materials with adaptable physical and chemical characteristics. This approach enables the emergence of novel functionalities, aiming to develop multifunctional hybrid systems suited for electronic applications beyond CMOS technology, in line with the “more than Moore” strategy of functional diversification.[1]

In my lecture, I will present our recent advances in employing chemical strategies on colloidal dispersions of 2D nanosheets and hybrid networks thereof, and demonstrate their outstanding and tunable characteristics in proof-of-concept applications. These include flexible pressure sensors with improved performance metrics[2] for both cardiovascular health monitoring[3] and smart insoles-based gait analysis, as well as sophisticated, multi-responsive optoelectronic systems[4] and optoionic memories powered by biopolymer hydrogels [5] capable of mimicking neuromorphic logic functions.[6]

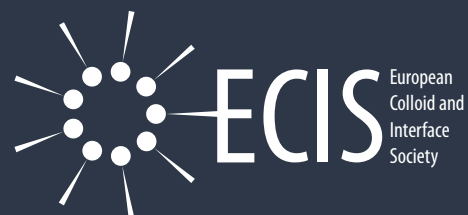
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Multiphase Lipid Nanoparticles: Exploiting Topological Frustration for Enhanced Nucleic Acid Delivery

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Lipid nanoparticles (LNPs) represent a prototypical class of soft colloidal carriers for nucleic acid (NA) delivery. Despite their widespread use, current formulations suffer from inefficient cytosolic delivery, largely due to endosomal sequestration. This limitation calls for a deeper understanding of how internal phase behavior and structural frustration in complex lipid assemblies can be harnessed to control biological function.

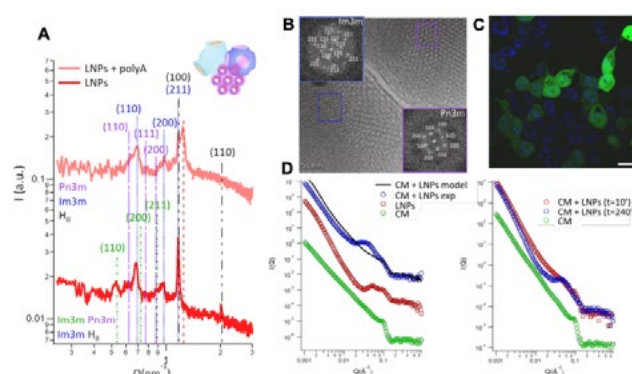
Here, we introduce a design framework for non-lamellar, multiphase LNPs that exploits topological mismatch and packing frustration to generate defect-rich internal architectures. By combining glycerol monooleate (GMO), a curvature-promoting lipid, with both cationic and ionizable species, we induce phase separation into coexisting domains with distinct local curvature and packing symmetry. This results in heterogeneous nanoparticles characterized by a high density of internal interfaces and topological defects, arising from geometric and electrostatic incompatibilities.

The resulting colloidal structures were investigated through a multiscale characterization approach, including DLS, ζ -potential, SAXS/SANS, and cryo-EM, complemented by QCM-D and neutron reflectometry (NR) to probe interfacial interactions with biomimetic lipid membranes. These measurements reveal composition-dependent multiphasic organization of the LNPs and show that increasing the degree of multiphasicity and defect density correlates with enhanced interaction with lipid bilayers. These defect-rich LNPs exhibit an alternative delivery pathway involving direct plasma membrane fusion, in contrast to conventional endocytosis-dominated mechanisms. Functional assays in HEK293 cells confirm enhanced delivery and transfection efficacy of both siRNA and mRNA.

This work positions LNPs as tunable soft colloidal systems in which phase coexistence, interfacial curvature, and topological defects can be engineered to modulate function. More broadly, it highlights the role of multiphase, non-equilibrium nanostructures in dictating interactions at biological interfaces, providing new design principles for colloidal carriers.

Keywords:

Lipid Nanoparticles, RNA delivery, Non-Lamellar Nanoparticles, Nanocarriers, Biomimetic membranes



Multiphase structure of lipid nanoparticles (LNPs) characterized via (A) SAXS and (B) cryo-EM; (C) Confocal microscopy image of HEK293 cells incubated with LNPs loaded with mRNA encoding GFP; (D) NR curves of biomimetic membranes incubated with LNPs

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Acknowledgements:

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The effect of antiviral drugs on the surface properties and stability of model lipid viral envelopes.

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Lipid viral envelopes protect the viral genetic material and contribute to virion stability, making them attractive auxiliary targets for antiviral agents. Recently, we developed physicochemically relevant model lipid envelopes for two enveloped viruses, influenza A (AH1N1) and SARS-CoV-2, with lipid compositions adjusted to reflect the major phospholipids characteristic of their native membranes [1]. Two-dimensional (2D) models were prepared as Langmuir monolayers and characterized using surface pressure–area isotherms and Brewster angle microscopy, while selected systems were further analyzed by grazing-incidence X-ray diffraction and polarization modulation infrared reflection–absorption spectroscopy. To account for membrane curvature and extend the study to three-dimensional (3D) systems, liposomes and giant unilamellar vesicles of corresponding lipid compositions were also prepared and investigated by dynamic light scattering, zeta potential measurements, and fluorescence microscopy.

These model systems were then used to examine the interactions of two antiviral agents with viral lipid envelopes: oseltamivir phosphate with the influenza A envelope model and amantadine with the SARS-CoV-2 envelope model. In both cases, the drugs altered membrane organization, but the extent and mechanism of these effects depended strongly on membrane composition, lipid charge, and packing. Oseltamivir significantly disorganized the influenza ternary monolayer, shifted the isotherms toward larger molecular areas, reduced the compression modulus, weakened attractive intermolecular interactions, and delayed condensed domain formation, indicating fluidization and reduced membrane order. Its strongest effect was observed for the negatively charged DMPS component, pointing to a dominant role of electrostatic interactions [2].

Amantadine also reorganized the SARS-CoV-2 envelope models, but its behavior depended on the lipid environment. In more fluid DOPC- and PI-containing layers it promoted molecular expansion and incorporation into the membrane, whereas in case of DMPS monolayers stronger electrostatic interactions modified packing in a different way. For the ternary SARS-CoV-2 model, hysteresis analysis and Brewster angle microscopy indicated drug-induced domain formation and phase separation. In 3D bilayer models, amantadine changed liposome hydrodynamic diameter and surface charge, while fluorescence microscopy confirmed its incorporation and bilayer reorganization. Molecular dynamics simulations further supported preferential localization of amantadine near the membrane interface with partial insertion into the lipid layer.

Overall, our results show that standard antiviral agents can directly affect viral lipid envelope organization in a composition-dependent manner. This supports the concept that the lipid envelope, beyond viral proteins alone, may serve as a relevant physicochemical target in the design of new antiviral strategies.

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Stimuli-responsive bio-inspired catanionic vesicles: from molecular design to tunable biocargo delivery

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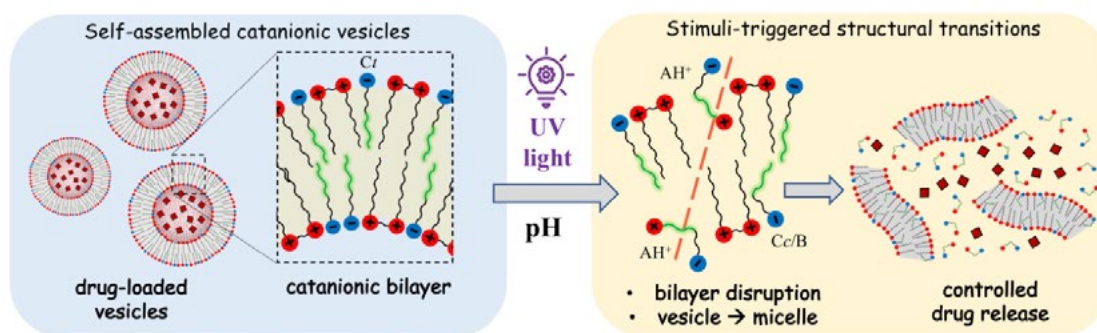
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Achieving precise spatial and temporal control over molecular delivery requires nanocarriers whose behavior can be predictably programmed from molecular interactions to mesoscopic structure. In colloidal systems, this remains particularly challenging under multiple stimuli and complex environments.

Here, we present a bio-inspired design framework for catanionic vesicles in which responsiveness is encoded at the molecular level and propagated through self-assembly. Surfactants derived from natural motifs—namely chalcone/flavylium photoswitch units and amino acid-based headgroups—form catanionic mixtures that exhibit strong non-ideal interactions, enabling spontaneous vesicle formation with tunable composition, charge, and stability [1,2].

The chalcone-based systems display coupled pH- and light-responsiveness [1], where photo-induced molecular switching drives structural transitions (e.g., vesicle-to-micelle and vesicle reorganization), thereby modulating encapsulation and release of drugs such as doxorubicin and paclitaxel. Combined analysis of phase behavior, scattering (including SAXS), spectroscopy, and microscopy shows how these molecular transformations translate into changes in aggregate structure and drug release kinetics.

Extending this approach, pH-responsive sarcosinate-based catanionic vesicles [2] are integrated into thermoresponsive block copolymer networks, where polymer–surfactant interactions lead to mixed assemblies and temperature-dependent reorganization. This coupling between vesicles and the polymer matrix enables sustained and localized delivery, while offering insight into the interplay between self-assembly, co-assembly/self-sorting, and functional control of release behavior.



Molecular design → Self-assembly → Stimuli-response → Functional output

Stimuli-triggered structural transitions in catanionic vesicles enabling controlled drug release.

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We acknowledge the Portuguese Foundation for Science and Technology (FCT) for financial support (Smart4Vir and MultiDNA projects) and Diamond Light Source (UK) for beamtime and experimental support.

mRNA-lipid nanoparticles as a vaccine platform: structural effect of cholesterol substitution with an adjuvant lipid

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Lipid nanoparticles (LNPs) are the leading delivery system for mRNA vaccines. LNPs are composed of a cationic ionizable lipid, a phospholipid, cholesterol, and a pegylated lipid. A major challenge remains the dose-dependent reactogenicity, primarily due to the ionizable component. Despite the clear potential of mRNA vaccines, the structure-function relationship of mRNA-LNPs remains relatively unexplored. Only a few studies have investigated the structure and lipid organisation in mRNA-LNPs and correlated it to their biological function; particularly with the clinically approved ONPATTMTRO[®] formulation based on DLin-MC3-DMA, which displayed a core-shell sphere structure. ^{1,2}

Here, we substitute cholesterol with monomycoloyl glycerol (MMG-1), which is a known adjuvant and stabiliser, potentially enabling reduction of the dose of ionisable lipid and hence reactogenicity. Promising results from our collaborators show that MMG-1 stabilises mRNA-LNPs without reducing vaccine potency. ³

We investigated mRNA-LNP formulations based on the cationic ionisable lipidoid C12-200, the phospholipid DOPE, pegylated lipid DMPE-PEG, and cholesterol, and a range of formulations where cholesterol was replaced by MMG-1 to reveal the effect on particle shape, structure and lipid arrangement.

We employed small-angle x-ray and neutron scattering (SAXS and SANS) in a range of temperature and pH values to mimic relevant physiological conditions. We have used deuterated cholesterol, deuterated C12-200, and deuterated MMG-1 to investigate the component distribution in mRNA-LNPs.

mRNA-LNPs displayed shape and internal structure slightly dependent on the lipid composition but highly affected by the presence of mRNA cargo and by the pH conditions. Overall, this study contributes to the understanding of the composition-structure relationship in mRNA-LNPs. We aim to use this knowledge for the rational design of safer and more effective mRNA vaccines.

Keywords:

mRNA-lipid nanoparticles, small-angle scattering

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How a few help all: cooperative crossing of lipid membranes by COSAN anions

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Cobaltabisdicarbollide (COSAN) nano-ions have an unexpectedly rich self-assembly behaviour, which can lead to vesicles and micelles without having a classical surfactant molecular architecture. The reason for that behaviour is that water stabilizes a particular rotameric form of these nano ions (the cisoid rotamer) that has a well-defined hydrophilic polar region and a hydrophobic apolar region, as shown by our electronic structure calculations (DFT) and molecular dynamics simulations (MD) [1].

This peculiar self-assembly behaviour has consequences on the ability of COSAN nanoions to cross biological membranes, a question of conceptual importance but also with practical consequences due to the potential applications of COSAN in boron neutron capture therapy (BNCT). Experimental results show that COSAN nanoions are able to cross intact artificial phospholipid bilayers in spite of the high Born free energy estimated for these nano ions. Our molecular dynamics simulations [2] show that the permeation of COSAN anions across a lipid bilayer proceeds in a cooperative manner. Single nano-ions can enter the bilayer but permeation is hampered by a free energy barrier of about 8kBT. The interaction between these nano-ions inside a leaflet induces a flip-flop translocation mechanism with the formation of transient, elongated structure inside the membrane. This cooperative flip-flop allows an efficient distribution of COSAN anions in both leaflets of the bilayer. These results suggest the existence of a new mechanism for permeation of nano-ions across lipid membranes, relevant for those that have the appropriate self-assembly character.

Our simulations also show that the flip-flop mechanism depends strongly on the phospholipid composition. This simulation result provides an explanation for the different biodistribution of COSAN ions between different organs observed experimentally that indicate that COSAN anions are able to cross specific biological barriers.

Keywords:

nanoions, molecular dynamics, biomembranes

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From Spiral Nanostructures to Membrane Fusion: Force-Directed Self-Assembly of Viral Peptides at Soft Interfaces

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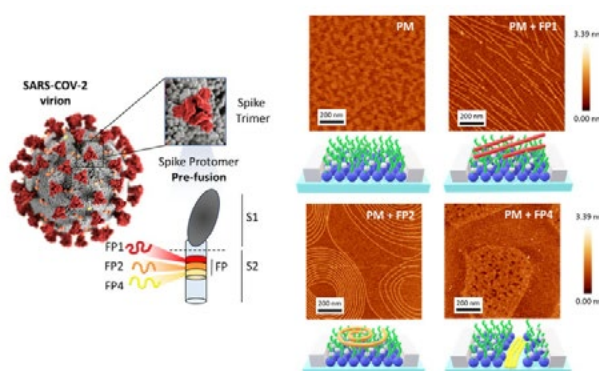
Understanding how molecular self-assembly at fluid interfaces translates into mechanical work is a central challenge in colloid and interface science. Here, we address this question using fusion peptides (FPs) derived from the SARS-CoV-2 Spike protein as model amphiphilic building blocks that spontaneously organize at lipid-decorated air–water interfaces, coupling supramolecular assembly with targeted membrane restructuring [1,2].

Three peptide sequences — FP1 (residues 816–837), FP2 (835–856), and FP4 (885–909) — were investigated at biomimetic plasma membrane monolayers comprising phospholipids, sphingomyelin, and cholesterol (~50 mol%). By modulating lateral packing through uniaxial compression in a Langmuir–Blodgett trough, we explored how interfacial confinement governs peptide oligomerization, lipid phase behavior, and mechanical response. Grazing-incidence X-ray diffraction and neutron reflectometry revealed that all three FPs displace cholesterol-rich nanodomains, suppressing raft-like order and increasing local membrane fluidity through competitive peptide–lipid packing [3].

Each peptide contributes a distinct mechanical function. FP1 forms rigid fibrils (persistence length $\approx 2.3 \mu\text{m}$) that anchor into the acyl chain region. FP2 assembles into flexible spirals (persistence length $\approx 0.14 \mu\text{m}$) storing $\sim 25 \text{ k}_\text{BT}$ of elastic energy per spiral — released upon compression as a loaded-spring mechanism reminiscent of ESCRT-III filament behavior [3]. FP4 transitions from surface-adsorbed to membrane-inserted β -sheet fibrils under high lateral packing, disrupting bilayer continuity. A tandem FP1–FP2 construct confirmed the cooperative nature of anchoring and curvature generation.

Atomic force microscopy, laser direct infrared spectroscopy, and interfacial shear rheology provided complementary morphological, structural, and viscoelastic characterization. The spiral nanostructures additionally served as templates for sub-10 nm metallic replicas over cm^2 areas, illustrating how mechanically active peptide assemblies can be repurposed for functional nanofabrication [4].

These results establish a framework in which simple peptide motifs at fluid interfaces capture, store, and release mechanical energy with spatial precision — offering design principles for responsive soft materials and adaptive colloidal systems.



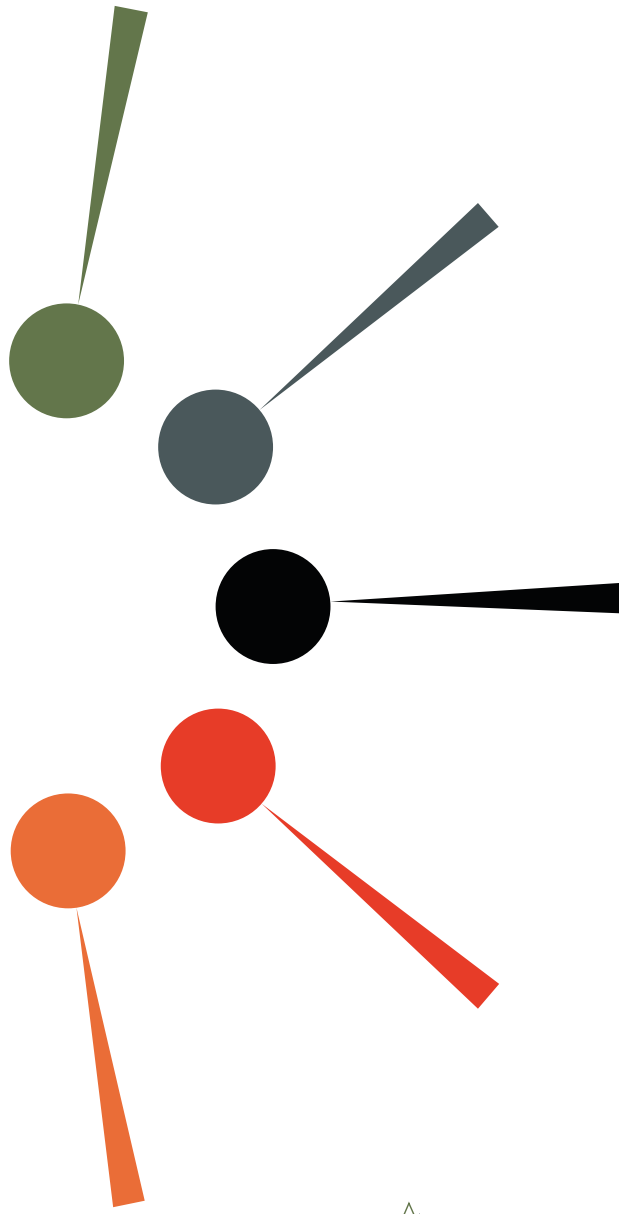
Left: Schematic of the SARS-CoV-2 virion and the Spike protein in its prefusion conformation, highlighting the location of fusion peptides FP1 (red), FP2 (orange), and FP4 (yellow) within the S2 subunit. Right: AFM topographical micrographs and corresponding topographical profiles.

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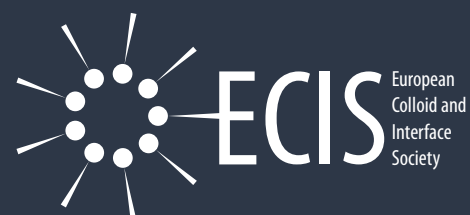
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Towards drug delivery systems triggered by ion-selective interactions

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Achieving well controlled drug delivery is important for effective, safe and convenient administration of drugs to the site of intended action. Active, ion triggered drug delivery is of high interest however, most of the systems proposed respond to change in H^+ ions concentration. We developed a system that allows release of drug ions selective in response to change in the concentration of trigger ions – others than hydrogen ions.

The approach herein proposed ¹ is inspired by ion-selective sensors operation principle. A drug delivery system offered allows release of a charged ion drug from a lipophilic polymer in response to ion-selective interactions of trigger ions from solution with ionophore present in the polymer. Spontaneous and stoichiometric incorporation of trigger ions driven by preferential binding to uncharged ionophore results in charged drug ions release to preserve electroneutrality. This requires preloading of the polymer matrix (apart from ionophore selective to trigger ions) with tailor made ion-exchanger containing drug ions.

The idea was verified on a model example: as drug ions - methylene blue cations (Mb^+) were applied. The Mb^+ containing ion exchanger salt: methylene blue - tetrakis[3,5-bis(trifluoromethyl)phenyl]borate, Mb-TFPB, was prepared. Mb-TFPB was loaded into the polymeric phase together with model potassium ions ligand - valinomycin. Thus, obtained system allows using potassium ions as trigger to release the model drug ions to solution. Both polymeric films and nanofibers were tested to demonstrate the effect of format of the applied lipophilic phase on the rate of release of the drug ions.

The herein proposed approach was also further developed to allow doxycycline delivery in response to change in potassium ions concentration in solution.

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Acknowledgements:

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Hexosomes and Cubosomes from PDMS–PEG block copolymers as Potential Drug Carriers

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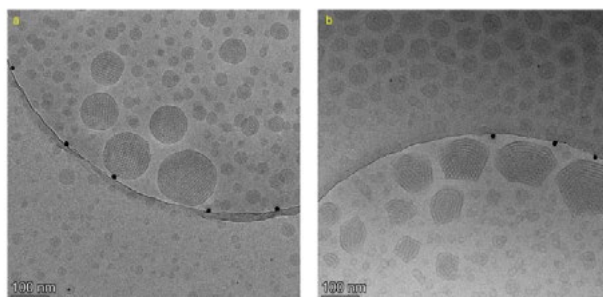
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Non-lamellar liquid crystal particles, such as hexosomes and cubosomes, are promising as drug delivery carriers ¹. However, in most cases, they are derived from lipids, which limits the range of characteristic dimensions within particles. Herein, we report for the first time on the preparation of hexosomes and cubosomes from amphiphilic poly(dimethylsiloxane)-poly (ethylene glycol) (PDMS-PEG) block copolymers. PDMS features extremely low glass transition temperatures, i.e, the polymer chains are liquid-like and flexible at molecular lengths much longer than those of hydrocarbon chains in lipids, a condition that is highly favorable for the formation of inverse phases due to the low chain-packing constraints. PDMS-PEG linear block copolymers were synthesized by hydrosilation from hydride-terminated PDMS (900 g/mol) and allyl methyl ether PEGs (450 and 550 g/mol). ¹H NMR and ¹³C-NMR analyses confirmed the successful conjugation of PDMS and PEG. PDMS₉₀₀-PEG₅₅₀ and PDMS₉₀₀-PEG₄₅₀ show surface activity, reducing the water surface tension to 21 mN/m and 24 mN/m, respectively. Polarized optical microscopy revealed birefringence upon hydration of PDMS₉₀₀-PEG₅₅₀, indicating the formation of anisotropic liquid-crystals. Small-angle X-ray scattering (SAXS) analysis and phase behavior studies confirmed the formation of an inverse hexagonal (H₂) phase for hydrated PDMS₉₀₀-PEG₅₅₀, with characteristic SAXS peak ratios of 1 : $\sqrt{3}$: $\sqrt{4}$, and an inverse micellar cubic (I₂) phase with an Fd3m space group for hydrated PDMS₉₀₀-PEG₄₅₀, as evidenced by 14 diffraction peaks observed using synchrotron SAXS. These results suggest that inverse liquid crystal structure and morphology can be tuned by changing PEG chain length. Quantitative structural analysis allowed to determine the radius of the micellar cores and the interfacial area per molecule in the H₂ and I₂ phases ². Hexosome and cubosome dispersions in PBS can be prepared from the H₂ and I₂ phases, respectively, via the emulsification-evaporation method, using poly(oxyethylene) stearyl ether (Brij S-100) as a stabilizer, as confirmed by synchrotron SAXS and Cryo-TEM experiments. The colloidal stability of hexosome and cubosome dispersions was monitored using TurbiscanTM. Colloidally stable formulations have hydrodynamic sizes of 153.2 ± 4.4 nm (PDI of 0.15 ± 0.05) for PDMS₉₀₀-PEG₅₅₀ hexosomes and 139.4 ± 3.1 nm (PDI of 0.19 ± 0.1) for PDMS₉₀₀-PEG₄₅₀ cubosomes. Additionally, these formulations were studied for the encapsulation and release of ibuprofen as model drug by using High-Performance Liquid Chromatography (HPLC). Cytotoxicity and cell internalization were further evaluated in vitro to assess biocompatibility.

Keywords:

Lyotropic liquid crystals, amphiphilic block copolymers, self-assembly, hexosomes, cubosomes, colloidal stability, drug delivery.



Representative Cryo-TEM images of a) PDMS900-PEG450 cubosomes and b) PDMS900-PEG550 hexosomes.

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Fate of self-assembled squalene non-lamellar liquid crystalline nanoparticles acting as painkillers in a biomimetic medium assessed by scattering techniques

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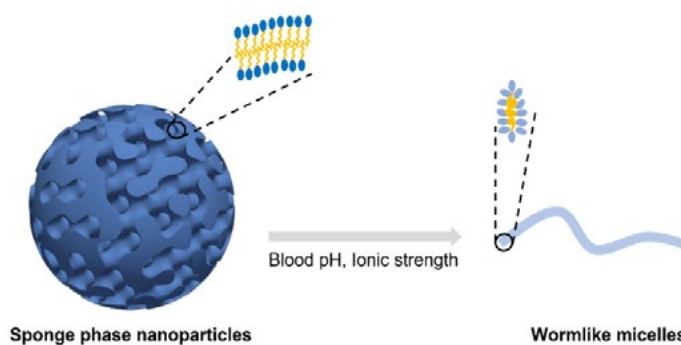
Recently, the Leucine-enkephalin-squalene (LENK-SQ) prodrug, when formulated as nanoparticles (NPs), has been shown to be an efficient formulation for pain treatment after intravenous administration, offering a promising alternative to conventional opioid therapies [1]. These LENK-SQ NPs belong to the general class of non-lamellar lyotropic liquid crystalline lipid NPs whose unique supramolecular organization enables enhanced targeting, reduced toxicity, and improved pharmacokinetic profiles [2]. Despite these advantages, their physicochemical behavior *in vivo* remains incompletely understood, particularly regarding NP morphology, colloidal stability, and interactions with biological components.

Using the specific case of LENK-SQ bioconjugate, which bears an ionizable group on its LENK peptide moiety, we explored how the pH and ionic strength influence its supramolecular organization and stability, an area that remains largely unstudied despite its likely strong impact on therapeutic efficacy.

We elucidated the behavior of LENK-SQ NPs in biomimetic environments using complementary physicochemical techniques, with particular emphasis on small- and wide-angle X-ray scattering (SAXS/WAXS), small-angle neutron scattering (SANS) and cryogenic electron microscopy (cryo-TEM). In this respect, the NPs were studied in buffers simulating physiological pH and ionic strength.

Our results revealed a dynamic equilibrium between free LENK-SQ bioconjugates, sponge phase NPs, and elongated micelles, strongly influenced by buffer composition and concentration. The relative proportions of these species were found to be primarily governed by pH, highlighting its critical role in controlling the supramolecular morphology of self-assembled bioconjugates, which may influence their biological performance [3].

Furthermore, ongoing investigations into the behavior of these NPs in the presence of plasma proteins, recently initiated [4,5], also suggest a transition of the NPs towards micelles in equilibrium with the proteins. These findings provide important insights into how the physicochemical environment modulates peptide amphiphile NPs and, potentially, biological performance. Moreover, they offer rational tools for designing NPs with tunable morphologies and controlled release [5].



Nanoparticles/micelles transition triggered by blood pH and ionic strength.

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Bioinspired Engineering of Surface Coatings for Protein Corona Control

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Nanoparticles have emerged as highly versatile platforms in modern biomedicine, offering unprecedented opportunities for drug delivery, imaging, diagnostics, and therapeutic interventions. Their tunable size, shape, and surface chemistry allows researchers to engineer materials capable of navigating complex biological environments with precision. However, despite their enormous potential, a major challenge arises the moment these nanomaterials encounter biological fluids. Upon contact with serum, plasma, or any protein-rich medium, their surface becomes rapidly covered by a dynamic layer of adsorbed proteins and biomolecules known as the *protein corona*. This corona effectively redefines the nanoparticle's biological identity, influencing its colloidal stability, cellular uptake, biodistribution, immune recognition, and overall bioactivity. In many cases, the formation of an uncontrolled corona leads to loss of targeting ability, accelerated clearance, or unexpected biological responses, which has driven intense efforts to develop reliable “stealth” or antifouling surface strategies.

A wide range of antifouling strategies has been explored to control protein corona formation, including peptide-based coatings, zwitterionic polymers, and hydrophilic polymer layers designed to minimize nonspecific adsorption. However, we propose a different approach: looking directly at nature, and specifically at the complex surfaces of endogenous proteins. These biomolecules present heterogeneous charge distributions and well-defined domains that allow them to travel through the bloodstream while avoiding nonspecific interactions with other proteins and biomolecules. Inspired by this natural design, we aim to mimic the charge balance of human serum albumin (HSA) surface (the most abundant protein in plasma) by combining PEG-SH molecules functionalized with amino, carboxyl, and methoxy terminal groups. [1]

Since protein corona formation is strongly influenced by multiple physicochemical and environmental factors, we aimed to evaluate the generality and robustness of our biomimetic coating by systematically varying several key parameters. For this purpose, we studied corona formation on gold nanoparticles while modifying i) the overall surface charge, ii) nanoparticle curvature [2], iii) particle shape, iv) PEG chain length, v) the biological environment (including exposure to isolated proteins such as HSA and γ -globulin, human serum, and plasma), and vi) flat gold surfaces. Corona formation was characterized by using TEM, DLS, QCM, and UV-VIs

Our results shed light on the curvature, chain length, and shape of nanoparticles as relevant parameters influencing the protein corona inhibition. They reveal a markedly drastically enhanced stealth behavior in nanoparticles coated with the biomimetic PEG system, while demonstrating significantly reduced protein adsorption across a wide range of conditions. These findings deepen our understanding of structure–property relationships in biomimetic surface engineering and highlight the potential of charge-balanced, protein-inspired coatings as a broadly applicable strategy for next-generation biomedical nanomaterials.

Keywords:

Biomimicking, protein corona, nanoparticles, stealth, and antifouling surfaces.

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Ultra-Small Gold Nanoparticle Adsorption and Uptake Is Directed by Bio-Membrane Composition

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Introduction: Nanomaterials are widely investigated in biological contexts due to their potential use in advanced nanomedicine and diagnostic technologies. For most nanoparticle-based biotechnologies to be effective, particles must interact with, and often cross, cellular membranes. However, the mechanisms governing nanoparticle–membrane interactions—particularly for ultra-small nanoparticles and compositionally complex membranes—remain poorly characterised.

Aim: This work combines advanced experimental and computational approaches to elucidate how ultra-small (≈ 5 nm) gold nanoparticles (AuNPs) interact dynamically with synthetic biomembranes, with a specific focus on the roles of particle capping chemistry, membrane cholesterol content, and membrane - liposugar incorporation.

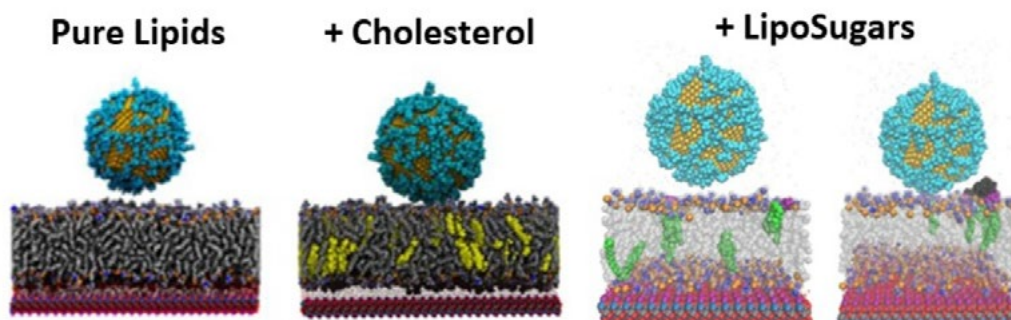
Methods: A combination of atomic force microscopy, light and energy scattering techniques, and molecular dynamics simulations was employed to investigate AuNP behaviour at the biomembrane–liquid interface. Model systems consisted of supported lipid bilayers (SLBs) and free-floating liposomes, serving as archetypal biomembranes. Systematically varied membrane compositions incorporating cholesterol and liposugars to mimic increasing biological complexity were used.

Results: We systematically investigated the dynamics, adsorption, incorporation, and translocation of 5 nm AuNPs across a range of membrane environments. Cholesterol content was found to strongly modulate nanoparticle adsorption kinetics and membrane deformation, while liposugars altered both the local interaction potential and the propensity for particle incorporation. Particle capping chemistry further dictated adsorption strength, residence time, and membrane restructuring. Together, these measurements provide localised, nanoscale insight into how membrane composition and particle size collectively govern AuNP–membrane interactions.

Conclusion: The mechanisms by which ultra-small AuNPs interact with biomembranes are increasingly resolved, revealing a multistep process involving: (1) initial adsorption, (2) membrane-mediated particle stabilisation, (3) particle-induced membrane reorganisation or phase modulation, and (4) nanoparticle incorporation and/or translocation. These findings highlight the critical importance of both nanoparticle surface chemistry and membrane composition in directing bio–nano interactions, with broad implications for nanomedicine, toxicology, and the rational design of nanoparticle-based therapeutics.

Keywords:

Bio-Membrane, Nanoparticle, Adsorption, Adhesion, AFM



AuNP Interactions with Biomimetic Membranes of Increasing Complexity.

The role of supramolecular aggregation for cationic peptide in fast bacterial killing

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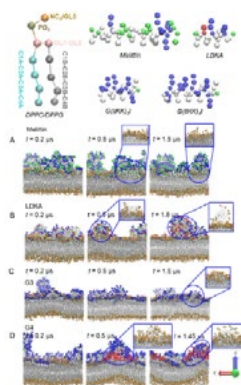
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In light of the growing global threat of multidrug-resistant bacterial infections, there is an urgent need to develop novel antimicrobial agents. Short, rationally-designed antimicrobial peptides (AMPs) offer significant potential due to their tunable properties and distinct mode of action targeting bacterial membranes. This research employs an integrated multi-technique approach—combining molecular dynamics (MD) simulations, neutron reflection/scattering (NR/SANS), and stochastic optical reconstruction microscopy (STORM), to unravel the detailed mechanism of membrane disruption by designed AMPs such as G(IKK)₃I-NH₂ (G3) and its derivatives. Our central finding is that the formation of specific intramembrane peptide nanoaggregates is a critical determinant of bactericidal efficacy. The physicochemical properties of the peptides, particularly hydrophobicity and charge, govern the inter/intramolecular interactions and following extent, depth, and morphology of these aggregates within bacterial lipid bilayers. Optimal nanoaggregation induces membrane rigidification, hydrophobic mismatch, and peptide-aggregate-driven phase separation, leading to accelerated and catastrophic membrane disintegration. This process directly correlates with rapid dynamic killing and high potency against resistant strains like ESBL-*E. coli*, MRSA, while allowing for the fine-tuning of hemolytic cytotoxicity. By establishing intramembrane self-assembly as a core design principle, this work provides a crucial mechanistic framework for developing next-generation, aggregation-optimized peptide antibiotics.

Keywords:

AMP design, intramembrane nanoaggregates, membrane-disruption kinetics, multidrug-resistant bacteria



AMPs' intermolecular interaction with DPPG bilayers at changing simulation times (A. Melittin, B. LDKA, C. G3, D. G4). The inset graphs show the enlarged features inside the corresponding side views, and AMPs are ignored here to highlight lipid molecular restructuring caused by AMP aggregation.

pH Dependence of the Structure of Drug-Free Lipid Nanoparticle Dispersions (LNPs)

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Lipid nanoparticle (LNP) dispersions have emerged as promising systems for drug delivery due to their ability to encapsulate and deliver a variety of therapeutic agents effectively [1]. The outer stabilizing shell of LNPs can be engineered to control the release of drugs [2]. Despite their potential, the precise mechanisms governing drug release and delivery remain not well understood. LNPs continue to be a subject of intense research, with a focus on optimizing their performance in drug delivery applications. A key feature of many LNPs is their responsiveness to environmental changes, particularly in pH. For instance, LNPs can release their encapsulated drugs in the acidic environment of endosomes. The current opinion is that the acidic pH triggers a phase transition in the core of the LNPs, destabilizing the LNP structure and leading to drug release into the cytoplasm of the target cells. In our research, we synthesized drug-free LNP dispersions using an antisolvent precipitation technique [3]. These dispersions were designed to mimic the drug-free version of the commercial Comirnaty formulation (Pfizer/BioNTech). To investigate the impact of pH on the structural properties of the LNPs, we performed simultaneous small angle X-ray (SAXS) and neutron scattering (SANS) measurements at the corresponding unique experimental setup at the D22 instrument of the Institut Laue-Langevin (ILL). These techniques provide information about particle swelling and phase transformations in the LNPs as a function of the pH (cf. Fig. 1). The systems were further characterized by in-situ measurements, conducted via a custom-made flow-through setup. These experiments revealed that the conformational changes triggered by pH variations were reversible which could be confirmed by microscopic observations. It has also been observed that pH variations during dialysis exhibit variable exchange rates (cf. Fig. 2). These differences may arise from multiple factors, including variations in buffer capacity and shifts in the apparent pKa, all of which will be systematically analyzed. The structural change triggered by pH variations is a critical feature of LNPs, suggesting that they can be engineered to release their contents in response to specific pH environments within the body. Moreover, the SAXS/SANS data, combined with photon correlation spectroscopy (PCS), allowed us to investigate the particle size distribution (PSD) and gain insights into the LNPs' behavior under different contrasts and pH conditions. By using an iterative SAXS/SANS/PCS approach, we identified a complex particle size distribution that provided valuable insights into the structural dynamics of LNPs [4]. These findings provide key insights for designing LNPs with improved control over drug release and targeting in future therapeutic applications.

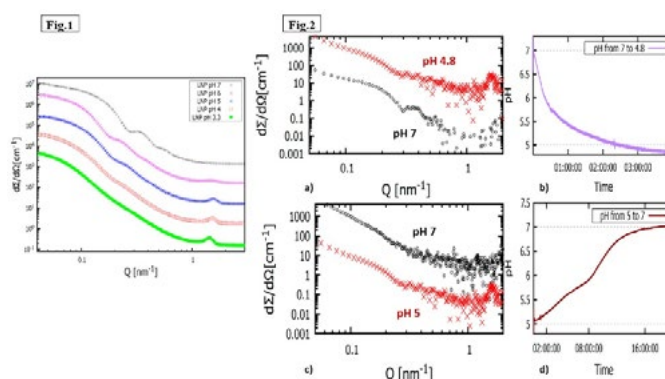


Fig. 1: SANS measurements of LNPs synthesized at pH 3.3–7 (D22, ILL); curves at pH 4–7 are scaled ($\times 10^{-4}$) for clarity. Fig. 2: SAXS (a, c) and pH (b, d) measurements using a flow-through dialysis cell; selected curves are scaled ($\times 100$) for visualization.

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Membrane-targeted nanoparticles for neuronal photo-modulation

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Selective targeting of nanoparticles to the neuronal interface is central for the tailored development of precision neurotechnologies [1,2]. We present a bioorthogonal approach for retaining gold nanoparticles [3] on the membranes of primary neurons and SH-SY5Y neuroblastoma cells. Using confocal and electron microscopy, ICP-MP, we determined that our approach can anchor hundreds of nanoparticles to the membrane of an individual cell. The labeled neurons we tested in wireless photothermal neuromodulation using an NIR laser showed a 45% decrease in MFR at a moderate energy dose of 13 J/cm² per pulse, corroborating results obtained by exposing the neurons to bulk reversible thermal heating. Nanoparticle retention at the membrane is rapid, requiring only one hour of total incubation, with no cytotoxic effect. These results expand the repertoire of light-activated nanomaterials for non-invasive neuromodulation.

Keywords:

Gold nanoparticles, plasmonics, neurotechnologies, neuromodulation

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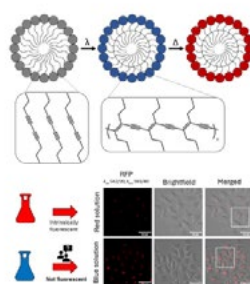
Exploiting the Mechano-Responsiveness of Polydiacetylene Nanoparticles to Track Polymeric Nanoparticle Blends During Cellular Uptake

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Polydiacetylene nanoparticles (PDA NPs) are conjugated polymeric NPs known for their vivid chromatic transitions in response to external stimuli (e.g. temperature, pH, and mechanical stress)¹ which can induce a red-shift and fluorescent colorimetric change, making PDAs highly valuable in sensor applications.² These transitions arise from conformational changes in the polymer backbone, typically composed of alternating C=C and CC bonds formed by UV-induced polymerisation (Figure TOP). PDAs exhibit a blue, non-fluorescent colour, which shifts to red and fluorescent upon structural perturbation. The mechanochromic behaviour of PDAs has been documented in solid and liquid state systems.³ Differently, in the present work, we have observed a spontaneous blue-to-red transition in PDA NPs upon uptake into live cells in 2D culture of different cell types, breast (Figure BOTTOM) and skin cancer and fibroblast. Our preliminary controls screened temperature effects and showed no chromatic alteration under the pH conditions of cell culture media or at endosomal pH levels, suggesting instead effects on PDA backbone structure NPs during the wrapping and endocytosis processes. In this regard, it has been previously observed that soft NPs would deform during the uptake.⁴ However, PDA chromatic change due to cell uptake has not been described in the literature before and represents an interesting strategy to track polymeric NPs. In fact, for therapeutic applications, it is crucial to monitor the kinetics of tissue and cellular drug uptake, organ-specific accumulation, *in vivo* biodistribution, and the intracellular fate of therapeutics. In particular, *in vitro* experiments, polymeric NPs are commonly loaded with fluorophores. However, this approach suffers from dye leakage and separation from the nanoparticles, making it difficult to distinguish signals from intact particles versus free fluorophore, often leading to overestimation of nanoparticle uptake.⁵ Polymer blending offers an alternative that can minimise unwanted drug release and reduce fluorescence.⁶ To our knowledge, the transition blue-to-red (fluorescent) occurring at the interface of cell membranes of PDAs NPs alone or blended with other polymers has not yet been explored and could be used as a low-cost, non-leachable alternative to track polymeric NPs. Importantly, this chromatic response could also be harnessed in more environmentally relevant contexts, for instance to monitor the fate of polymer liquid formulations (PLFs) such as polymeric surfactants or additives following their release into natural systems. This broadens the utility of the phenomenon beyond cellular models.



TOP. Schematic of the PDA micelles (as simplest representation) formation/polymerisation under light irradiation and conformational change under external stimuli (e.g., temperature, pH and mechanical stress). BOTTOM. Uptake characteristics of red solutions of PCDA formulations in breast cells.

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Engineering size-controlled amorphous magnesium calcium phosphate nanoparticles via molecular and polymeric stabilization for drug delivery applications

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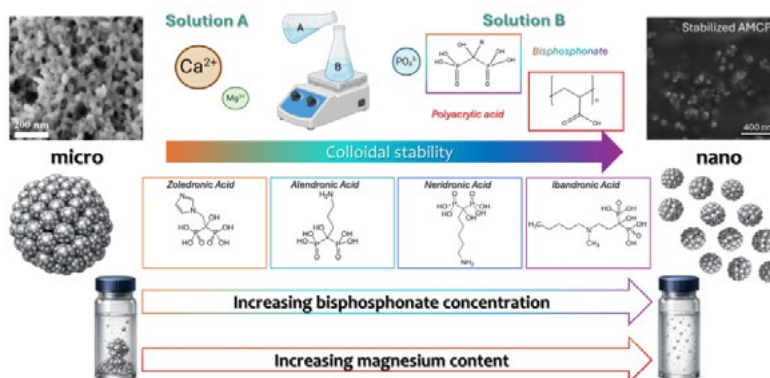
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Calcium phosphate particles are attractive materials for biomedical applications because of their biocompatibility, pH-responsive behavior, and compositional similarity to mineralized tissues [1]. However, controlling particle size, colloidal stability, and crystallinity remains a major challenge, especially when targeting amorphous magnesium calcium phosphate (AMCP)-based systems, which tend to aggregate and evolve toward more crystalline phases. To address this bottleneck, we developed a molecular and polymeric stabilization route to engineer AMCP-based nanometric particles by acting directly on nucleation and early growth, where size and phase evolution are determined. Molecular or polymeric stabilizers enable fine control over both colloidal behaviour and amorphous-phase persistence. In this framework, bisphosphonates bind calcium species in solution and interact with the forming calcium phosphate clusters, regulating growth pathways and shifting the resulting particle size distributions. Beyond size control, this systematic study shows that colloidal stability can be tuned as a function of bisphosphonate chain length, identifying molecular architecture as a practical design parameter. Polyacrylate provides a complementary strategy by strongly limiting irreversible clustering and yielding AMCP-based dispersions with excellent redispersibility upon handling and storage [2]. Particle dimensions can be further adjusted through composition: varying magnesium content offers an additional, independent strategy to regulate the size of the obtained particles. To link stabilizer chemistry to particle properties, the systems were investigated through a multi-technique workflow, combining dynamic light scattering (size in suspension), electron microscopy (morphology), X-ray diffraction together with IR spectroscopy (phase/crystallinity), and thermal analysis (amorphous-to-crystalline conversion). Overall, these results outline a simple and experimentally grounded approach to obtain AMCP-based sub-micron particles with tunable size and controllable stability, supporting their development as formulation-ready platforms for nanomedicine.

Keywords:

Amorphous magnesium calcium phosphate, bisphosphonates, polyacrylate, stability, particle size control



Graphical overview of the molecular and polymeric stabilization strategy for AMCP particles, highlighting the role of bisphosphonates, polyacrylate, and magnesium content in controlling particle size and colloidal stability.

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Layer-by-layer approach as a tool for enhanced functionality: Surface engineering of vesicular-type nanocarriers co-loaded with persistent luminescence nanoparticles and photosensitizers

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One of the possible approaches for organic-to-water phase transfer of luminescence nanoparticles (NPs), with potential biomedical applications, is to encapsulate them in L- α -phosphatidylcholine-based nanocarriers, stabilized with selected mild surfactant, cocamidopropyl betaine (NCR-NPs). Such colloidal NCR-NPs can be distinguished by high stability and loading capacity, as well as their ability to effectively sustain the NPs emission while transferring hydrophobic cargo to an aqueous environment. Additionally, co-encapsulation of NPs with selected second-generation photosensitizers (e.g., chlorin e6) can enhance the nanoplatform application properties, e.g., in photodynamic therapy (PDT). Though, if these NCR-NPs are intended for *in vivo* applications, additional surface functionalization to achieve specificity towards selected cells is needed. For such enhanced functionality, the layer-by-layer (LbL) approach seems like a reasonable solution. LbL serves as a bottom-up surface engineering tool that enables precise control over architecture, composition and structure through sequential assembly of complementary polyelectrolytes.[1,2] For related lipid-based NCR, literature reports enhanced cellular uptake in selected cancer cells (e.g., human ovarian cancer cells) via folic acid surface engineering, enabled by the LbL assembly method.[3] Accordingly, the purpose of this work was the sequential adsorption of selected polyelectrolytes (including modified chitosan and PEGylated hyaluronic acid) onto the surface of NCR-NPs, to evaluate their effect on skin permeability and cellular uptake. As an active cargo, ZnGa₂O₄:Cr³⁺ NPs showing prolonged afterglow were chosen due to their intriguing optical properties, and the matching of luminescence spectra with the absorption of the chosen photosensitizer. Physicochemical techniques such as electrophoretic and dynamic light scattering (DLS and ELS) were used to control the ζ -potential and size (hydrodynamic diameter) changes due to successive layer deposition. Imaging characteristics of the samples were studied using atomic force microscopy combined with infrared spectroscopy (AFM-IR), providing additional information on their morphology and chemical composition at the nanoscale, allowing for precise confirmation of the nanoplatform self-assembly. Our study established the successful layer-by-layer adsorption of polyelectrolytes onto the surface of NCR-NPs, as confirmed by ELS and DLS measurements, while AFM-IR provided insight into their morphology and chemical composition. The resulting structures provide a platform with tunable surface functionality and enhanced specificity, along with potential for applications in PDT, enabled by the NPs core.

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Understanding molecular interactions between dengue virus capsid protein and lipid droplets

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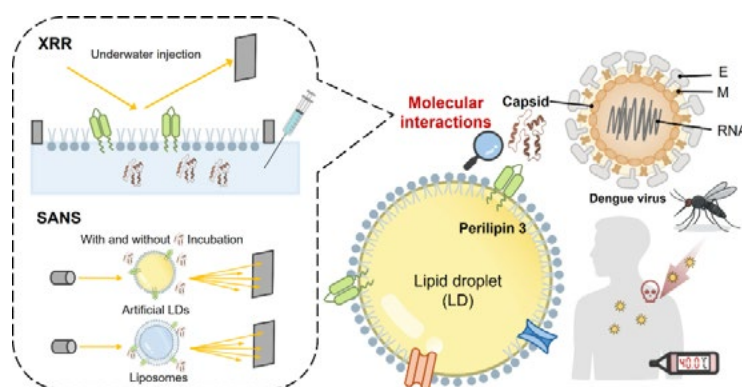
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Dengue virus (DENV), a flavivirus transmitted by mosquitoes, infects over 400 million people each year, yet effective antiviral treatments are still lacking. Recent studies show that lipid droplets (LDs), which are intercellular organelles with a neutral lipid core and a phospholipid monolayer, play a key role in the DENV lifecycle. The viral capsid protein (DENV-C) accumulates on LD surfaces and is involved in nucleocapsid formation and viral assembly. However, the molecular details of how DENV-C interacts with LDs remain unclear, particularly the role of its intrinsically disordered N-terminal region in membrane binding. LD surfaces are not made of lipids alone but also contain functional proteins such as Perilipin 3 (PLIN3), which regulate LDs' metabolism. PLIN3 may therefore influence how viral proteins, including DENV-C, are recruited and organized at LDs, but this has not been fully understood.

In this study, biomimetic LD surfaces are created using phospholipid monolayers at the air–water interface in a Langmuir–Blodgett trough. Surface pressure–area (π – A) isotherms showed that the DOPC/DOPE/DAG monolayers collapsed at $\pi \sim 39$ mN/m. The PLIN3 underwater injection was conducted at $\pi \sim 25$ mN/m, which induced an initial increase in surface pressure followed by a decrease. A two-layer model was used to fit the X-ray reflectivity (XRR) data, yielding a phospholipid monolayer thickness of ~ 24 Å, with no significant changes in either thickness or SLD (scattering length density) observed after the injection of PLIN3, full-length DENV-C protein, or DENV-C pep12-23 (a segment of the protein). However, a change in the SLD of the hydrophilic layer was observed when pep12-23 was injected following PLIN3 incorporation. This result indicates that PLIN3 is essential for DENV-C binding to lipid droplets. Furthermore, complementary quartz crystal microbalance with dissipation (QCM-D) measurements revealed binding kinetics, mass adsorption, and viscoelastic properties as DENV-C and the peptide were added to preformed DOPC/DOPE membranes. Together, these results provide a first mechanistic insight into the role of Plin3 protein in mediating DENV-C binding to the lipid droplet surface, pivotal to future development of antiviral strategies.

Keywords:

Dengue virus, lipid droplets, X-ray reflectivity, monolayer



XRR probes Dengue virus capsid protein adsorption at lipid monolayer, while SANS characterizes structural changes in artificial lipid droplets and liposomes. These model interfaces reveal interactions between Dengue virus Capsid protein and Perilipin-3-functionalized lipid systems.

Preparation, characterization and anticancer activity of β -cyclodextrin nanosponges formulated with two chemotherapeutic drugs

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Cyclodextrin (CD)-based polymers and nanoparticles offer significant opportunities in drug delivery due to their high drug loading capacity, low cytotoxicity, and ease of surface functionalization for specific cell targeting. In our laboratory, β -cyclodextrin (β -CD)-based nanosponges (CNs) were synthesized using two different crosslinkers: citric acid and epichlorohydrin, by varying the β -CD/crosslinker ratios. After purification, the epichlorohydrin-crosslinked CNs were further modified with 2,3-Epoxypropyl trimethyl ammonium chloride to generate positively charged CNs. The resulting library of CNs exhibited extremely small particle sizes ranging from 50 to 30 nm (DLS, SEM and AFM) and carried a surface charge between -20 mV and $+20$ mV.

CNs, which possess both hydrophobic and hydrophilic domains, were used to co-encapsulate different anticancer drugs: N,N-bis (5-ethyl-2-hydroxybenzyl) methylamine (EMD), Dasatinib and Doxorubicin, that act through different mechanisms on cancer cells. EMD promotes apoptosis through c-Myc suppression, Das is a multi-kinase inhibitor that primarily targets the BCR-ABL1 oncoprotein and SRC-family kinases while Doxorubicin damages DNA and stops cancer cells growth. CNs were encapsulated with single drugs and combinations of them. Successful drug encapsulation was confirmed and quantified by UV, fluorescence and ¹H NMR spectroscopy. By NOESY NMR spectroscopy, Fluorescence Spectroscopy and Molecular Dynamic we were able to differentiate drugs encapsulated in the hydrophobic β -CD pocket or in the hydrophilic regions between β -CDs. In vitro drug release studies were conducted at different pH to simulate physiological and endosomal environments. Cellular uptake and cytotoxicity studies of drug-loaded CNs were performed with human lung cancer cells (A549), human breast cancer cells (MCF-7), and normal human lung fibroblast cells (WI-38). Results demonstrated synergistic cytotoxic effects against cancer cells when EMD and Doxo were co-encapsulated, enabling the use of lower drug doses compared to single-drug treatments, with potential decrease on drug side effects. Furthermore, the CNs loaded with two drugs exhibited higher cytotoxicity toward cancer cells than toward normal cells. These findings suggest that β -CD-based nanosponges are promising nanocarriers for the co-delivery of anticancer agents, enhancing therapeutic outcomes through improved efficacy and cell specificity.

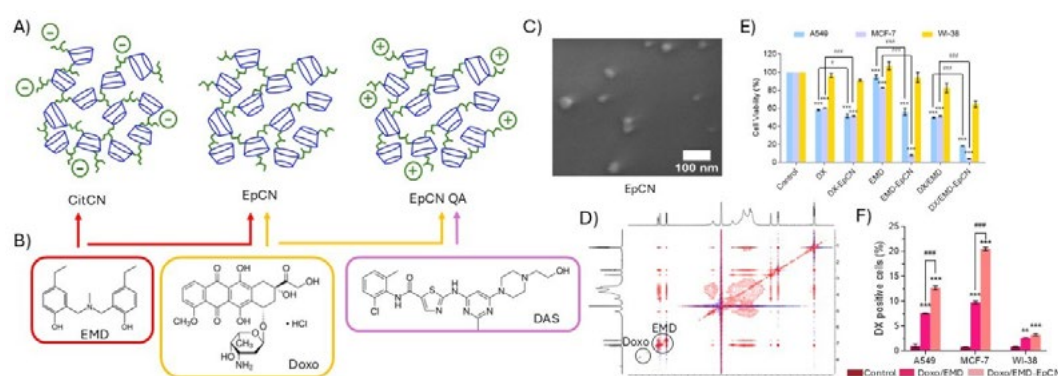


Figure. A) CNs prepared, B) drugs encapsulated, C) EpCN SEM, D) Doxo/EMD-EpCN NOESY NMR, E) cell viability and F) cellular uptake.

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Interactions of Gold Nanoparticles and Model Membranes

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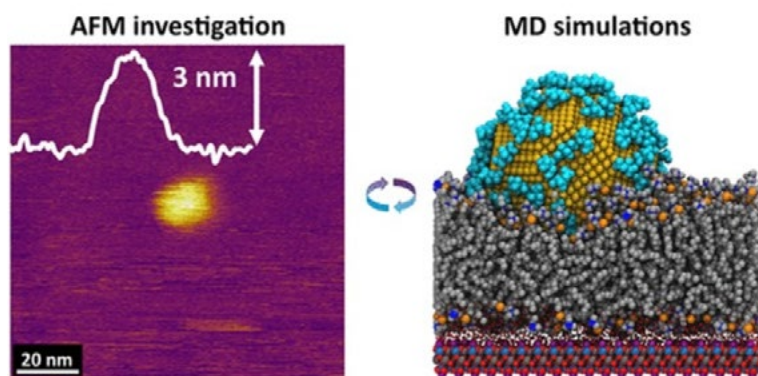
Nanoparticles (NPs) are being explored for their biomedical applications, particularly for identifying and treating disease at the cellular level. Applications of NPs include cell imaging, drug delivery and control of biological processes. To facilitate their function, NPs must interact with the cellular membrane. However, the molecular mechanisms of interaction between NPs and cellular membranes remain difficult to elucidate due to the heterogeneous chemical environment of the cell membrane. For the more effective design of biomedical nanotherapeutics necessitates the need for more fundamental analysis of the interactions that govern NP and biological membranes.

This work investigates the adsorption process of various 5 nm AuNPs onto supported lipid bilayers (SLBs) using a combination of atomic force microscopy (AFM) and molecular dynamics (MD) simulations. First, the adsorption process of a citrate-coated 5 nm AuNP against homogeneous fluid phase (DOPC) and gel phase (DPPC) supported lipid bilayers (SLBs) was studied. It was primarily observed that AuNP underwent easier adsorption into the fluid phase, and the dissociation of the citrate-coating facilitated the adsorption process; whilst the adsorption of the AuNPs disrupted bilayer integrity.

The adsorption capabilities of the citrate capped 5nm AuNP were then tested against a binary phase separated bilayer of fluid (DOPC) and gel (DPPC) lipids. The AuNP was observed to primarily undergo adsorption into the fluid phase domain. The AuNP adsorption also induced lateral lipid mixing and a partial dissolution of the phase boundary domain. Whilst the movement of the AuNP was primarily localized towards the phase boundary and remained in contact with both lipid phases.

Next, the role of the ligand capping agent on the adsorption process was studied. The interaction of a 5 nm AuNP capped with various strongly physisorbed or weakly physisorbed ligands against a fluid phase (DOPC) SLB was characterized. The weakly adsorbed ligands promoted adsorption into the SLB, whereas the more strongly adsorbed ligands increase steric hindrance and shield the AuNP-surface from interacting with the bilayer inhibiting complete adsorption of the AuNP. Ligand morphology, functional group, and binding motifs of the more strongly adsorbed ligands further altered the interaction either promoting or hindering interfacial adsorption.

Finally, the role of AuNP geometry and nanoparticle concentration of the citrate capped 5nm AuNPs onto a fluid phase (DOPC) SLB was investigated. It was observed that the typical faceted nature adopted by face-centered-cubic (FCC) metallic NPs underwent adsorption quicker as compared to more spherical AuNPs, and that increasing the number of AuNPs in a SLB system increases the cost of adsorption due to increases in steric hindrance and volume exclusion effects.



Combined atomic force microscopy and molecular dynamics simulations elucidate adsorption mechanics of gold nanoparticles onto supported lipid bilayers.

Polymer-Coated TiO₂ Nanoparticles: Mechanistic Insights into Antimicrobial Activity via Particle–Membrane Interactions

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Surface modification is a widely employed strategy to enhance the antimicrobial performance of photocatalytic nanoparticles (NPs); however, the underlying particle–membrane interactions remain insufficiently understood. In this work, we investigate how coating TiO₂ nanoparticles with the cationic polymer PDMAEMA (poly((2-dimethylamino)ethyl methacrylate) methyl chloride quaternary salt) influences their interactions with bacterial membranes.

Compared to bare TiO₂, PDMAEMA-coated nanoparticles exhibit significantly enhanced adsorption to negatively charged bacterial cells and model membranes. Upon UV illumination, this increased association leads to enhanced membrane permeabilization driven by reactive oxygen species (ROS) generation. Importantly, the polymer coating does not hinder ROS production and remains stable under UV exposure over timescales relevant for membrane binding and disruption.

The observed membrane damage is highly localized near nanoparticle binding sites. Notably, coated nanoparticles show preferential accumulation at poles and division sites of *Escherichia coli*. We hypothesize that this localization is driven by interactions with anionic lipid domains, particularly cardiolipin. This hypothesis is supported by experiments on giant unilamellar vesicles, where nanoparticles preferentially bind to cardiolipin-rich regions, whether uniformly distributed or phase-separated.

These findings demonstrate that antimicrobial activity of photocatalytic nanoparticles is governed not only by bulk ROS generation but also by localized nanoparticle–membrane interactions. Our results highlight the importance of spatial heterogeneity in bacterial membranes and provide new insights for the rational design of nanoparticle-based antimicrobial systems.

Keywords:

Antimicrobial nanoparticles, cationic modification, lipid membrane, reactive oxygen species, membrane permeation, mechanism

Acknowledgements:

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Sponge phase lipid nanoparticles interacting with biomimetic membranes: lipid exchange and delivery of proteins

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The development of lipid nanoparticles (LNPs) for the delivery of drugs and other functional components requires knowledge of how they interact with e.g. cell membranes as well as the mode of interaction and uptake of the compounds loaded within the LNPs. We have used neutron reflectometry and electrochemical impedance spectroscopy to reveal the interaction of lipid sponge phase nanoparticles (L₃ NPs) with model membranes composed of POPC lipid (1-palmitoyl-2-oleoyl-*sn*-glycero-3-phosphocholine) on silica substrate surfaces. The sponge phases are bicontinuous with curved flexible bilayer structures, with tuneable lipid composition, that are organised in such a way that they form relatively large (>10nm) aqueous channels [1,2]. Similar structures can also be found in cell organelles. We have previously shown that we can encapsulate myoglobin in lipid sponge phases [3]. The structural features of L₃ NPs, based on mixtures of acyl glycerides and phospholipids and their interfacial behaviour at model lipid biomembranes was explored by using scattering, microscopy, and surface-sensitive techniques [4].

Here we will discuss how neutron reflectometry and different isotopic contrast, i.e. H₂O and D₂O buffers and deuterated lipids can be used to separate between the different components, i.e. lipids and protein, to reveal whether lipid exchange and/or protein delivery occurs. Both lipids and protein cargo (myoglobin) from the L₃ NPs end up in the model POPC biomembrane. We observed that lipid exchange occurs, but the overall integrity of the POPC bilayer is preserved. This is confirmed by electrochemical impedance spectroscopy measurements, which suggest that the L₃ NPs do not induce substantial leakage of the model biomembrane. For the L₃ NPs with myoglobin, the proteins appear to end up in the upper leaflet of the bilayer. These findings provide valuable insights for optimizing protein encapsulation and controlling the release mechanisms of sponge phase delivery systems. Furthermore, we show that L₃ NPs can penetrate living cells without detrimental effect on cell viability, as shown by preliminary studies using A549 lung cancer cells.

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Semisolid lipid nanoparticles with thermoresponsive properties: structural and rheological characterization

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One of the main challenges in topical drug delivery is overcoming the skin barrier, particularly the stratum corneum (SC), which prevents transepidermal water loss and limits the penetration of external agents. Lipid-based nanoparticles, such as solid lipid nanoparticles (SLNs) and nanostructured lipid carriers (NLCs), represent a promising strategy to enhance the delivery of active compounds¹. Their high affinity for the SC and adhesion to the skin improves penetration and bioavailability, induces an occlusive effect, and enhances skin hydration². However, in topical formulations the efficacy and applicability of the final product is strictly dependent on its rheological properties, and the incorporation of SLNs into conventional dermal formulations can be challenging due to possible incompatibilities and limited SLNs loading³. Thus, we developed bulk lipid nanocarrier dispersions with the appropriate semisolid consistency desirable for dermal products and ready for application. This formulation showed thermotropic and thixotropic behavior, with a spontaneous and reversible gel-to-liquid transition from 20°C to 36°C, improving nanosystem spreadability and consequent absorption upon contact with the skin. Small-angle X-ray scattering experiments performed at 20°C and 40°C of both SLNs and NLCs revealed that gelation is associated with the formation of a lamellar liquid crystalline mesophase (Figure 1A). This was confirmed also by the birefringent spherulite structure and Maltese cross patterns revealed by Polarized light microscopy that evidenced the thermotropic nature of the material (Figure 1a insert). Rheological measurements proved the viscoelastic microstructure and thixotropic behavior at both temperatures, with a significant decrease of elasticity at 40°C (Figure 1B). Dynamic Light Scattering measurements on the liquid dispersions showed small and monodisperse population. The addition of a liquid lipid to the core reduced the elastic modulus, likely due to decreased interparticle interactions deriving from lower particle contact and/or differences in particle shape. This may reflect changes in physical state and organization of the lipidic matrix, as suggested by a decrease in the melting point of the lipid core shown by DSC and broadening of SAXS peaks.

Keywords:

drug delivery, lipid nanoparticles, thermoresponsive systems

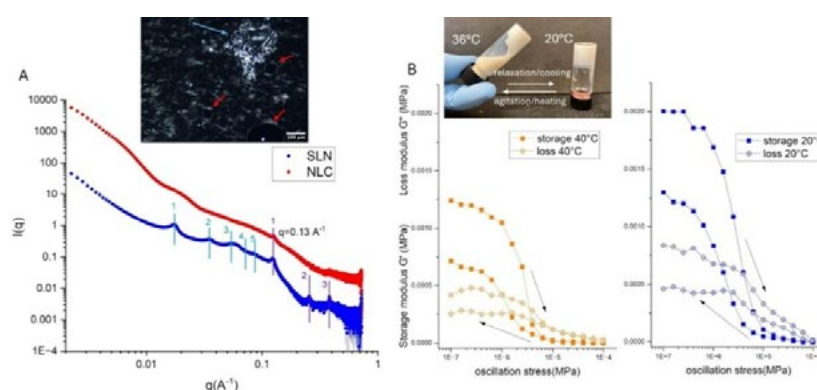


Figure 1: (A) SAXS profile of SLN and NLC liquid crystalline mesophase (inset) polarized optical images showing birefringent aggregates and Maltese cross patterns. (B) Complex modulus plots at 20°C and 40°C (inset) liquid to solid bulk transition

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Camouflaging lipid particles with cell membranes for effective gene delivery to cancer cells

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The low tumor targeting of lipid nanoparticles (LNPs) limits their clinical applications in oncology as nonviral RNA delivery systems. We functionally integrated LNPs with cancer cell membrane components to enhance their targeting capabilities, exploiting cancer cell self-recognition and interactions with stromal cells in the tumor microenvironment. The biomimetic nanocarrier was developed by cloaking RNA-loaded LNPs with nanoghosts obtained from the membrane of triple negative breast cancer cells. RNA-LNPs were fabricated by microfluidics and were incorporated into nanoghosts using ultrasound-assisted fusion, yielding stable biomimetic LNPs [1]. The structure is well defined, characterized by an RNA-LNP core, preserving the internal arrangement of lipids and RNA, enveloped by a nanoghost shell, as assessed by physicochemical analyses and Small-Angle X-ray Scattering. Biomimetic LNPs displayed strong affinity for both cancer-associated fibroblasts and homotypic cancer cells, resulting in significantly improved biological activity compared to uncoated LNPs. This work provides proof of concept that RNA-LNPs can be effectively integrated into self-assembled biomimetic carriers to enable dual targeting of tumor and stromal cells. The enhanced selectivity and delivery performance of biomimetic LNPs highlight their therapeutic potential for overcoming stromal barriers in tumors such as triple negative breast cancer.

Keywords:

Lipid nanoparticles, RNA delivery, Camouflaging nanoparticles, SAXS, Heterotypic targeting

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PRISM: a phase-resolved surface equation of state enabling automated analysis of Langmuir isotherms

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The interpretation of π -A isotherms of Langmuir monolayers is traditionally limited by subjective manual segmentation and a lack of thermodynamic consistency, particularly within complex phase coexistence regions [1, 2]. Here, we propose the Phase-Resolved Interfacial Surface Model (PRISM), an equation-of-state framework that enables the automated extraction of physically meaningful parameters—structural, mechanical and thermodynamic properties—while ensuring rigorous uncertainty quantification through statistical model selection.

The model is based on fundamental thermodynamic relations for monocomponent monolayers of insoluble surfactants. PRISM integrates domain-correction mechanisms to account for deviations from ideality, such as the sloped coexistence segments often observed experimentally, which arise from phase domain formation and line tension. A nested-model selection strategy activates these corrections only when statistically justified, providing a continuous and thermodynamically consistent description of the isotherm while reducing artifacts associated with conventional analysis.

From π -A isotherms, whether obtained experimentally or from molecular dynamics simulations, PRISM enables the estimation of key structural (e.g.: area per molecule), mechanical (e.g.: compressibility modulus) and thermodynamic quantities (e.g.: changes in chemical potential, Gibbs free energy variations) associated with phase transitions. The model is validated across representative lipid monolayers, providing a consistent and reproducible framework for interfacial thermodynamic characterization.

Keywords:

Langmuir monolayers, interfacial thermodynamics, surface tension, equation of state, phase coexistence, compressibility modulus.

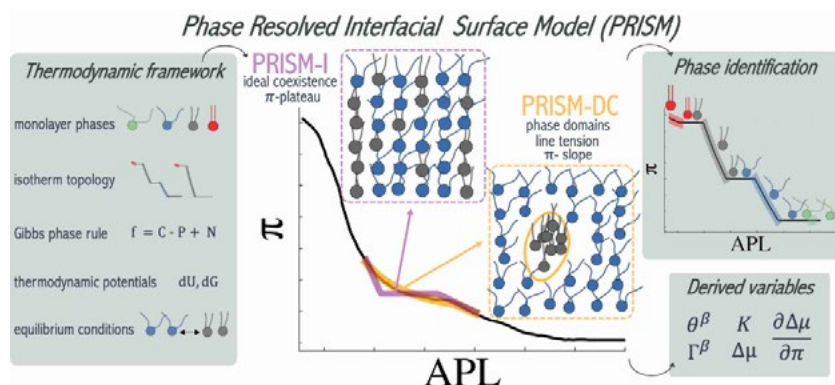


Figure 1: Scheme of the PRISM model proposed as equation of state for π -APL isotherms.

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Triphenylphosphonium bolaamphiphile-liposomes loaded with resveratrol and Trolox: Mitochondriotropic formulations with Therapeutic Potential in Neurodegeneration and Cancer

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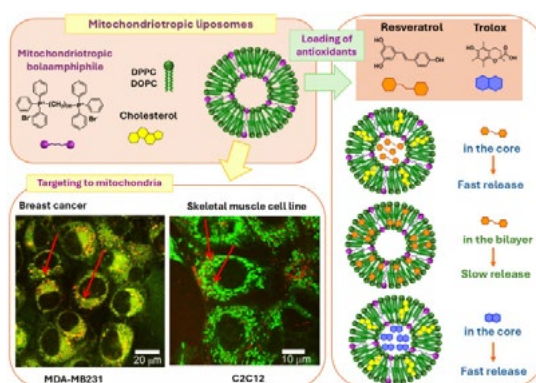
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Drug delivery to mitochondria represents a promising therapeutic strategy because mitochondrial dysfunctions are associated with many different pathologies, from neurodegenerative diseases to diabetes, obesity, cancer, and physiological disorders related to ageing. Actually, mitochondria targeting is particularly challenging due the inner highly convoluted, densely packed membrane, characterized by a strong negative potential that significantly hinders drug delivery. Cationic amphiphilic structures derived by triphenylphosphonium (TPP) are planar structures with highly delocalized cationic charge which is driven to mitochondria by the strong negative potential of the inner mitochondrial membrane and can cross the membrane barriers due to the “soft” nature of their cationic headgroups. A novel single-chain TPP-bolaamphiphile, with two TPP moieties connected by chains of 20 methylene units [1,2] has been explored to realize novel nanocarriers for mitochondrial delivery [3]. The amount of TPP and liposome composition jointly affect the physicochemical properties of liposomes and the bilayer organization. We explored the ability to reach mitochondria in two different cell lines, the murine skeletal muscle C2C12 and the multi drug-resistant (MDR) human breast cancer MDA-MB231, useful to investigate different pathological situations, namely, the oxidative stress associated with ageing and neurodegenerative muscle diseases and the multidrug resistance in cancer. Liposomes with 2.5% of TPP were non toxic and able to target mitochondria, thus resulting good candidates for encapsulation of the antioxidant *trans*-resveratrol. TPP-liposomes encapsulating *trans*-resveratrol in the bilayer or, for the first time, in the aqueous core, were developed with high entrapment efficiency in both cases. Trolox was encapsulated for the first time in the aqueous core of liposomes by remote loading, with very high entrapment efficiency and enhanced stability following encapsulation. The release rate of resveratrol is dependent on its localization in the bilayer; interestingly, this gives the possibility to modulate release in dependence on the application. Finally, we showed that TPP3-liposomes can deliver resveratrol to the mitochondria in the MDA-MB231 cells, exerting a protective activity on the mitochondrial structure. Our results support its potential therapeutic use as an adjuvant for a protective activity in neurodegenerative diseases or for a sensitizing activity against drug resistant tumor cells [3].

Keywords:

Mitochondriotropic liposomes, Antioxidants, Sensitizing agents, MDR in cancer, Neurodegenerative diseases.



TPP-liposomes loaded with resveratrol or Trolox for delivery to mitochondria

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Molecular Insights into Janus Kinase Inhibitor Interactions with Model Intestinal Epithelial Membranes: From Langmuir Monolayers to Asymmetric Bilayers

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Most drugs administered to humans influence the organization and surface properties of biological membranes, thereby modulating cellular functions. The epithelial membrane of the small intestine constitutes the first barrier in drug absorption and is a key target for anti-inflammatory therapies based on Janus kinase inhibitors (JAKs). Despite their widespread clinical use, the molecular mechanisms underlying JAK–membrane interactions remain insufficiently understood.

In this study, multicomponent lipid systems mimicking the intestinal epithelial membrane were employed, progressing from Langmuir monolayers to asymmetric bilayer architectures. The models comprised physiologically relevant lipid mixtures (PC/SM/PE/PS/PI), including asymmetric bilayers with an inner leaflet (DPPC:DPPE:DMPS) and an outer leaflet (POPC:POPE:SM) reflecting inflammation-related membrane conditions. Selected JAK inhibitors were incorporated into these systems and analyzed using complementary surface-sensitive, spectroscopic (PM-IRRAS), electrochemical (capacitance measurements), and atomic force microscopy (AFM) techniques, enabling systematic evaluation of drug-induced effects in both membrane leaflets.

The results demonstrate that JAK inhibitors interact specifically with lipid components, with their effects strongly dependent on chemical structure and lipophilicity. More lipophilic compounds induce membrane fluidization, modulate phase separation, and promote defect healing within lipid layers. These findings reveal structure–interaction relationships governing drug localization and affinity for lipid headgroups. A detailed understanding of these processes provides valuable insight into the molecular basis of JAK-based anti-inflammatory therapies and supports their optimization to enhance efficacy while minimizing adverse effects.

Keywords:

Janus kinase inhibitors (JAK inhibitors); drug–membrane interactions; intestinal epithelial membrane; asymmetric lipid bilayers; Langmuir monolayers;

Acknowledgements:

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Towards a mechanistic understanding of water-in-water emulsion stabilization by bio-based polymers

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Water-in-water (W/W) emulsions are dispersions of two polymer-rich aqueous phases, immiscible above a given concentration. Due to the absence of organic solvents, they are increasingly considered as attractive systems for the delivery of active compounds, particularly because of their biocompatibility and low environmental impact. However, their large-scale development must overcome the challenges of stabilization related to the high interface thickness and the ultralow interfacial tension, which strongly reduce the efficiency of conventional surfactants (1). The aim of this work is to provide a better understanding of the stabilization mechanisms of W/W emulsions using bio-based polymers, by establishing the relationships between interfacial properties, emulsion microstructure, and stability. Three different strategies are investigated: nanoparticle-based stabilization, described in this abstract, lignin-chitosan complexation, and lignin-derived block copolymers. A range of bio-based polymers derived from lignin, chitin, and cellulose were considered, with particular attention given to lignin nanoparticles (LNPs) extracted via enzymatic hydrolysis (LNPs-EH) and soda processes (LNPs-SP). W/W emulsions were formulated using a model aqueous two-phase system composed of dextran and poly(ethylene oxide) (PEO). The phase diagram of dextran/PEO system was experimentally determined by turbidimetric titration using a cloud/clear point approach (2). The morphology and surface properties of the bio-based nanoparticles were characterized by transmission and scanning electron microscopy (TEM and SEM), Fourier-transform infrared (FTIR) spectroscopy, and zeta potential measurements. Wettability was assessed by contact angle measurements, while emulsion stability was monitored over time using optical and confocal microscopy, bottle tests, and static multiple light scattering. Wettability tests on glass slides show that LNPs-SP are more hydrophilic than LNPs-EH, and in lyophilized pellet-form, these display lower contact angles with dextran- and PEO-rich phases, indicating a higher affinity for both phases. This difference leads to distinct interfacial behaviors: LNPs-SP exhibit a greater tendency to adsorb at the water–water interface, while LNPs-EH remain predominantly in the bulk phase (Figure 1). Despite the adsorption of LNPs-SP onto the droplet surface, the emulsion coalesces gradually. This discrepancy in stabilization mode can be due to variations in surface chemistry induced by the extraction processes. Moreover, LNPs-SP improve emulsion stability compared to LNPs-EH, highlighting the key role of wettability in controlling interfacial adsorption and relative stabilization in W/W emulsions, in Pickering-like mechanism. Future research will investigate the combined use of different bio-based nanoparticles to improve interfacial structuring and emulsion stability.

Keywords:

water-in-water emulsion, bio-based stabilizers, lignin, interfacial adsorption, emulsion stability

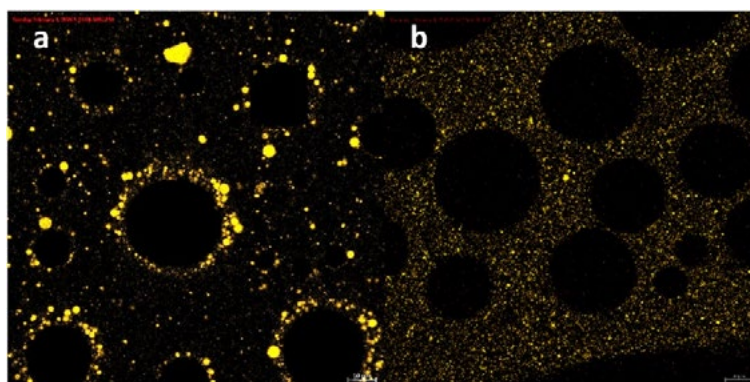


Figure 1 : Confocal fluorescence microscopy images of W/W emulsions acquired 3h after formulation using a $\times 63$ immersion objective: (a) emulsion formulated with LNPs-SP; (b) emulsion formulated with LNPs-EH. LNPs appear in orange.

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Multinano star gold-silica nanoparticles for dual cancer therapy

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Nanomaterials exhibit unique physicochemical properties arising from their high surface-to-volume ratio, which enhances reactivity, functionalization capacity, and loading efficiency. These features have enabled broad applications in catalysis, sensing, energy conversion, and biomedical delivery. Multicomponent nanostructures further expand this versatility and functionality by integrating several components with different properties into a single platform. Architectures such as core-shell, Janus, patchy, and yolk-shell nanoparticles provide controlled interfaces, anisotropic functionalities, or compartmentalized domains, allowing the design of multifunctional systems tailored for complex tasks. [1]

Among the materials used in multicomponent nanosystems, gold nanostructures are notable for their tunable plasmonic properties, which depend strongly on particle geometry. [2] Gold nanostars display intense near-infrared LSPR responses suitable for biomedical imaging, photothermal applications, and chemical detection, among others, since their branched shape shifts the plasmon resonance into the biological transparency window and provides tip hot spots. Silica, in contrast, offers chemical stability, biocompatibility, and high loading capacity, making it an ideal complementary component for controlled delivery and optical engineering.

In this work, we develop complex patchy Au@SiO₂ nanoparticles in which a gold core is partially coated with silica domains, leaving exposed regions that serve as nucleation sites for gold nanostar growth. This architecture creates a heterogeneous surface combining the plasmonic activity of the nanostars with the tunable chemistry and loading capacity of silica. To synthesize these anisotropic hybrid systems, we exploited the ability of the thiolated ligands, MUA and PEG, to segregate on the gold surface [3]. When both ligands are co-adsorbed, their phase segregation generates chemically distinct surface domains, patches. Silica growth is promoted on the MUA patches, generating anisotropic silica deposition, or lobes. By tuning the MUA:PEG ratio, we can control the number of silica lobes formed around the gold core, and consequently, the amount of exposed gold available for subsequent nanostar growth, and the generation of multinano star nanoparticles with promising applicability in sensing, hyperthermia, etc.

We have explored the capabilities of these nanoparticles in biomedical applications for cancer therapies. For that, the nanoparticles were loaded with the anticancer drug doxorubicin into the silica component, and it was subsequently released by the use of photothermal activity. Preliminary results in vitro show an excellent anticancer effect, and a promising alternative as anticancer nanotreatment, opening the door to less invasive, low-dose medical treatments.

[1] *Materials Today Chemistry* **2022**, 26, 101220

[2] *Chem.Soc.Rev* **2017**, 46, 3866-3885

[3] *ACS Nano* **2023**, 17, 955-965

Keywords:

hybrid nanoparticles, doxorubicin, polymer segregation.

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[1] *Materials Today Chemistry* **2022**, 26, 101220

[2] *Chem.Soc.Rev* **2017**, 46, 3866-3885

[3] *ACS Nano* **2023**, 17, 955-965

Synthesis of sub-10 nm gold nanostars for applications in sensing, catalysis, and hyperthermia

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Gold nanostars (NSs) have emerged as highly promising nanostructures for advanced applications spanning biomedicine, catalysis, and chemical sensing [1]. Their distinctive anisotropic morphology—characterized by sharp protruding spikes radiating from a central core—provides exceptional optical performance and broad spectral tunability. Numerous wet-chemical synthetic strategies have been reported to produce NSs with diverse morphologies. In most cases, their size can be readily adjusted by modifying synthesis parameters, such as the seed-to-growth solution ratio in seed-mediated protocols. While the fabrication of large nanostars (>100 nm) is relatively straightforward, achieving significantly smaller NSs that still exhibit strong plasmonic responses at long wavelengths remains challenging. This limitation arises from the minimum structural dimensions required to induce crystal growth defects, promote anisotropic spike formation, and maintain sufficient spike volume.

In this work, we demonstrate that a poly(vinylpyrrolidone)-mediated reduction in dimethylformamide can be strategically modified through the introduction of copper ions, yielding nanostars with a greater number of sharper spikes that develop at earlier growth stages. This modification enables the synthesis of ultra-small nanostars (USNSs) with volumes as low as 420 nm³ (corresponding to an equivalent spherical diameter of 9.2 nm), while preserving a plasmon resonance in the near-infrared region. To achieve this, we systematically investigate the influence of key synthesis parameters on NS size and optical behaviour. The LSPR can be further modified by the growth of Ag, generating ultrasmall Au@Ag NSs where Au tips protrude from Au@Ag core.

Finally, we evaluated the performance of the resulting USNSs in catalysis, surface-enhanced Raman spectroscopy (SERS) chemical sensing, and photothermal applications in the biomedical application of cancer treatments. In all cases, the USNSs exhibit excellent performance, benefiting from their reduced dimensions, which enhance properties associated with increased surface-to-volume ratio and improved colloidal diffusivity [2].

Keywords:

Gold nanostars, plasmonic, Au@Ag coreshell, sensing, hyperthermia

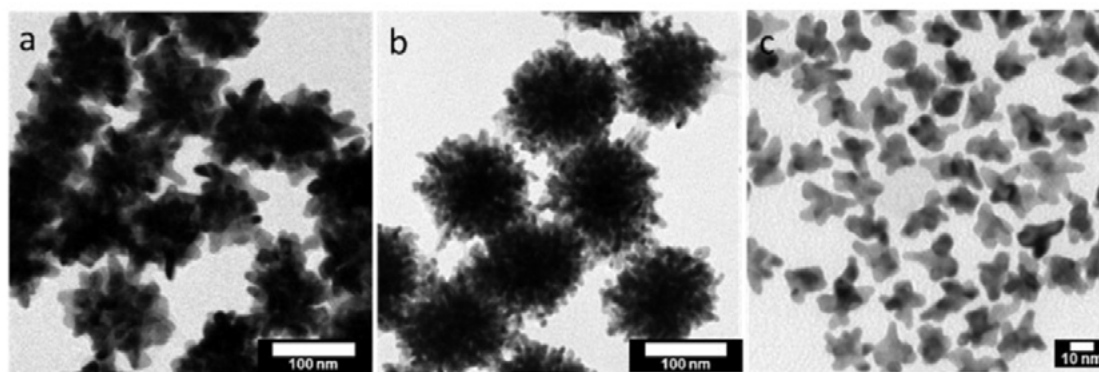


Figure: TEM images of gold NSs. a) Standard synthesis. b) Ultra-sharp NSs, c) ultra-small NSs.

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Light-Induced Drug Release to Interfaces with Lipid Monolayers

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Light-induced drug release using photoresponsive nanocarriers is increasingly explored for targeted therapeutic applications. While most studies characterize release in bulk aqueous environments, transport of a drug across aqueous-organic interfaces is equally important. That is because these interfaces represent the drug's entry point into cells. We recently demonstrated light-induced drug release to air-water interface as a simplified model for the cell membrane interface.[1,2] However, passive diffusion of anticancer agents across lipid membranes is a key transport mechanism, yet direct quantitative data on drug-lipid interactions and their influence on release remain limited.

In this contribution, we report on using photoswitchable arylazopyrazole (AAP) amphiphiles as micellar nanocarriers and doxorubicin (Dox) as a representative anticancer drug and study how the composition of the lipid monolayers governs light-induced drug release to the interfacial layer. This is done by studying Lipid monolayers in a Langmuir-Pockels trough though interface-specific vibrational sum-frequency generation (SFG) spectroscopy as a function of the available mean molecular area. Using SFG spectroscopy, we quantitatively estimate drug release to lipid monolayers at air-water interfaces as (our) model membrane. To systematically address the specific effects of the lipid headgroup, we have studied DMPC, DMPG, DMPS, and DMPE which share identical alkyl tails but differ in charge and polarity of their headgroups. As nanocarriers, we use micelles of octyl-AAP sulfonates which can be photoisomerize between E and Z states, with the E form being substantially more surface active than Z form. In addition, E/Z photoisomerization can be utilized to change the critical micelle concentration dramatically from 0.1 mM (E isomer) to 1 mM (Z isomer). This gives rise to effective encapsulation of Dox in micelles of the E isomer and effective release of Dox after E (micelles) to Z (monomers) photoisomerization e.g. at a octyl-AAP concentration of 0.3 mM. Note, the latter has been found to cause substantial release to the air-water interface without a lipid being present [1,2]. In comparison, water surfaces with DMPC, DMPG, DMPS, and DMPE lipids exhibit a selective release of Dox mostly to anionic lipid (DMPS, DMPG) interfaces while the release to interfaces with zwitterionic lipids (DMPC, DMPE) was neglectable.

These results will elucidate how lipid-drug interactions modulate release efficiencies at membrane-like interfaces, providing insights relevant to the design of photoresponsive nanocarrier systems for targeted drug delivery.

Keywords:

Lipid monolayer, interface spectroscopy, adsorption, photoswitchable surfactants, nanocarriers, micelles

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Decoding Bio–Nano Interactions: From Protein Corona Formation to Cellular and Membrane Responses.

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Despite significant advances in nanotechnology, the number of clinically approved nanomedicines remains limited. Current approvals are largely driven by improved safety profiles rather than enhanced therapeutic efficacy. A major barrier to successful translation is the incomplete understanding of how nanosystems interact with biological environments. This work focuses on elucidating the biological identity of nanosystems under physiologically relevant conditions. In particular, we investigate how interactions with biological fluids lead to the formation of protein corona complexes, which critically influence nanoparticle behavior, targeting, and cellular responses¹⁻³. We present recent findings on the interactions between biomolecules and nanosystems with model lipid membranes and living cells in protein-rich environments. These studies highlight how the presence of biological fluids modulates bio–nano interactions, ultimately affecting membrane dynamics, cellular uptake, and biological outcomes. A deeper understanding of these processes is essential for the rational design of more effective and reliable nanomedicine platforms.

Keywords:

nanoparticles, protein corona, lipid bilayers, scattering

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Nanocellulose hydrogels for biomedical applications: using atomic force microscopy techniques to understand and control cell adhesion and spheroid formation

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Ethical considerations and legislative initiatives have further encouraged the development of *in vitro*, three-dimensional (3D) cell culture models to replace or minimize animal experimentation in biomedical applications like drug testing or disease modelling. Nanocellulose hydrogels from plant biomass have proven to be a promising material in this field because, in addition to abundance and biocompatibility, their fibrillar network can structurally mimic the extracellular matrix of tissues. Nanocellulose hydrogels have been successfully used to grow 3D cell cultures *in vitro*, facilitating the formation of 3D cell aggregates called spheroids [1,2]. Nevertheless, to further exploit this biomaterial in biomedical applications and tissue engineering, a fundamental understanding on how cells interact with nanocellulose is needed. Using the versatility of atomic force microscopy (AFM) and the high sensitivity AFM-based force spectroscopy techniques, we carried out a detailed quantitative analysis of the adhesion and single binding forces between cellulose nanofibrils (CNFs) and human hepatocarcinoma cells (HepG2) and pluripotent stem cells (WA07 and iPS (IMR90)-4). For comparison, the interaction of cells with protein materials like laminin-521 (LN-521) and Matrigel was also analyzed. Our results indicate that the adhesion of cells to CNFs is governed by non-specific interactions, that is, interactions not mediated by binding proteins on cell membranes [3]. This is in contrast with cell adhesion to LN-521 substrates, where cell membrane integrins play a very important role in cell adhesion as specific receptors for LN-521 molecules. By analysing each of the multiple single bonds contributing to the total adhesion, we observed that the binding force of single bonds between cells and CNFs was similar to that of single integrin-protein bonds, within the range 20 - 60 pN [4,5]. Still, the presence of a higher number of single bonds made the adhesion of cells to LN-521 significantly stronger than to CNFs. In this regard, we proved that coating CNF hydrogels with LN-521 enhanced cell adhesion and proliferation, opening new routes for the development of nanocellulose-based hydrogels with tunable cell adhesion properties [5]. Another interesting conclusion was drawn when correlating the AFM results for cell-material and cell-cell interactions with gene expression tests: culturing cells in CNF hydrogels enhanced the expression of cadherins, cell membrane proteins involved in cell-cell adhesion. On the contrary, cadherin expression was down-regulated in 3D cell cultures using Matrigel as a matrix [4]. These results were in line with the experimental observation that spheroids formed in CNF hydrogels were more compact than the cell aggregates obtained in Matrigel. In summary, our work provides important insights into the molecular mechanisms involved in cell adhesion to CNFs and spheroid formation in nanocellulose hydrogels, supporting a rational understanding, tunability and application of this biomaterial in the biomedical field.

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Single-Polynucleotide Lipid Nanoparticles: Ultrafast Assembly and Multiscale Structure

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Lipid nanoparticles (LNPs) have emerged as key carriers for the delivery of polynucleotides such as mRNA, and their two-step synthesis involving nanoprecipitation followed by dialysis is under intense scrutiny in the scientific literature. Despite their widespread use, the mechanisms governing LNP formation remain poorly understood, involving complex internal structures, multiple particle populations, and strong coupling between composition, assembly pathway, and delivery performance. This complexity makes it difficult to establish clear structure–function relationships and calls for approaches yielding more homogeneous and well-defined objects. Here, we show that LNP assembly can be directed toward the formation of smaller and more structurally defined nanoparticles. Using small-angle X-ray and neutron scattering (SAXS/SANS) and cryogenic transmission electron microscopy (cryo-TEM), we demonstrate that the resulting nanoparticles encapsulate a single polynucleotide and quantify their multiscale organization. Direct in situ measurements reveal that these particles assemble through a rapid and cooperative co-assembly process occurring on the millisecond timescale^{1,2}, consistent with a kinetically driven pathway far from equilibrium controlled by molecular diffusion rather than colloidal aggregation³. We further show that the final structure is highly responsive to its environment, including ionic strength and pH, highlighting the role of physicochemical conditions in tuning nanoparticle organization^{3–5}. Despite this responsiveness, the nanoparticles remain stable upon storage at 4 °C while maintaining efficient transfection. Overall, this work establishes a direct link between assembly pathway, structure, and function, and provides new insights for the rational design of lipid-based nanocarriers.

Keywords:

Lipid nanoparticle, kinetics, co-assembly

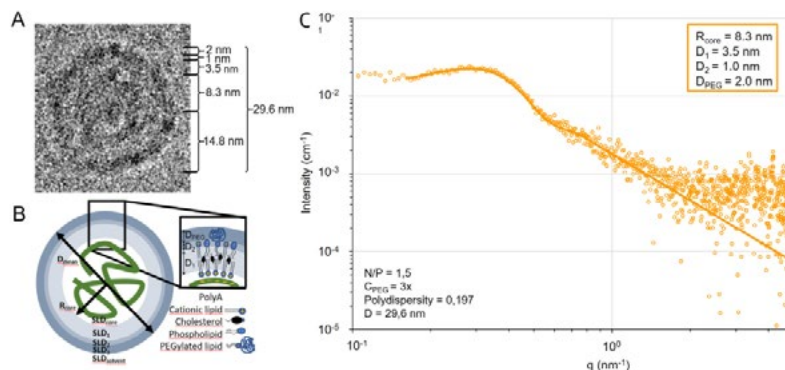


Fig. 1: (A) Representative cryo-TEM image of PEGylated LNP, revealing the internal structural features and characteristic length scales within the particles. (B) Proposed structural model of the LNP architecture. (C) SAXS profile of PEGylated LNPs fitted using the structural model shown in panel (B)

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Making Endotoxins Visible with Engineered F/ZnO Nano-Bio-Interfaces

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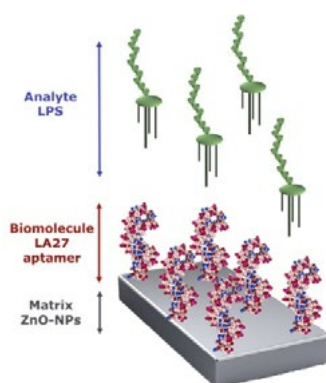
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The development of rapid, sensitive, and selective platforms for endotoxin detection remains a critical challenge in biomedical diagnostics and environmental monitoring. Here, we present an innovative optical aptasensor based on engineered zinc oxide (ZnO) nano-bio interfaces, combining the outstanding photophysical properties of fluorine-doped ZnO quantum dots (QDs) with the high specificity of DNA aptamers for bacterial lipopolysaccharides (LPS).

Fluorine doping and controlled synthesis were strategically employed to tailor defect density and emission behavior of ZnO QDs. ¹ These nanomaterials were then assembled into highly uniform and fluorescent thin films via an optimized spin-coating process, yielding robust nano-interfaces with finely tunable morphology and optical response. ² The integration of the LA27 aptamer onto these platforms enabled selective recognition of LPS/LOS from Gram-negative bacteria.

Remarkably, the sensing mechanism exploits the interplay between nano-interface photoluminescence and aptamer–target interactions, which vary according to the structural complexity of the endotoxins. Distinct binding modes, ranging from deep membrane insertion to surface-level adhesion, translate into specific and measurable optical signatures, allowing not only sensitive detection but also discrimination among different LPS architectures. ³

This work demonstrates how defect-engineered ZnO nano-interfaces can be transformed into powerful transduction platforms when coupled with biomolecular recognition elements. The proposed system offers a compelling alternative to conventional endotoxin assays, opening new avenues for the design of next-generation optical biosensors with enhanced performance, scalability, and application potential in healthcare and environmental safety.



Schematic representation of the aptasensor

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Synergistic opto-electrochemical dual transduction for advanced biosensing

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Conventional biosensors typically rely on a single transduction mode, either optical or electrochemical, and face multiple challenges to detect and quantify trace biomarkers in noninvasive body fluids like sweat, tears, and saliva. This is due to the presence of extremely low concentration of analytes, which requires advanced biosensing technology with high sensitivity and selectivity. Atomically precise metal nanoclusters (NCs) are the ultrasmall assemblies (< 2 nm) of few metal atoms, encapsulated by organic ligands. [1] Such ultrasmall NCs in conjugation with two-dimensional (2D) inorganic nanosheets (NSs) could serve as a foundational scaffold, enhancing light-matter interactions and functionality. [2] In this study, we present a dual-mode concept of light-driven photo-induced electrochemical approach by combining gold NCs with conductive 2D NSs. Strong interfacial bonding and charge transfer between NCs and the 2D scaffold reorganize local electronic states, establishing an efficient pathway for carrier separation under illumination. Photoexcited NCs upon interaction with analytes could directly oxidize the molecules by their photogenerated holes, while the conductive NSs extract and transport the photoelectrons to the electrode, suppressing recombination and amplifying the signal (Figure 1). Such a hybrid platform delivers rapid, reversible on/off responses with low background, quantitative signals across broad concentration ranges, and robust selectivity against common interferents.

Keywords:

Gold nanoclusters, 2D nanosheets, Charge transfer, Biosensing

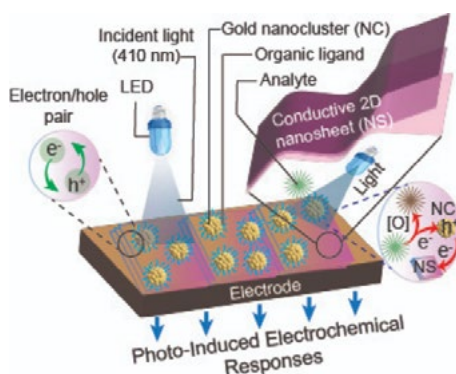


Figure 1. Schematic representation for the generation of photo-induced electrochemical responses.

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Diffusion, Degradation, and Protein Corona Effects Governing Nanoparticle Transport in Articular Cartilage

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Purpose: Cationic nanoparticles (NPs) interact strongly with negatively charged tissues such as articular cartilage and are therefore promising drug carriers for arthritis. ¹ NP transport in cartilage is governed by a balance of diffusion, electrostatic interactions, steric hindrance, specific binding, and dynamic surface modification via protein adsorption. ^{2,3} Articular cartilage represents a heterogeneous, degradable polyelectrolyte system, whose nanoscale transport properties are further altered by enzymatic remodeling and exposure to synovial fluid during disease. ⁴ Here, we present a diffusion-based experimental platform to investigate how NP surface chemistry, matrix composition, and protein corona formation jointly regulate spatiotemporal transport across cartilage depth. Polyamidoamine (PAMAM) dendritic NPs with varied surface functionalities were used as probes to elucidate how catabolic cartilage environments influence diffusivity, surface partitioning, and uptake.

Methods: NP diffusion into porcine cartilage explants was examined using a custom-designed platform that enforces controlled boundary conditions, enabling interaction-limited transport. Cationic PAMAM NPs (~6–7 nm) were functionalized to exhibit (i) weak electrostatic interactions (PAMAM-FITC), (ii) steric stabilization (PAMAM-PEG), or (iii) ligand-mediated binding (PAMAM-PEP). Cartilage explants were subjected to ECM-specific enzymatic degradation to selectively alter matrix charge density or network integrity. NPs were applied to the cartilage surface, and depth-resolved NP distributions were monitored over time using confocal microscopy. Transport behavior was additionally assessed under inflammatory arthritis-relevant synovial fluid conditions using fluorescence-based uptake and kinetic analyses.

Results: In native cartilage, weakly interacting PAMAM-FITC showed rapid surface partitioning followed by diffusion-dominated penetration, reaching near-homogeneous spatial distributions over time. Enzymatic reduction of matrix charge density accelerated NP diffusion, consistent with reduced electrostatic trapping. Sterically stabilized PAMAM-PEG displayed slower diffusion, pronounced surface accumulation, and reduced uptake under collagen-degrading conditions. Ligand-functionalized PAMAM-PEP exhibited strong surface entrapment and delayed penetration, with uptake particularly sensitive to enzymatic cartilage degradation. Exposure to inflammatory arthritis synovial fluid altered NP transport in a formulation-dependent manner, reducing uptake of PEGylated NPs while enhancing penetration of targeting PAMAM-PEP, consistent with protein corona-mediated effects.

Conclusions: NP transport in cartilage is governed predominantly by colloidal interaction mechanisms rather than particle size alone and is highly sensitive to disease-relevant biochemical environments. Enzymatic remodeling and synovial fluid-driven protein corona formation jointly modulate diffusion, surface partitioning, and uptake by altering effective NP surface properties and matrix accessibility. This platform enables direct visualization of diffusion-adsorption competition in a degradable polyelectrolyte network and provides design principles for nanocarriers optimized for physiological and patient-specific cartilage environments.

Keywords:

nanoparticle, transport, cartilage, nanomedicine, arthritis

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Understanding response of lipid nanoparticles' structure to Phospholipase D activity

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Aberrant regulation of certain enzymes has been implicated in the pathogenesis of various diseases. Specifically, Phospholipase D (PLD), a pivotal enzyme responsible for hydrolyzing phospholipids to remove choline headgroups, is overexpressed in breast cancer [1]. Given the emerging importance of lipid nanoparticles (LNPs) as drug and gene vectors, understanding how LNP structure may be related to their biological performance in complex environments is needed. If, for example, PLD can discriminate between LNPs with different structures, it may be feasible to design enzyme-responsive carriers and tune their properties for cancer therapy. Recently, the group [2] showed that PLD degrades the lipid substrate at different rates in cubosomes and vesicles, hinting to a specific role of the structure of the carrier. In this work, we address how surface coverage (stabilizer concentration), inner structure and morphology of different LNPs, *e.g.*, cubosomes, hexosomes, vesicles and clinically relevant LNPs may influence their response to PLD. LNPs were prepared using clinically relevant lipid compositions (*e.g.*, Pfizer, Onpattro, Moderna vaccines) and lipid compositions yielding non-lamellar structures studied by the group [2,3]. Employing NTA, DLS, zeta potential measurements and a fluorescence assay, we monitor the enzymatic conversion of DOPC and DSPC (both substrates of the enzyme) to free choline in solution, and how this affects the properties of the LNPs in terms of size, surface charge, and concentration. Overall, structured LNPs present a higher activity respect to the lamellar counterparts and clinically relevant formulations; in addition, the surface coverage of the PEGylated lipids in LNPs slows down the kinetics of the enzymatic degradation of the substrate. Different endpoints are reached in the fluorescence assay depending on the LNP structure and composition, highlighting a different accessibility of the substrate within the LNP. SAXS experiments are performed on the LNPs incubated with PLD in the same conditions, showing that the enzymatic reaction decreases the order of the structure and induces phase transitions. Preliminary SANS characterization shows that the addition of PLD to structured LNPs induced a change in the lipid redistribution, most likely due to accumulation of high anionic charge in the membrane via PC cleavage. This study aids in further structure-function correlations of LNPs for cancer therapy and in design of smarter drug carriers.

Keywords:

structure-function, responsive carriers, scattering, drug delivery, bilayers

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Investigating the interaction between microbial glycolipids and bio-mimetic membranes

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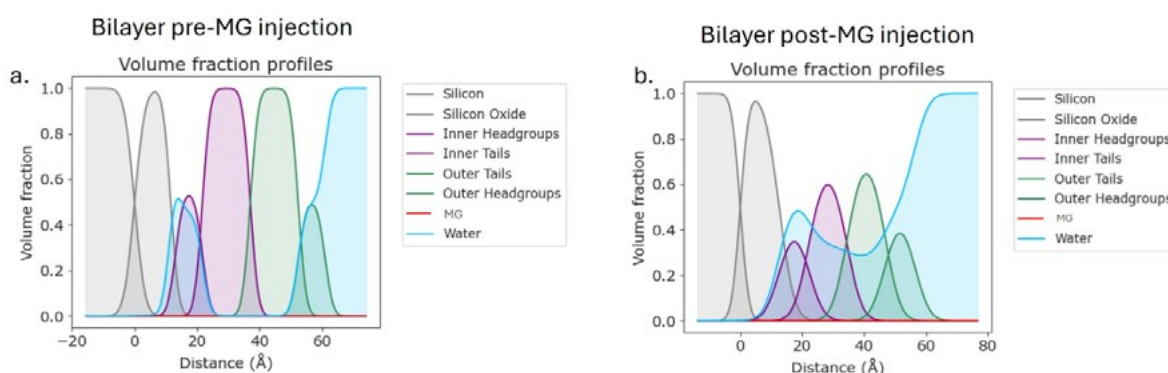
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Microbial glycolipids (MGs) are bio-based amphiphiles composed of a hydrophilic sugar head covalently bonded with fatty acid chain conferring them amphiphilic and surfactant properties with a physicochemical behaviour depending on temperature, pH and type of metal ion present in solution. The colloidal and surfactant activities of MGs have been extensively studied and compared with conventional surfactants [1], highlighting their potential as promising and innovative bio-based lipidic material for cosmetic formulation and drug encapsulation. Although numerous studies have investigated the effect of MGs over bio-membrane phospholipids in relation to their antimicrobial effects, the actual physicochemical mechanism governing their interaction with bacterial membranes remain poorly explored. In this work, we investigate the interaction between biomimetic membranes and MGs from a structural and interfacial perspective, to address current knowledge gaps in the mechanism driving MGs antimicrobial activity. Four different MGs (glucolipid G-C18:1, acetylated acidic sophorolipid SL C18:1, monorhamnolipid mono-RL, di-rhamnolipid di-RL) were tested to compare their effects on the biomimetic membrane composed by different lipidic composition and ratios between 1,2-dioleoyl-sn-glycero-3-phosphocholine (DOPC), 1,2-dioleoyl-sn-glycero-3-phosphatidylglycerol (DOPG), N-octadecanoyl-D-erythro-sphingosylphosphorylcholine (SM) and cholesterol (Chol). Specifically, three different membranes models were tested: DOPC, DOPC:DOPG 75:25 and DOPC:SM:Chol 2:2:1. Since it is reported that MGs structural, self-assembly and interfacial properties strongly depend on the pH [2], each MG has been dissolved in water at different pHs to obtain vesicles or micelles suspensions. We explored the interaction of MGs with supported lipid bilayers using interfacial analysis at the solid/liquid interface by using Quartz-Crystal Microbalance with Dissipation monitoring (QCM-D) system and Neutron Reflectivity (NR) with MGs both in vesicles and micelle formulation. QCM-D results have showed that, all four MGs produce effect in the structure of bilayers, resulting in a loss of lipid material. The strongest effect was observed with G-C18:1 and mono-RL vesicles, whereas a smaller impact was provided by SL C18:1 micelles. Our findings, supported by NR experiments, indicate that MGs are responsible for removing a substantial portion of the bilayer, significantly lowering its coverage (Figure 1).

Keywords:

Antimicrobial, Biosurfactant, Interface, Solid/Liquid, Biomembranes



Volume fraction profile of supported DOPC bilayer before (a.) and after (b.) the interaction with MGs vesicles obtained with NR

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Closed-Loop Control and Spatiotemporal Tracking of Hydrogel Extrusion and Cell Morphology

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Extrusion-based bioprinting is inherently challenged by the non-Newtonian and often time-dependent nature of hydrogel bioinks, which compromises flow stability, reproducibility, and control over the mechanical cues experienced by encapsulated cells [1]. Here, we design, build, and validate a closed-loop extrusion platform able to quantitatively track hydrogel flow dynamics and cell morphology from in-needle transport to post-extrusion deposition. The system combines a dual-syringe architecture, flow-rate and pressure-drop sensing, and adaptive proportional–integral–derivative (PID) control to regulate extrusion in real time under both stress- and deformation-controlled conditions, thereby overcoming key limitations of conventional open-loop pneumatic dispensing.

The platform was first validated using water and glycerol as Newtonian reference fluids and then applied to self-healing gelatin–oxidized laminarin hydrogels, with and without embedded cells. In addition, the setup was shown to operate as a capillary rheometer for non-Newtonian fluids, including correction of entrance and exit effects and assessment of wall-slip contributions. These measurements were complemented by torsional rheometry, computational fluid dynamics (CFD), and micro-particle image velocimetry (μ PIV), enabling direct comparison between rheological constitutive behavior, predicted velocity fields, and experimentally resolved in-channel flow profiles.

Closed-loop operation markedly improved flow-rate accuracy relative to open-loop extrusion, particularly for hydrogels. Velocity-profile measurements confirmed parabolic flow for Newtonian liquids and plug-like flow for hydrogels, in agreement with their yield-stress character. The framework also provided access to the spatiotemporal mechanical history experienced by cells during extrusion, enabling correlation between in-needle hydrodynamics, post-extrusion filament stretching, and cellular morphological evolution.

Overall, this work establishes a reproducible methodology for real-time hydrogel extrusion control and characterization, with direct implications for improving structural fidelity, process standardization, and biological performance in extrusion bioprinting.

Keywords:

Hydrogel extrusion, bioprinting, closed-loop control, capillary rheometry, micro-PIV

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Buffer Specificity as a Governing Principle at Nano-Bio Interfaces

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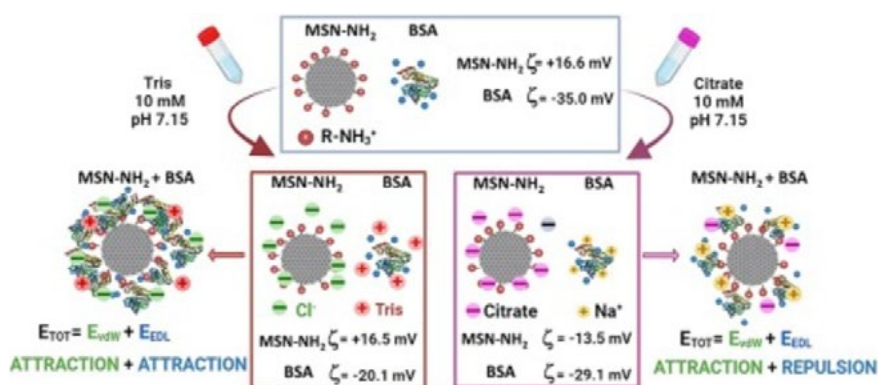
Specific ion effects are known to modulate biological interactions beyond what is predicted by pH and ionic strength alone. However, buffer species are still commonly treated as chemically inert components acting solely as pH regulators. Here, we show that buffer specificity constitutes a governing principle at nano–bio interfaces, controlling interfacial structure, interaction strength, and functional behaviour across different systems.

Within this framework, interactions at charged nano–bio interfaces are intrinsically buffer dependent. DNA–lipid bilayers and proteins adsorbing at solid surfaces display clear buffer hierarchies and non-monotonic dependencies on monovalent cations, revealing the limits of classical mean-field electrostatic descriptions [1]. These trends originate from the interplay between ion hydration, electrostatic screening, and ion-specific dispersion forces, which renormalize effective surface charge and interaction potentials. The same physical picture governs protein corona formation on amino-functionalized mesoporous silica nanoparticles. At identical pH and ionic strength, protein adsorption varies strongly with buffer identity, while buffer-induced surface charge modulation marks a breakdown of purely electrostatic models and highlights the role of ion-specific dispersion interactions [2]. Buffer specificity further affects mesoscopic organisation and biological function in ionizable lipid nanoparticles. In this case, buffer-dependent shifts of pH-controlled structural transitions in ionizable lipid/cholesterol mesophases alter curvature elasticity and stabilize or destabilize fusogenic inverse phases. These structural changes directly modulate endosomal escape and transfection efficiency, providing a clear mechanistic connection between ion-specific interfacial energetics and macroscopic functional outcomes [3].

Overall, these results demonstrate that buffers must be treated as active components of the interfacial free energy in nano–bio systems. Incorporating buffer-specific ion effects provides a unified conceptual framework connecting molecular interactions, mesoscopic organization, and biological function, with important implications for experimental reproducibility, predictive theory, and the rational design of biointerfaces and nanomedicine platforms.

Keywords:

ion and buffer-specific effects; nano–bio interfaces; DNA–lipid interactions; protein corona; lipid nanoparticles



Specific buffer effects on BSA adsorption on functionalized mesoporous silica nanoparticles (MSN-NH₂) at pH 7.15

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Biopolymer-Based Nanocarriers toward Multifunctional Cancer Therapeutics and Diagnostics

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The development of effective nanocarriers for cancer therapy and diagnosis remains a major challenge in translating nanotechnology into clinical practice. Such systems must combine biocompatibility, stability, prolonged circulation, and selective targeting. Here, we employ biopolymer-based strategies to design versatile nanocarriers with integrated functionality. We first present hyaluronic acid nanocapsules for the pH-responsive delivery of doxorubicin [1]. These systems exhibit enhanced drug release under acidic conditions while maintaining high physicochemical stability, making them promising candidates for stimuli-responsive delivery with intrinsic targeting potential. Beyond nanocapsule design, hyaluronic acid combined with albumin is used to coat various nanoparticles, including gold nanorods, using our previously established protocols [2,3]. This strategy offers potential targeting functionality toward breast cancer cells for selective drug delivery, photothermal therapy and biomedical imaging, while also providing chemical versatility for further functionalization. The resulting hyaluronic acid nanocapsules and biopolymer coated gold nanorods exhibit high stability, good cytocompatibility, and stimuli-responsive behavior, highlighting their potential as adaptable nanoplatforms for cancer therapy and diagnosis.

Keywords:

nanocapsules, hyaluronic acid, gold nanorods, pH-responsive, drug delivery

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Phase separation of a microtubule plus-end tracking protein into a fluid fractal network

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Microtubule plus-end tracking proteins (+TIPs) orchestrate essential cellular processes like mitosis through dynamic condensates, yet their internal supramolecular architecture remains elusive. Our study presents a breakthrough in understanding the phase separation of Bik1, a CLIP-170 family member in budding yeast, revealing that its condensates form a fluid fractal network rather than a homogeneous liquid.

Utilizing small-angle X-ray scattering (SAXS) on preformed Bik1 droplets flowing within a microfluidic chip, we captured the nanoscale organization of the condensed phase [1]. The scattering intensity follows a distinct power-law decay, $I(q) \sim q^{-2}$, across length scales from 300 Å to 3000 Å. This behavior corresponds to a fractal dimension close to 2, providing direct experimental evidence for percolation-based models of biomolecular condensates. Real-space reconstructions derived from the SAXS data visualize a heterogeneous structure characterized by alternating protein-rich clusters and solvent-rich voids. This fractal topology explains the extraordinary material properties of Bik1 droplets: they exhibit unusually high viscosity despite maintaining a relatively low protein concentration, a feature critical for their function as the "+TIP body" in vivo.

Complementing the SAXS findings, crosslinking mass spectrometry (XL-MS) identified specific conformational rearrangements driving this transition. We observed a significant increase in self-links within the central coiled-coil domain and enhanced interactions between the N-terminal CAP-Gly domain and the C-terminal EEY/F-like motif during condensation. Truncation mutants lacking either terminal domain failed to form droplets, confirming that multivalent interactions mediated by these regions are essential for establishing the fractal network.

Our SAXS data and empirical structural model demonstrates that the fractal nature of Bik1 condensates optimizes space-filling while preserving dynamic exchange. This framework offers a template for investigating the supramolecular organization of other complex, oligomeric biomolecular condensates.

Keywords:

Phase separation, Fractal network, Biomolecular condensates, Bik1

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Deciphering Electrostatic and Allosteric Determinants of Thermoresponsive Liquid–Liquid Phase Separation in Rabies Virus Phosphoprotein

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Liquid–liquid phase separation (LLPS) is the process by which membrane-less compartments form in biological systems. However, the molecular driving forces behind LLPS remain incompletely understood in these systems. The rabies virus phosphoprotein (P) is an intrinsically disordered scaffold protein of the viral factories that provides a compelling model for investigating how sequence patterning, conformational heterogeneity, electrostatics and multivalency interplay to control biomolecular condensation.

P forms star-shaped dimers comprising long negatively charged, flexible N-terminal arms and C-terminal globular domains characterised by a large dipole moment (~ 700 D). Using light scattering, small-angle X-ray scattering, analytical ultracentrifugation and calorimetry, we demonstrate that P exhibits thermoresponsive LLPS with a lower critical solution temperature (LCST), indicative of entropically driven condensation. Phase separation exhibits reentrant behaviour as a function of salt concentration or pH, revealing a delicate balance between electrostatic screening and dipolar attractions.

Our results show that self-association occurs below the macroscopic saturation concentration through conformation-specific interactions, highlighting the importance of pre-condensation molecular organisation. We propose a minimal three-state model, whereby the disordered N-terminal regions modulate the effective interactions between the anisotropic macrodipolar domains. This results in a narrow window of phase stability and a calorimetric apparent second-order transition.

Light and X-ray scattering at an absolute scale reveals that condensed droplets are 30 times more concentrated than the surrounding supernatant. We measured the surface tension of the condensates using atomic force microscopy and used a combination of high-sensitivity light scattering, the Gouy method and small-angle X-ray scattering (SAXS). We propose that dipole–dipole interactions, together with allosteric regulation of surface dipole accessibility, constitute subtle mechanisms underlying the in vitro formation of condensates, a process crucial for viral replication.

Keywords:

LLPS, LCST, rabies virus, viral factories

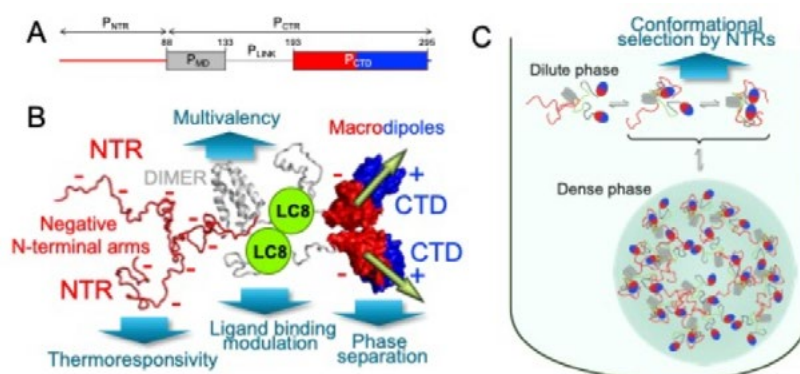


Figure | RABV P thermoresponsive phase separation. (A) Schematic representation of RABV P protein. Boxes = folded domains, Lines = IDRs. (B) Structural model of RABV P showing the roles of the different moieties in controlling PS. (C) Illustration of the demixing into dilute and dense phases.

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Bouchama et al., Rabies Virus Phosphoprotein Exhibits Thermoresponsive Phase Separation with a Lower Critical Solution Temperature. *J Mol Biol* 437, 168889 (2025). DOI:10.1016/j.jmb.2024.168889

Quantifying the structural evolution of *Pseudomonas putida* biofilms under flow

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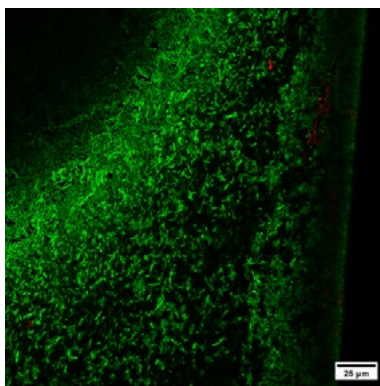
Biofilms are surface-associated bacterial communities embedded in an extracellular polymeric substance (EPS) matrix, whose structure governs transport, mechanical stability, and function. However, quantitative, time-resolved characterization of biofilm architecture under controlled flow conditions remains limited.

Here, we combine time-lapse confocal microscopy with microfluidic cultivation to track the three-dimensional evolution of *Pseudomonas putida* biofilms under well-defined flow, nutrient, and temperature conditions [1]. Image data are analysed using a convolutional neural network for robust segmentation. From the segmented data, we extract a comprehensive set of structural descriptors capturing local density, orientational order, and spatial correlations. These metrics enable a quantitative description of biofilm architecture across scales, from single-cell organization to collective structure. Preliminary results indicate a partial alignment of cells with the flow, and an initial increase in local density and coordination, after which a dynamical equilibrium between growth and shear-induced removal sets in.

We show that flow conditions and nutrient availability systematically modulate biofilm architecture, affecting both local cell organization and long-range structural correlations during growth. This approach establishes a quantitative framework to link environmental conditions to biofilm structural evolution, and highlights the potential of integrated microfluidics and imaging for probing biofilm structure.

Keywords:

Biofilms, microfluidics, confocal microscopy, image segmentation, structural descriptors, multi-scale architecture



*Figure: confocal micrograph of a *P. putida* biofilm 3h after start of the experiment (left). The live cells are visible in green, the dead cells in red. Image taken 5 μm below the PDMS surface of the microfluidic channel.*

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Acknowledgements:

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Interaction and Integration of Amphiphilic Single-Chain Nanoparticles into Lipid Model Membranes

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Single-chain nanoparticles (SCNPs) are ultrasmall polymeric nano-objects formed by the intramolecular folding of individual polymer chains.¹ Amphiphilic copolymers of 2-acetoacetoxyethyl methacrylate (AEMA) and *N*-isopropylacrylamide (NIPAM) form SCNPs that adopt a core-shell morphology in aqueous media, with a hydrophobic core and a thermoresponsive hydrophilic corona whose conformation can be tuned by temperature and pH.² Their capacity to encapsulate therapeutic molecules, such as peptides, makes them attractive drug delivery candidates.³ However, experimental insight into how SCNPs interact with and permeate lipid membranes remains scarce, with most existing studies limited to Monte Carlo simulations.⁴ In this work, we experimentally investigated the interaction and integration of amphiphilic SCNPs into lipid bilayers by combining neutron scattering with confocal microscopy. Amphiphilic random copolymers were synthesized via RAFT polymerization, and SCNP formation was verified by small-angle X-ray scattering and dynamic light scattering. Neutron reflectometry (NR) on solid-supported 1,2-dioleoyl-sn-glycero-3-phosphocholine (DOPC) bilayers demonstrated the incorporation of SCNPs into the lipid membrane (Figure 1A). Confocal microscopy on giant unilamellar vesicles (GUVs), labelled with Texas Red-DHPE, further confirmed that fluorescein-tagged SCNPs translocate across the lipid membrane (Figure 1B). These findings demonstrate that amphiphilic SCNPs can integrate into lipid bilayers, highlighting their potential for drug delivery applications. This behaviour is relevant not only for controlled membrane permeation in nanomedicine but also for targeted drug release.

Keywords:

Single-chain nanoparticles, amphiphilic copolymers, lipid bilayers, membrane translocation, neutron reflectometry, drug delivery

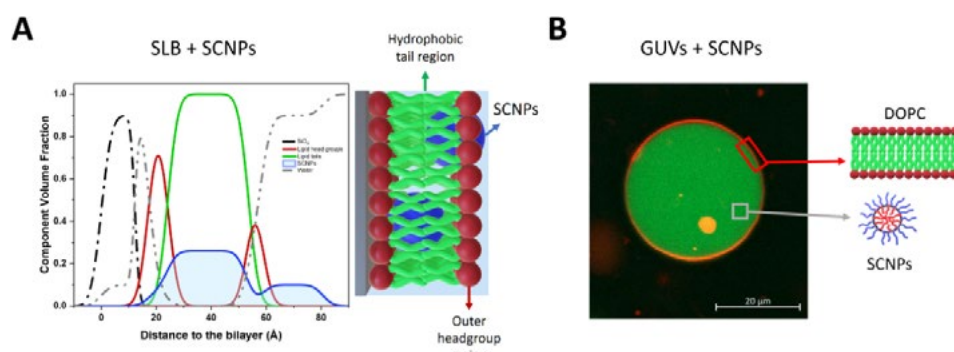
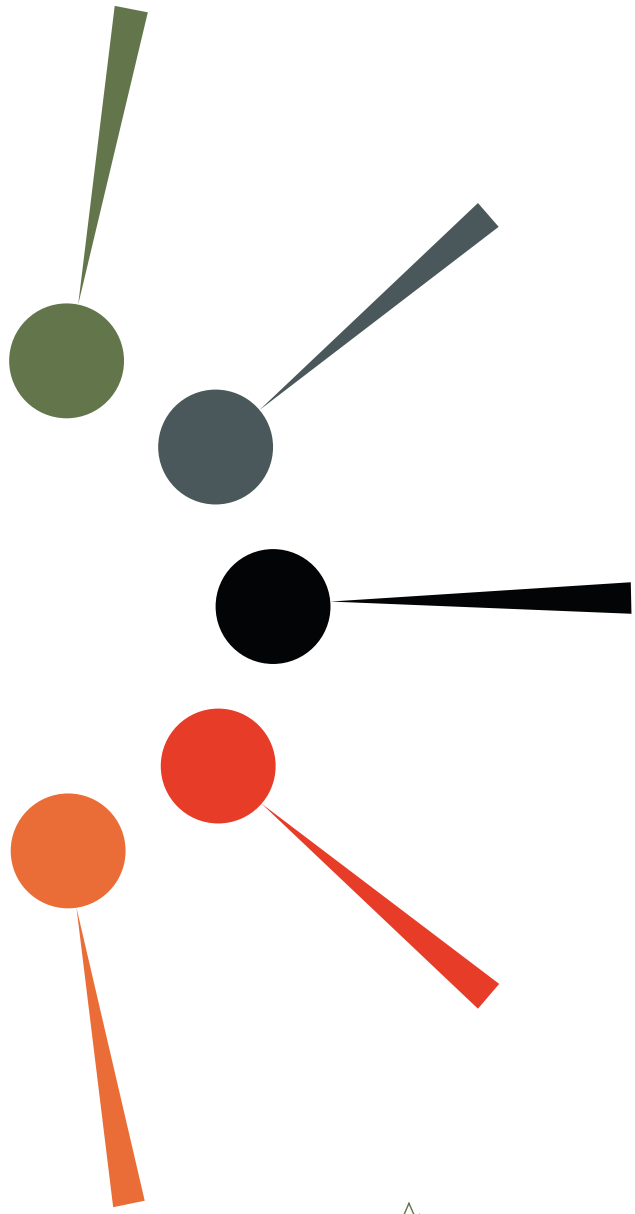


Figure 1. A) Volume fraction profile (VFP) of SCNPs interacting with a DOPC SLB derived from NR data (left) and schematic illustration of the VFP (right). B) Confocal microscopy image showing translocation of SCNPs (green) across GUV membranes (red). Scale bar: 20 μm.

References:

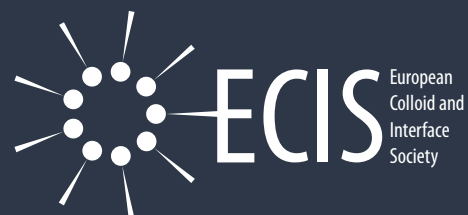
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Metal Phenolic Network Nanolayer Coatings on Cathode Active Materials for Lithium Ion Battery Performance

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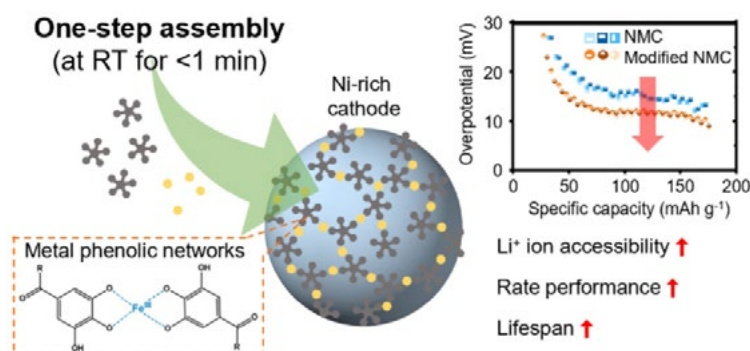
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The talk reports on the coating of cathode active materials with a rapid (1 min) one-step assembly of a metal-phenolic network (MPN) for enhancement of electrochemical performance in lithium-ion batteries (LIBs). Here, a Fe(III)-tannic acid (TA) MPN coating was used on cathode active material ($\text{LiNi}_{0.6}\text{Mn}_{0.2}\text{Co}_{0.2}\text{O}_2$ (NMC)) which enabled progressive electrolyte infiltration and faster lithium-ion diffusion, while simultaneously protecting the cathode surface and suppressing uncontrolled solid electrolyte interphase (SEI) growth. In full-coin cell format, the modified cathode exhibited a 10% increase in capacity and a 54% increase in lifespan for constant current cycling. In addition to a 5% increase in capacity and a 25% increase in lifespan for constant current-constant voltage (CCCV) cycling. Moving further, various metal chelating ions (TA-Ni(II), TA-Zn(II), TA-Mn(III), TA-Ti(IV) and TA-Zr(IV) coatings were employed on a different active cathode material, namely, lithium iron phosphate (LFP). By changing the metal ion the ion transport properties (liquid and interfacial mass transport) were affected within the MPN [1]. Observed variations in interfacial transport consequently led to changes in the liquid transport kinetics with TA-Ti(IV) and TA-Zr(IV) coatings showing the greatest increase in rate capability at high mass loadings. This work paves the way for improving anode and cathode materials' performance via eco-friendly lithium-ion attraction strategies.

Keywords:

Metal phenolic networks, batteries, active material, interfacial electronic and ionic transport



Metal phenolic network (MPN) coatings on high nickel manganese cobalt oxide materials reduce overpotential and improve battery performance and lifespan.

References:

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Unravelling Structural Changes of Pea Globulins during Heat Treatment as Studied Using Atomistic Model-based SAXS

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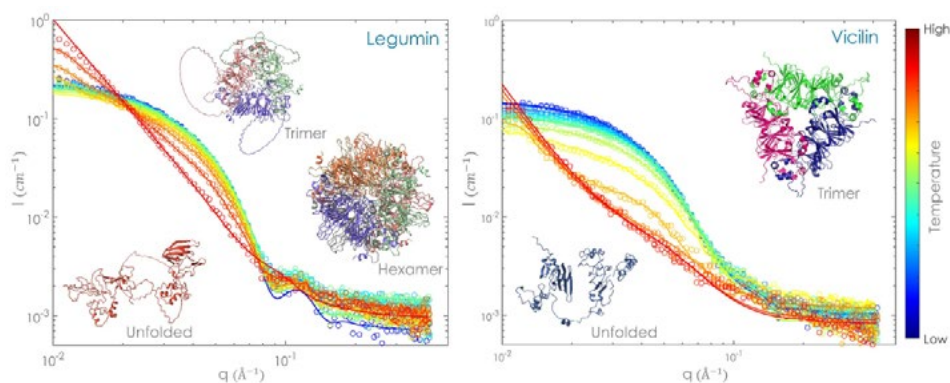
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Legumin and Vicilin are the most abundant storage proteins in pea (*Pisum sativum*), comprising approximately $53 \pm 7\%$ (w/w) of the total protein, and understanding both their native structures and thermally induced structural changes is essential for optimizing the design of plant-based products. Small-angle X-ray scattering (SAXS) is widely used to probe macromolecular structures in solution; however, conventional analyses often rely on low-resolution models that overlook important chemical and molecular details. To address this limitation, we present a methodology that integrates high-resolution SAXS modeling with AlphaFold-predicted oligomeric assemblies, enabling hypothesis-driven structural interpretation under complex and physiologically relevant conditions. Using pea globulins as a model system, isolates of Legumin and Vicilin were obtained through isoelectric precipitation followed by size exclusion chromatography fractionation, and their structures were examined in solution across a temperature range of 25–85 °C. At near-ambient temperatures, Vicilin adopted a trimeric structure, while Legumin existed as a mixture of trimers and hexamers. Association behavior was described using structure factors, and thermally unfolded states were modeled through rigid-body refinement. Upon heating, both proteins transitioned from native globular assemblies to unfolded conformations and, notably, did not revert to their native structures upon cooling. This hybrid approach, which bridges computational prediction with experimental scattering data, enables precise characterization of proteins across diverse conformational states and provides deeper insight into oligomerization, unfolding, and processing-related phase transitions. Overall, these findings advance our understanding of the thermal stability and structural plasticity of pea proteins, broaden the applicability of SAXS in studying protein dynamics in food systems, and offer valuable guidance for designing sustainable plant-based products as well as improving knowledge of other storage proteins from leguminous plants

Keywords:

Pea protein, SAXS, Structural changes



Temperature induced unfolding of Vicilin and Legumin studied using SAXS.

Colloidal Coatings on Cellulose Fiber Bottles for the Sustainable Packaging of Liquids

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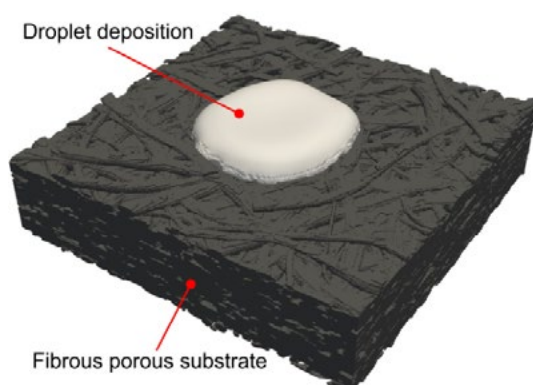
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Plastic waste poses a major global environmental problem, because it degrades habitats, impedes natural processes, and can directly harm life on Earth. Cellulose fibre is a promising alternative to conventional petroleum-derived plastic for packaging applications [1]. Cellulose fibre packaging is sustainable, because it uses renewable feedstock, its manufacture has a lower carbon footprint compared to plastics and glass, and it can be recycled with paper in existing waste streams. Cellulose containers (e.g. bottles) for liquids, which are suitable for foods, beverages, and homecare products, require a barrier coating to yield a low permeability to water and other solvents. In this presentation, developments in barrier coatings deposited from waterborne polymer colloids will be presented. The academic and industrial team in the UK's SustaPack project are investigating several facets of the processing of barrier coatings. The spray deposition of coatings was investigated at the single droplet level using high-speed photography. In parallel, a high-resolution numerical framework is used to simulate droplet impact and spreading at the microscale. A time-dependent wetting model was implemented within an interface capturing approach and validated against experimental measurements, demonstrating accurate prediction of droplet deformation and wetting behaviour. To simulate the spray-coating of cellulose-based packaging, realistic 3D fibrous porous substrates were reconstructed from microscopic images of paper. Simulations of water droplet impact captured droplet spreading on the substrate, followed by liquid penetration and transport within the entangled fibre network. The modelling framework was subsequently extended to a non-Newtonian colloidal liquid, showing good consistency with experimental observations. To gain unprecedented insight into spray-coating process, asynchronous visual sensor (AVS) technology is being developed to break the reliance on existing frame-based hardware to offer a step-change in acquisition speeds. AVS operates at ultra-high-rates compared to standard visual sensing, making it ideal for ultra-high-speed quality control and visual inspection tasks. AVS offers additional benefits of low power consumption and bandwidth and data sparsity. The new technology has allowed plume shapes to be seen as they evolve over time, and the paths of droplet clusters to be tracked. Infrared thermal imaging provides complementary information on the uniformity of the coverage of coatings. With Sustapack's technological input to support the industrial manufacturing of fibre-based packaging at scale by Pulpex Ltd., consumer goods manufacturers will in future be better placed to meet their Net Zero targets and to comply with Extended Producer Responsibility regulations.

Keywords:

wetting, cellulose, packaging, latex, spray-coating; computer vision; film formation



Single colloidal droplet deposition on a fibrous porous substrate

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Acknowledgements:

This research was funded by EPSRC through the SustaPack Prosperity Partnership (UKRI560).

Using Foam to Separate Ions: Superchaotropic Effects as a New Route toward Sustainable Chemistry

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The selective separation of ions in aqueous systems is a longstanding challenge in chemistry, environmental remediation, and resource recovery. We present a novel, solvent-free strategy that leverages *superchaotropic effects* to extract anionic metal species using foam flotation.

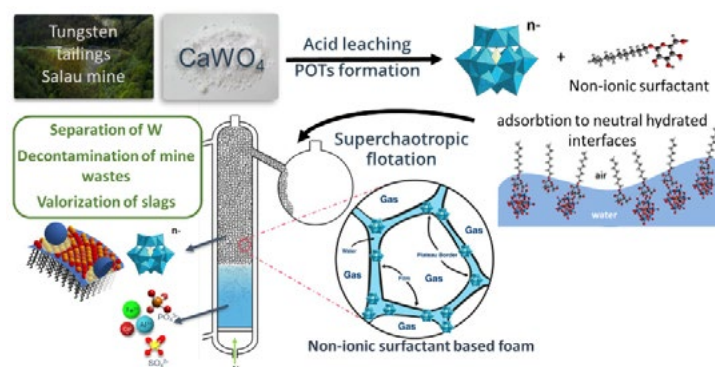
Unlike classical ion flotation, which requires charged surfactants, superchaotropic nano-ions, such as some polyoxomolybdates and polyoxotungstates, adsorb efficiently onto non-ionic surfactant films. ^[1] This unexpected affinity allows their selective enrichment in foam under mild conditions, providing a sustainable platform with minimal organic content. ^[2]

We illustrate the feasibility of superchaotropic flotation with two systems. Molybdenum forms iso-polyoxomolybdates at low pH whose superchaotropic character drives foam-mediated separation. ^[2] Tungsten forms heteropolyoxotungstates with phosphate, which are also superchaotropic; importantly, these species can be generated from real mining residues, demonstrating the potential for environmental remediation and the valorization of industrial waste. ^[3]

These results demonstrate how the fundamental concept of superchaotropicity, introduced in 2015 ^[1, 4], can now be harnessed for applied separation chemistry, bridging interfacial science with sustainable, solvent-free technologies.

Keywords:

foam, flotation, ion, separation, solvent-free



Example of superchaotropic flotation for the recovery and valorization of tungsten mine tailings

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Polyol-Controlled Self-Assembly and Removal of Hydrophobic oil Films in Nonionic Surfactant/Polyol/Water Systems

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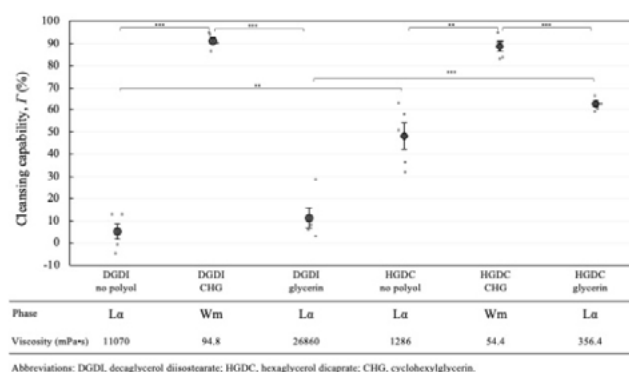
The cleansing capability of aqueous surfactant formulations against hydrophobic oil films depends not only on surfactant concentration and molecular architecture but also on aggregate phase behavior and mesoscale organization [1]. Polyols can tune solvent polarity, hydration, and partitioning between water and surfactant assemblies, but how these effects regulate aggregate packing and hydrophobic oil-film removal remains insufficiently understood [2,3]. Here, we examine nonionic surfactant/polyol/water systems based on decaglycerol diisostearate, hexaglycerol dicaprates, and their mixture. Polyol-free, cyclohexylglycerin-containing, and glycerin-containing formulations were characterized in terms of viscosity, pH, and cleansing capability against hydrophobic oil films. Visual observations together with small-angle X-ray scattering (SAXS) were used to assess phase behavior, while structural parameters, including micelle size, lamellar multilamellarity, interlamellar spacing, and bilayer flexibility, were estimated from the SAXS profiles. In parallel, dissipative particle dynamics (DPD) simulations have been initiated to examine how polyol identity modulates self-assembled structures and associated nanoscale and nanosecond-timescale processes, thereby complementing the experimental characterization [4].

In the absence of polyol, all three surfactant systems predominantly exhibited lamellar organization and showed limited cleansing capability. Cyclohexylglycerin markedly lowered viscosity and promoted lamellar-to-micellar transitions in most formulations; even where lamellar structures persisted, the degree of multilamellarity was reduced. These changes in colloidal organization were accompanied by a pronounced enhancement in cleansing capability across all systems. By contrast, glycerin largely preserved lamellar phases while altering their internal structure. Interlamellar spacing increased substantially, whereas changes in multilamellarity depended on surfactant composition. The corresponding improvement in cleansing capability was modest for decaglycerol diisostearate formulations but more evident for hexaglycerol dicaprates and mixed formulations.

Overall, these results show that hydrophobic oil-film removal is controlled not simply by phase identity but by polyol-dependent changes in aggregate curvature, lamellar packing, and mesoscale organization. This work provides a colloid-based structure-property framework for designing aqueous cleansing formulations.

Keywords:

polyol partitioning, nonionic surfactant, self-assembly, cleansing capability, SAXS, dissipative particle dynamics.



Effect of polyol condition and surfactant type on aggregate phase and cleansing capability (Γ , %) at 30 wt% surfactant.

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Acknowledgements:

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Synergistic and Antagonistic Effects Experienced by Surface-Active Compounds

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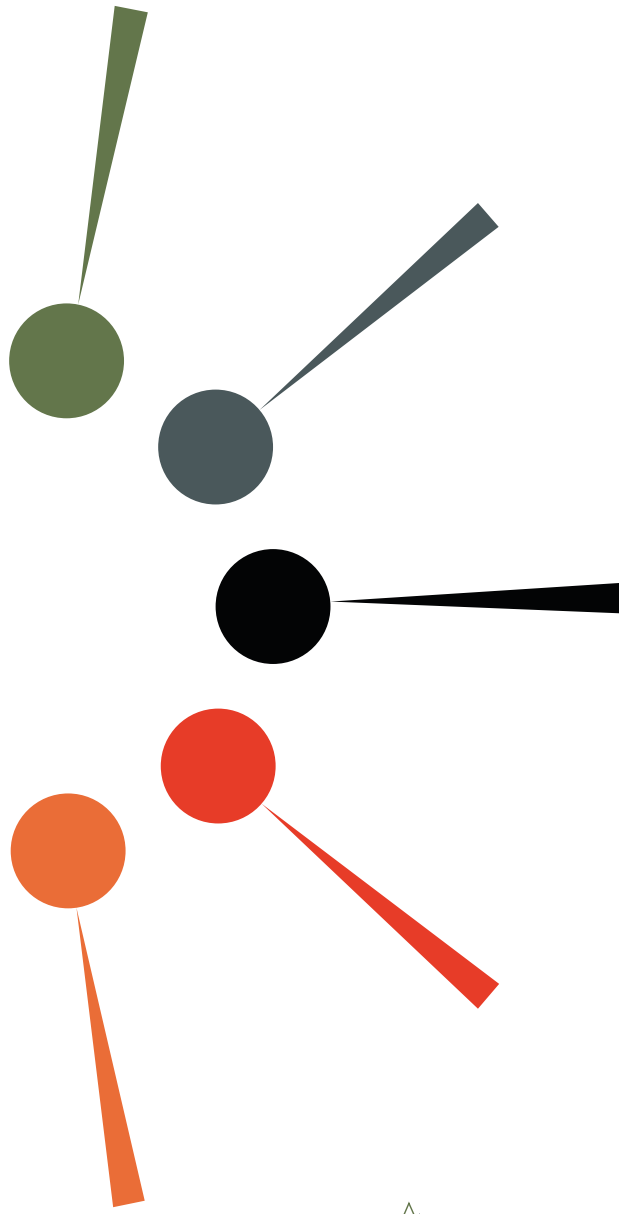
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Most commercial products, pharmaceutical formulations, as well as consumer products are complex systems that contain multiple surface-active compounds. Formulating these products require extensive and expensive trial-and-error procedures because such compounds can compete for access to interfaces in ways that are difficult to predict. For example, simple ions are known to increase the surface tension of water while most surfactants are known to reduce it. Both synergistic and antagonistic effects are possible, depending on system conditions. For example, it has been observed that mixing ionic and non-ionic surfactants leads to stronger reductions in surface tension compared to using only one of the two compounds. Molecular simulations offer the opportunity of systematically changing the properties of the chemicals considered, although of course they require significant amount of computing time, depend in their accuracy on the reliability of the force fields, and might be limited in their ability to probe systems that contain chemicals at very low concentration. Towards developing systematic quantitative observations that could lead to the prediction of the interfacial properties of realistic formulations, simulation results are presented here for systems that contain surfactants and alcohols, different surfactants, as well as surfactants and other surface-active compounds interacting with water-air and water-oil interfaces, as well as with more complex interfacial systems such as phospholipid bilayers.

Keywords:

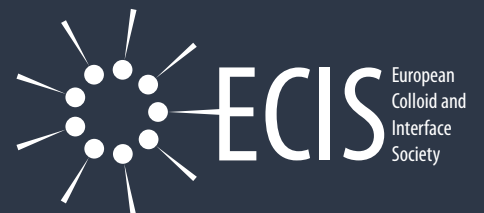
Molecular Simulations, Ion-Specific Effects, Self-Assembly, Surface Tension, Interfacial Tension



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Multiscale engineering of Green Oregano Essential Oil delivery: from interfacial control to deep skin imaging and clinical efficacy

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Green Oregano Essential Oil (GO-EO) is a potent natural anti-inflammatory complex, primarily driven by its main bioactive constituent, carvacrol [1], [2], [3], [4]. While its ability to inhibit PGE2 is well-established, its high volatility and complex delivery through the skin barrier remain significant hurdles. This work presents a holistic approach, combining advanced colloidal formulation, high-resolution mass spectrometry imaging, and clinical validation.

A major challenge identified was the high volatility of GO-EO, with up to 50% of the active lost during the application phase. To overcome this, we optimized a molecular encapsulation strategy using beta-cyclodextrins (beta-CD). By engineering a GO-EO/beta-CD inclusion complex at an optimal 1/9 ratio and incorporating a liquid fatty compound, we reduced evaporation by a factor of 3 to 6 while maintaining carvacrol bioavailability within the dry film formed on the skin.

EO diffusion was assessed using two *in vitro* screens: carvacrol detection via UV spectroscopy after membrane diffusion, and tissue viability (MTT assay) on EpiSkin models to correlate Green Oregano penetration with formulation performance.

The penetration pathways were elucidated using Time-of-Flight Secondary Ion Mass Spectrometry (ToF-SIMS) combined with SEM. This high-resolution imaging technique provided unprecedented visualization of carvacrol distribution across human skin cross-sections. Our results demonstrate that carvacrol effectively bypasses the stratum corneum, showing a pronounced accumulation in the deeper parts of the dermis, specifically within triglyceride-containing structures (likely adipocytes and secretory coils of sweat glands). Quantitative analysis (GC-MS) confirmed that approximately 84% of the detected carvacrol reached the dermis, highlighting its strong lipophilic affinity and fast penetration kinetics [5].

The biological relevance of this deep delivery was confirmed through several monocenter, double-blind, randomized clinical studies. Optimized formulations (0.3% to 1% GO-EO) demonstrated significant efficacy in reducing UV-induced erythema and inflammatory skin signs. Furthermore, a 0.5% GO-EO formula significantly improved skin imperfections over 8 weeks, while a 0.3% formula provided superior soothing effects in after-shaving applications.

In conclusion, this study demonstrates how the synergy between fundamental interfacial science, advanced mass spectrometry imaging, and clinical research allows for the successful delivery of volatile essential oils, transforming carvacrol into a high-performance active for deep-skin soothing applications.

Keywords:

Carvacrol; Green Oregano; ToF-SIMS; Skin Imaging; beta-Cyclodextrin; Dermal Delivery; Anti-inflammatory; Clinical Efficacy

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<https://doi.org/10.1038/s41598-018-34286-x>

Coalescence of droplets stabilized by potato protease inhibitor: Microfluidic investigation on the effect of temperature and adsorption time on protein functionality

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The main product extracted from potatoes is starch. However, the leftover liquid has a high protein content, and is a potential source for alternative proteins. Particularly protease inhibitors show strong potential as natural emulsifiers for food applications. Their functionality, however, is highly sensitive to processing conditions during food production such as thermal treatment, and the process used to obtain these ingredients. Besides, the functionality of proteins is generally not known under the conditions at which they are applied. That is why we have used a microfluidic technique to investigate droplet stability under relevant conditions.

In this study, we focus on the protease inhibitor fraction of the potato protein Solanin 300 and its ability to stabilize oil-water interfaces under varying thermal conditions. We employ a custom-designed microfluidic chip (Figure 1) to investigate protein-stabilized emulsion droplet coalescence at millisecond timescales. The system enables precise control over droplet formation at a T-junction (highlighted in light blue), followed by real-time observation of droplet interactions within a coalescence chamber (medium to dark blue). This setup allows us to mimic and monitor the behavior of emulsions during food processing with unprecedented temporal and spatial resolution.

In this study, we examined the impact of heating (55, 65, and 75 °C) on the interfacial behavior of protease inhibitor fractions in both spray-dried (S300) and liquid (S300L) forms. Droplet stability was assessed at millisecond timescales. The effect of concentration and adsorption time (varied through the length of the adsorption channel as shown in figure 1, right side) were investigated. The results revealed that for the spray dried protein at lower concentrations, droplet stability decreased upon heating at 55 and 65 °C compared to non-heated samples, but improved markedly at 75 °C. In contrast, the liquid protein exhibited enhanced droplet stability at 55 °C and 65 °C relative to the control, with further improvement at 75 °C. Adsorption studies indicated that droplet stability generally increased with adsorption time for both samples; however, the spray-dried protein heated at 75 °C showed no change with time, an observation that appears unprecedented. We were able to connect this to differences in protein structure and conformation, caused by the isolation process as well as the heating temperature, as evidenced by surface hydrophobicity and circular dichroism spectroscopy measurements of the proteins. This shows that the process used to obtain the proteins has considerable influence on their operational functionality, and that the process used to make the emulsions can be tuned to facilitate droplet stability. Both aspects that are quantified in this work allow food designers to make informed choices on the use of this specific alternative protein. The approach can obviously be used in a much wider perspective, e.g., as a screening tool for new protein sources, as well as existing ones.

Keywords:

Potato proteins, Emulsion stability, Food emulsions, Protein processing

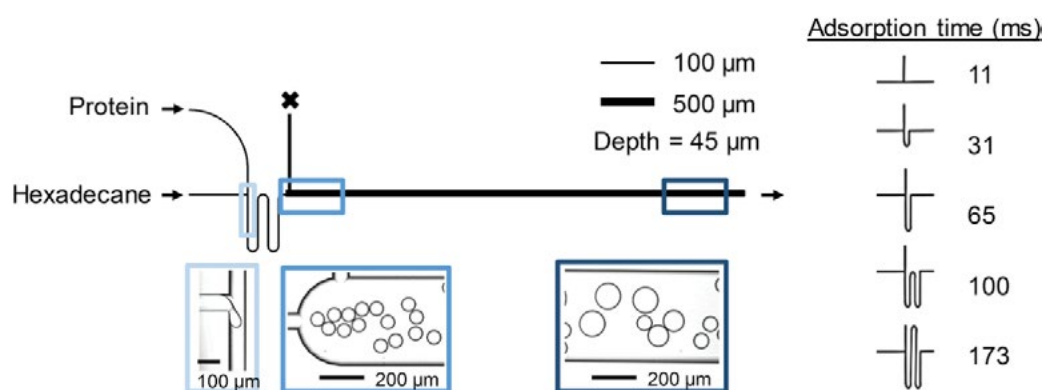


Figure 1: Schematic representation of microfluidic chip

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Sustainable, microplastic-free encapsulation of lipophilic fragrances using sodium alginate for cosmetic formulations

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Microencapsulation of volatile lipophilic compounds such as fragrances is essential in the cosmetic industry to control their prolonged release and delay their evaporation. However, conventional systems often rely on non-biodegradable microplastics, which involve environmental risks to aquatic ecosystems. Developing sustainable, biodegradable alternatives that maintain efficacy is therefore crucial for the industry.

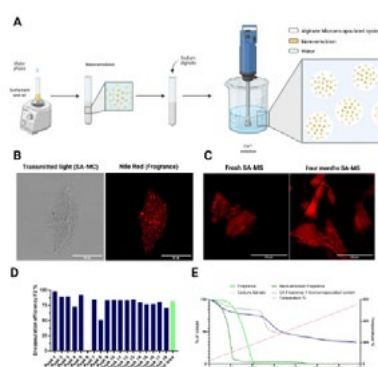
The strategy consists of a nano-emulsion within a gelled alginate matrix. O/W nano-emulsions were prepared via phase inversion composition (PIC) method using polysorbate 80, then microencapsulated through internal gelation with CaCl_2 and subsequent dispersion (Figure 1.A). Characterisation included DLS for size distribution, GC-MS for encapsulation efficiency, TGA for release profiles, Microscopy for morphology, Oil distillation for fragrance loading, and a 30-day organoleptic study with 21 trained panellists to evaluate fragrance intensity.

The optimised formulation produced long-term stable monodisperse nano-emulsions (around 160 nm). Confocal microscopy confirmed the retention of fragrance within the alginate microsystems (Figure 1.B). The system exhibited excellent stability in a carrier matrix for four months without phase separation (Figure 1.C). The encapsulation efficiency average-compounds is of 81% (up to 97% for individual compounds) (Figure 1.D). TGA (Figure 1.E) and Organoleptic studies showed prolonged release profiles and significantly higher perceived intensity compared to free fragrances.

This work demonstrates a viable biodegradable alternative to microplastic-based encapsulation systems for cosmetic applications. The strategy based on O/W emulsion encapsulated within the sodium alginate matrix achieves high encapsulation efficiency of the fragrances, prolonged diffusion-controlled release, and long-term stability, addressing environmental concerns being a useful alternative to non-biodegradable encapsulation systems.

Keywords:

O/W nano-emulsions, Microencapsulation system, Biodegradable polymer, Sodium Alginate, Fragrance encapsulation, Phase Inversion Composition



Design and characterization of SA-Fragrance Microencapsulated System. A) System designed B) CSFM images of system loaded with Nile Red. Channels at Brightfield and at 365 nm C) CSFM images of fresh and 4 months in a "conditioner matrix" D) Encapsulation Efficiency (%) E) TGA curves.

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Controlled Self-Organization of Gold Nanorods in Aqueous Dispersion via Surface Modification with Oligo(ethylene glycol)-Based Ligands

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Gold nanorods (AuNRs) exhibit highly tunable localized surface plasmon resonance (LSPR) derived from their morphological anisotropy. To leverage their anisotropic optical properties, various strategies have been explored to achieve orientation control of AuNRs in dispersion, where their rotational freedom enables dynamic responses to environmental changes or external stimuli. Such structural freedom enables control not only over orientation but also over interparticle spacing, which significantly alters LSPR characteristics through near-field coupling and gives rise to collective responses. However, achieving well-ordered AuNR assemblies in dispersion, particularly with dynamic control by external stimuli, remains challenging.

In this study, we investigated the pH-responsive self-organization of AuNRs in aqueous dispersions by tuning ligand structures. Two kinds of carboxy-terminated thiols were employed as ligands for surface modification: 16-mercaptohexadecanoic acid (MHA) with a linear alkyl chain and 20-(11-mercaptopundecyloxy)-3,6,9,12,15,18-hexaoxaicosanoic acid (C11EG6) with an oligo(ethylene glycol) (OEG) chain (Figure a). MHA-modified AuNRs, denoted as **CAR1**, and C11EG6-modified AuNRs, denoted as **CAR2**, were dispersed in water at 70 wt% and analyzed by small-angle X-ray scattering (SAXS).

CAR1 showed no scattering peaks assignable to ordered structures, whereas **CAR2** exhibited multiple peaks consistent with a hexagonal arrangement (Figure b). This difference is attributed to the OEG chains in C11EG6, which form a robust hydration layer [1] that suppresses irreversible aggregation and provides uniform surface coverage [2], thereby enabling uniform electrostatic repulsion from terminal carboxy groups. Furthermore, SAXS measurements under varying pH conditions revealed that **CAR2** formed highly ordered structures under strongly basic conditions (pH 12), where ten distinct sharp diffraction peaks assignable to a hexagonal structure were observed. These results suggest that the ionization state of surface ligands governs the self-organization of AuNRs in dispersion, highlighting the potential of ligand design for plasmonic nanoparticles in next-generation optical systems.

Keywords:

Organic-inorganic hybrid materials, Gold nanorods, Self-organization, Oligo(ethylene glycol)-based ligands, pH-responsiveness

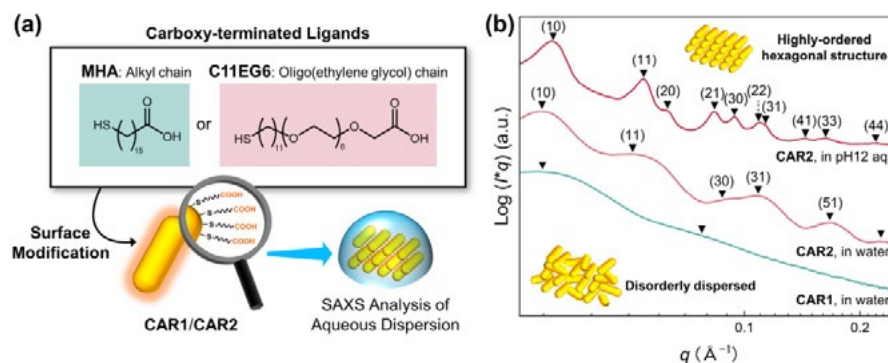


Figure. (a) Molecular structures of two ligands and a schematic illustration of this study; (b) SAXS patterns of CAR1 and CAR2 dispersed in water at 70 wt% and that of CAR2 dispersed at pH 12.

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From Waste to Interface: Tuning Amino Acid Surfactants Derived from Used Cooking Oils

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The environmental fee of conventional, non-biodegradable petrochemical surfactants has accelerated the demand for renewable, biobased alternatives. Consequently, the upcycling of used cooking oil (UCO) has emerged as a highly effective circular economy strategy[1]. Taking advantage of the versatile chemical structure of UCO-derived triacylglycerides (**1**), it is possible to design and synthesize high-value, sustainable surfactants.

Building on our previous work in biobased surfactant synthesis, we report a peptide-inspired, sustainable strategy to generate a library of amino acid-based surfactants from UCO. Using amino acids as natural, versatile building blocks, the surfactant charge can be tuned, yielding anionic, cationic, or amphoteric compounds depending on the reaction conditions[2]. This approach leads to surfactants with a smaller carbon footprint and enhanced properties.

Fatty acids from UCO triacylglycerides (**1**) were activated with *N*-hydroxysuccinimide (NHS) to increase their reactivity. Using both chemical and enzymatic methods, we successfully carried out the amidation between NHS esters and a variety of amino acid methyl hydrochlorides (**2**), yielding the surfactants (**3**). The physicochemical performance of the synthesized surfactants was evaluated in aqueous solutions using standard methods. Essentially, we observed that varying the amino acid headgroup significantly dictated colloidal behavior. Tensiometry and dynamic light scattering (DLS) analysis demonstrated that these biobased derivatives exhibit exceptionally low critical micelle concentrations (0.01 – 0.20 mM) and tunable self-assembly, forming either pure vesicles or mixed micelle-vesicle systems depending on side-chain polarity. Furthermore, the surfactants displayed excellent colloidal stability ($|\zeta| > 60$ mV) and remarkable emulsifying capacity, sustaining emulsions above 60 – 70% for up to seven days. Beyond their physical interfacial properties, the cationic arginine derivative (**3j**) exhibited significant antibacterial activity against *S. aureus* and *E. coli*, presenting significantly low minimum inhibitory concentrations (4 µg/mL and 31 µg/mL, respectively). These findings establish a framework for upcycling UCO into tunable surfactants, correlating molecular architecture with macroscopic interfacial properties.

Keywords:

waste valorization; circular economy; amino acid-based surfactants; self-assembly; emulsification properties

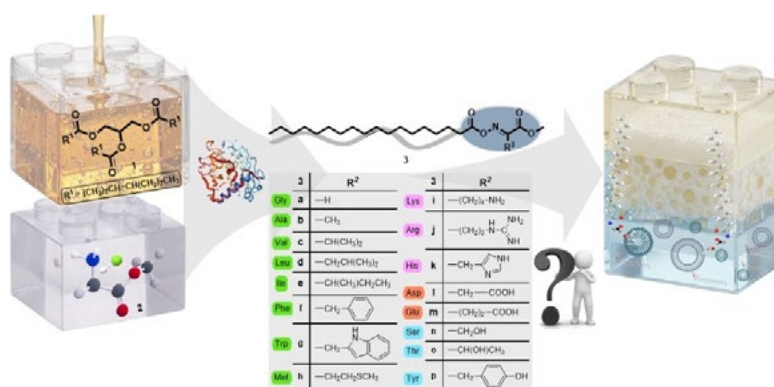


Figure 1: Synthesis of a diverse library of amino acid surfactants from used cooking oil (UCO) triacylglycerides, illustrating the study into how the amino acid side chain (R₂) directs surface activity and self-assembly behavior.

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Acknowledgements:

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Diffusion kinetics of dyes out of hair fibre: link with fibre properties and impact on cosmetic performances

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The durability of hair coloration, particularly its vibrancy, is an increasingly fundamental concern for consumers¹. Indeed, hydrophilic oxidation dyes are progressively extracted from the hair fibre during shampooing, leading to noticeable fading over time. In this context, our study explores the kinetics of dye diffusion out of the hair fibre to understand the impact of its damage on this phenomenon. Thanks to an original experimental protocol, we quantified the kinetics of dye release from the fibre using UV-visible spectrophotometry. We first highlight that temperature plays a predominant role in this phenomenon, while the presence of surfactants does not impact it. Furthermore, our results demonstrate that dye diffusion out of the fibre follows Fick's law, allowing for the calculation of diffusion coefficients. These are consistent with existing literature² and increase significantly with fibre damage. In addition, some technical pathways to reduce this loss have been explored, identifying a promising solution. This study stands out by presenting the first measurements of dye diffusion out of the fibre and paves the way for a better understanding of dye desorption, thereby enabling the development of innovative formulations for more durable hair coloration.

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U(VI)-Si colloids: metastable phases that should not be overlooked in the environment

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Actinides are present in the environment in many different ways, particularly due to activities related to the nuclear fuel cycle, military tests or severe accidents [1,2]. Several studies have demonstrated the existence of metastable polynuclear species incorporating actinides that can agglomerate under certain conditions to form nanometric-sized objects also called colloids [2–5]. Under this form, the mobility of actinides in soils, aquifers or surface waters can be strongly modified compared to soluble species, especially in presence of geological material [6]. These species could also act as reaction intermediaries between soluble species and crystalline phases in equilibrium with the solution. However, the conditions that favor the formation of actinide-based colloidal species remain only partially identified and their thermodynamic stability remains to be assessed.

In this study, we demonstrated the formation of metastable uranyl–silicate intrinsic colloids in model solutions having simplified compositions under air and at room temperature by centrifugation and ultrafiltration. The influence of the silicate ion concentration (between 10^{-4} and 10^{-2} M) and pH (from 7 to 13) on the quantity and nature of the formed species was investigated. The aqueous solutions were characterized by ICP-OES to determine the concentration of elements in solution and by *in situ* Small and Wide-Angle X-ray scattering (SWAXS) to characterize the formation of colloids. If precipitation occurred, High-Resolution Transmission Electron Microscopy (HR-TEM) has been used to determine the phase morphology. Using this methodology, we determined the formation and the evolution of the colloids in term of size, volume, concentration and stoichiometry under different conditions [5]. We also performed geochemical simulations with PHREEQC [7] to predict the phase precipitation and element speciation in our model solutions and compare these calculations with our experimental results. Taking into account all of these results, we demonstrated that pH and silicate concentration drive the nature of colloids and their lifetime, highlighting the need to integrate these intermediate species in geochemical calculations.

Keywords:

U(VI)-Si intrinsic colloids, actinide colloids, prenucleation cluster, Small and wide-angle X-ray scattering

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Viscosity and dynamic surface tension measurement: A guideline for appropriate measurement

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Dynamic surface tension (DST) measurements are central to understanding interfacial processes in liquids of widely differing viscosities, from low-viscous inkjet formulations to highly viscous coatings and resin systems. Although surface tension itself is independent of viscosity, the *measured* DST at young surface ages can be strongly distorted by the transient flow required for a newly created interface to relax to its equilibrium shape. This relaxation process sets a fundamental lower limit to the surface age at which DST values can be interpreted reliably. At younger times, apparent time-dependent behavior may be mistaken for surfactant kinetics even though it is purely driven by viscous or inertial effects.

In our recent study published in the *Journal of Colloid and Interface Science* (2026), we systematically quantified this minimum reliable surface age across three widely used DST techniques—pendant drop, Wilhelmy plate, and bubble pressure—spanning viscosities from water-like to highly viscous silicone standards. By using pure, surfactant-free liquids, we isolated viscosity-induced hydrodynamic artifacts and identified the characteristic time beyond which each method yields viscosity-independent values. The comparison reveals that each technique has a distinct operational regime: bubble pressure enables the youngest accessible surface ages for low-viscosity liquids, pendant drop becomes the most suitable for high-viscosity fluids, and Wilhelmy-plate measurements generally require substantially longer relaxation times.

Building on these insights, we present a practical phase-plot guideline that allows researchers to select the appropriate method and the youngest trustworthy surface age for any given viscosity. This ensures that observed DST dynamics truly reflect interfacial or surfactant behavior, rather than hidden viscosity effects. The updated guideline provides a simple and robust framework for scientists and engineers working with complex fluids to avoid misinterpretation and to perform more reliable dynamic surface tension measurements.

Keywords:

Dynamic surface tension (DSFT), Surface tension (SFT), Viscous effect, Equilibrium/relaxation time, Surface age, Hydrodynamic forces

References:

Vivek Kumar, JSM Quintero, Aleksey Baldygin, Paul Molina, Thomas Willers, Prashant R. Waghmare, Viscosity and dynamic surface tension measurement: A guideline for appropriate measurement, *Journal of Colloid and Interface Science*, Volume 709, 2026, 139929, ISSN 0021-9797, <https://doi.org/10.1016/j.jcis.2026.139929>.

Oligomeric Surfactant-Enhanced Leaching Coupled with Bioremediation for Petroleum-Contaminated Soils

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Introduction.

Petroleum-contaminated soils are difficult to remediate due to a wide range of point/nonpoint sources of pollution and complex components. Here, the leaching process were optimized through the selection of conventional eluting agents and the development of oligomers, modified bio-based surfactants and synergists, leading to a new and efficient leaching system. From a colloid and interface chemistry perspective, remediation efficiency is governed by interfacial activity, wettability alteration, and the solubilization/emulsification of hydrophobic petroleum components at the soil-water interface. In particular, regulation of interfacial tension and wetting reversal of oil-coated soil surfaces can enhance pollutant detachment and transfer. A subsequent bioremediation step was retained to further degrade residual hydrocarbons after leaching. This study provides an economical and environmentally friendly technical route for emergency oil-spill response and historical petroleum-contaminated sites.

Experimental/methodology.

A benzene ring was used as a reaction site, and carbonyl and imino functional groups and substituted benzene were subjected to polycondensation reaction through catalysis to construct a molecular skeleton of the oligomeric surfactant. A branched structure was formed by adding dialdehyde with double reaction sites, followed by incorporation of hydrophilic groups on the benzene ring.

All raw materials required for the oligomeric surfactant are readily available. Compared with traditional single-chain surfactants, dimeric and oligomeric surfactants can self-assemble to perform various functions at much lower dosage. Such behavior is favorable for emulsification/demulsification balance, contaminant desorption from soil particles, and enhanced washing performance in porous media.

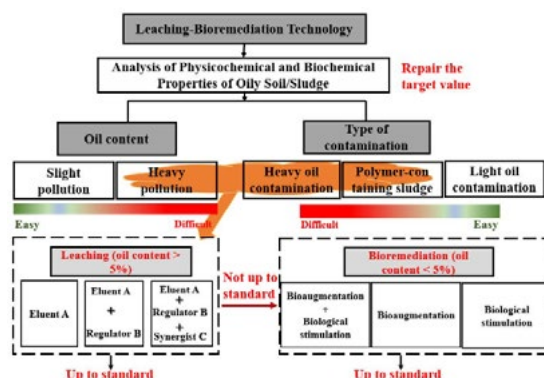
Results and discussion.

A new leaching agent system containing oligomers, green bio-based surfactant molecules, and synergists was developed to optimize soil-washing performance. The improved formulation showed advantages in interfacial activity and wetting regulation, promoting the desorption and mobilization of petroleum from soil particles. After leaching, a microbial polishing step was applied based on the characteristics of the treated soil, with screened petroleum-degrading bacteria used to remove residual heavy oil, polycyclic aromatic hydrocarbons and other pollutants.

According to the physical characteristics of different oily sludge and soil types, an economical and efficient remediation technology system and supporting implementation process were established, and finally, forming a "leaching-bioremediation" coupled treatment process. After treatment, the PHs content of actual contaminated soil was lower than 0.45%, and 12,000 t of contaminated soil was remediated. The results demonstrate that coupling interfacially tuned leaching with bioremediation is a practical strategy for petroleum-contaminated soils.

Keywords:

leaching, bioremediation, soil remediation, petroleum pollution, colloid and interface chemistry



Schematic diagram of the coupled leaching-bioremediation process for petroleum-contaminated soils

Elucidating Surfactant–Solvent interactions in dilute regimes to control Nanostructured Fluids features

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Surfactant-driven self-assembly underpins the formation of a broad class of complex fluids that are essential for applications ranging from drug delivery to conservation science.[1,2] However, the development of nanostructured fluids with targeted properties remains largely empirical, as formulation strategies still rely on iterative and time-intensive trial-and-error approaches. Advancing beyond this paradigm requires molecular-level insight into how surfactant structure and solvent environment collectively determine mesoscale organization and macroscopic behaviour.[3]

Here, we propose a systematic and experimentally accessible approach to probe surfactant–solvent interactions in dilute regimes.[4] A library of bio-derived polyethylene glycol (PEG) surfactants bearing distinct terminal functionalities was selected as a model system. Structural characteristics and translational dynamics were quantified in dilute aqueous and organic solutions using size-exclusion chromatography and nuclear magnetic resonance spectroscopy (NMR). These molecular descriptors were subsequently linked to the formation and evolution of micellar nanostructures through combined NMR and small-angle X-ray scattering analyses.

The study reveals well-defined relationships between surfactant molecular parameters, including molar mass, end-group chemistry, and hydrophilic–hydrophobic balance (logP), and the size, internal organization, and dynamic properties of the resulting micellar assemblies. In addition, the introduction of water-miscible organic solvents emerges as an effective strategy to tune micellar dimensions, internal solvation, and solvent encapsulation efficiency.

Taken together, these findings establish a coherent structure–property framework for the rational design of sustainable, bio-derived soft matter systems. The methodology presented here provides a foundation for the predictive engineering of tailored micellar fluids, offering new opportunities for performance optimization across a wide spectrum of soft-matter-based technologies.

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Hydrotrope-Controlled pKa Shifts and Supramolecular Reorganization in Glycyrrhizic Acid Hydrogels for Advanced Solubilization

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Achieving sustainable solubilization and encapsulation of hydrophobic molecules is still a key obstacle in contemporary formulation science. Although ammonium glycyrrhizinate (AGA)-based hydrogels offer promising biodegradability and biocompatibility, their natural capacity to solubilize poorly water-soluble compounds is limited. In this work, short-chain alcohols are systematically investigated as hydrotropes and co-solvents to tailor the acid-base equilibria, supramolecular organization, and nanocarrier performance of AGA/water/alcohol hydrogels.

Hydrotrope-specific effects on apparent pKa values, ionization states, and network structures were analysed in detail. Ethanol, characterised by its relatively low dielectric constant and pronounced amphiphilicity, induces an increase in apparent pKa values, while simultaneously promoting enhanced dissociation of glycyrrhizic acid. This seemingly counterintuitive behavior is attributed to hydrotrope intercalation within fibrillar aggregates, leading to increased spacing between carboxylate groups and modified electrostatic interactions. At moderate ethanol contents, these competing effects favour the formation of extended, entangled fibrillar networks, whereas at higher concentrations, fibril destabilization results in fragmentation into micelle-like aggregates. Isopropanol exhibits an even stronger impact, consistent with its lower permittivity and higher hydrotropic efficiency. In contrast, glycerol induces only minor pKa shifts and primarily stabilises AGA ions via extensive intra- and interfibrillar hydrogen bonding, yielding a moderately developed but increasingly robust network with rising glycerol content.

The resulting structural variations directly influence solubilization capacity and nanocarrier efficiency. These properties were evaluated using solutes of different hydrophobicity. In particular, the poorly water-soluble natural sweetener rebaudioside A exhibits up to a 25-fold increase in solubility in the presence of AGA hydrogels, along with thermoreversible gelation behaviour that surpasses conventional surfactant-based systems. Scattering and recovery experiments support a dual-aggregate scenario, involving both partial co-assembly within AGA fibrillar networks and the formation of solute-rich, spheroidal domains, analogous to systems containing ethanol.

Overall, AGA/short-chain alcohol hydrogels emerge as highly tuneable and sustainable solubilization systems and nanocarriers. Their properties can be precisely adjusted through hydrotrope selection and concentration, offering significant potential for applications in food, cosmetic, and pharmaceutical formulations.

Keywords:

glycyrrhizic acid, molecular gel

A Highly Anisotropic and Hydrolytically Degradable Pickering Emulsifier for Oil-in-Water Emulsions

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and S. P. Armes ^a

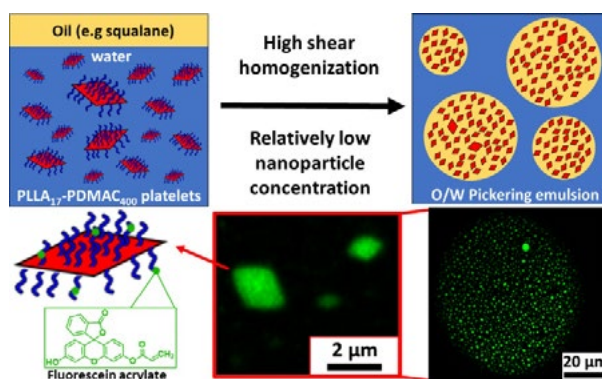
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Highly anisotropic poly(L-lactide)-based block copolymer nanoparticles are prepared by the judicious combination of reverse sequence polymerization-induced self-assembly (PISA) with crystallization-driven self-assembly (CDSA). Such nanoparticles can be efficiently prepared as a 30% w/w aqueous dispersion and possess a distinctive diamond platelet morphology as judged by transmission electron microscopy. X-ray diffraction studies confirm the semicrystalline nature of the poly(L-lactide) block while atomic force microscopy analysis suggests a mean thickness of approximately 6 nm for the dried platelets. Small-angle X-ray scattering studies suggest that these platelets form localized tactoids at copolymer concentrations as low as 1.0% w/w. Herein we evaluate these platelets as a hydrolytically degradable Pickering emulsifier for the preparation of oil-in-water emulsions using various oils. In the case of squalane, systematic variation of the copolymer concentration and the high-shear homogenization conditions enabled the mean oil droplet diameter to be varied from approximately 40 μm to 125 μm . Fluorescein-labeled platelets were imaged on the surface of oil droplets using confocal microscopy. Such studies indicate submonolayer coverage even under optimized conditions, which may account for the unexpected long-term instability observed for such Pickering emulsions.

Keywords:

Pickering Emulsion, Crystallization-Induced Self-Assembly, Reverse Sequence Polymerization-Induced Self-Assembly.



Preparation of Oil-in-Water Pickering Emulsions Using Hydrolytically Degradable Diblock Copolymer Platelets

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Modulating Fibroin Self-Assembly in Green Consolidants for Fragile Silk Artifacts

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Silk artifacts possess immense cultural and artistic significance but are highly vulnerable to degradation processes that alter the secondary structure of fibroin, the main structural protein of silk, leading to a progressive loss of mechanical performance. Effective and compatible consolidants for historic silk artifacts remain lacking with need for improved and reliable materials to preserve and transfer this heritage. To fill this gap, we developed consolidation formulations based on self-regenerated silk fibroin (SRSF) derived from waste silk, combining conservation requirements with sustainable material sourcing. In particular, hybrid formulations composed of SRSF and cellulose nanocrystals (SRSF-CNC) demonstrated enhanced consolidation efficiency when applied to artificially aged silk fibers [1][2]. However, while the incorporation of CNCs improves mechanical reinforcement, it also accelerates fibroin self-assembly, resulting in reduced formulation stability and limited shelf life. To overcome this limitation, we designed sustainable SRSF and SRSF-CNC formulations incorporating bio-derived additives, L-arginine and sericin, with the aim of regulating fibroin self-assembly and improving dispersion stability. Their self-assembly behavior and effectiveness as consolidants for aged silk fibers in the presence of the bio-derived additives were investigated using complementary physicochemical characterization techniques. In addition, application tests on historical textiles were conducted in collaboration with the Metropolitan Museum of Art (MET, New York). The results indicate that both L-arginine and sericin effectively modulate fibroin self-assembly without compromising consolidation efficacy, while preserving the visual appearance of silk artifacts. Overall, this work proposes a sustainable and adaptable approach to silk consolidation based on colloids and soft matter, contributing to the development of innovative conservation materials within a circular economy framework, and offering new perspectives for the long-term preservation of historical textile collections.

Keywords:

Self-regenerated silk fibroin , Self-assembly, Textile consolidation, Cultural heritage preservation

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Amyloid–Chitosan Aerogels for Efficient Removal of Pharmaceutical Contaminants and Heavy Metals

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Water contamination by pharmaceutical residues and heavy metals remains a persistent global challenge, driven by the limited efficiency of conventional treatment processes. Contaminants, such as hexavalent chromium (Cr^{VI}) [1] released from metal finishing or textile, and widely used pharmaceuticals, including ibuprofen (IBF) and sulfamethoxazole (SMX) [2], are frequently detected in aquatic systems at concerning levels, which highlight the urgent need for sustainable and high-performance adsorbents.

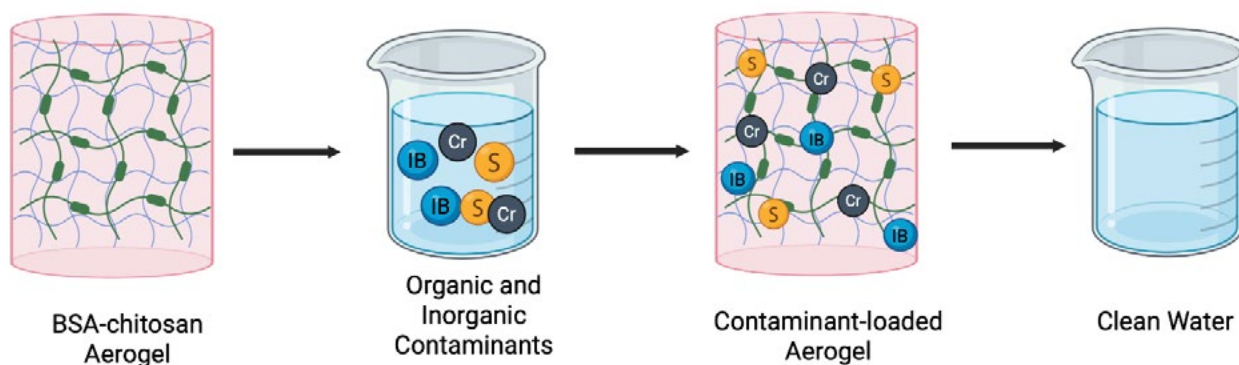
Herein, we present a class of protein–polysaccharide composite aerogels constructed from bovine serum albumin (BSA) amyloid fibrils and chitosan as multifunctional adsorbents for the removal of both inorganic and organic contaminants. Amyloid fibrils were prepared via acid-induced self-assembly and used as building blocks for aerogel fabrication. Chitosan was added post-fibrillation at tunable ratios, followed by crosslinking and freeze drying to yield mechanically durable, highly porous aerogel networks. To the best of our knowledge, this is the first study to integrate BSA amyloid fibrils with chitosan in an aerogel platform for the simultaneous removal of pharmaceutical pollutants and toxic heavy metals.

Comprehensive characterization (SEM, BET, FTIR, XPS, zeta potential, swelling, and mechanical testing) revealed that the chitosan incorporation enhances surface charge density, functional group availability, and structural stability, which collectively enable efficient contaminant capture. Chitosan incorporation significantly improved the physicochemical properties of the aerogels, increasing young modulus from ~ 300 kPa for BSA-only systems to ~ 770 kPa in hybrid structures. All samples reached swelling equilibrium within the first 30 minutes, with higher chitosan content leading to increased water uptake due to the presence of additional hydrophilic functional groups. Furthermore, the BET surface area increased from ~ 117 to $130 \text{ m}^2 \text{ g}^{-1}$, accompanied by a rise in pore volume from 0.0456 to $0.0856 \text{ cm}^3 \text{ g}^{-1}$. As a result of these structural and surface enhancements, the aerogels exhibit outstanding adsorption performance, achieving $>97\%$ removal of $\text{Cr}(\text{VI})$ and $>90\%$ removal of IBF and SMX under the same conditions, with optimal pharmaceutical removal observed at pH 6 and pH 3 for $\text{Cr}(\text{VI})$.

Mechanistically, the adsorption process is governed by a synergistic interplay of electrostatic interaction, hydrogen bonding, and hydrophobic effects. This work underscores the potential of BSA-chitosan bio-derived, structurally engineered aerogels as sustainable platforms for advanced water purification systems.

Keywords:

Amyloid fibrils; Chitosan; Composite aerogels; $\text{Cr}(\text{VI})$; Pharmaceutical pollutants; Emerging contaminants



Amyloid–Chitosan Aerogels for Dual Removal of Heavy Metals and Pharmaceutical Contaminants

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Nanostructured complex polymer films with long-lasting antimicrobial efficacy

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Development of long-lasting antimicrobial surfaces is critically important not only to prevent biofilm formation and limit contamination and transmission(1, 2), but also to reduce chemical usage and promote environmental sustainability(3-5). This project aims to understand the nanostructure of novel polymer coatings that underpin their newly discovered long-lasting antimicrobial efficacy, preventing the spread and growth of pathogens over a prolonged period of time. To this end, we have evaluated the components in a cleaning formulation developed by Wessex Chemical Factors, found to possess promising long-lasting antimicrobial properties against Gram-negative *Pseudomonas aeruginosa* and Gram-positive *Staphylococcus aureus* and yeasts 48 hours after a single spray application of the product on a surface.

The formulation actives comprise poly(dimethylsiloxane) (PDMS), a water-based silane emulsion, and biocides. To better understand the functional and structural role of each component within the produced film, we dip-coated them onto silicon wafers in a controlled manner and then analysed the film structure using X-ray reflectivity (XRR). The films were measured by X-ray reflectivity at beamline BM28 of the European Synchrotron Radiation Facility (ESRF) and at Diamond I07 (UK). The XRR Kiessig fringes (i.e. intensity oscillations) were observed on silica dip-coated in 1 wt% PDMS (WM 2,500 g mol⁻¹ with a corresponding viscosity of 65 cSt; Curve 1, Fig.1), indicating a well-organized film structure with a thickness of 14.8 nm and a roughness of 0.49 nm. However, after rinsing with hexane, the oscillations diminished, and the thickness decreased to 1.48 nm, with a roughness of 0.16 nm (Curve 2, Fig. 1). Another component in the formulation is a silane-based compound (silane, 0.14 wt%). To evaluate its role, we evaluated the XRR profile before and after rinsing, showing that the films remain after rinsing (thickness of 1.7nm) (data not shown). In contrast, when silane was dip-coated first (Fig. 1A), the thickness decreased from 14.8 nm to 4.0 nm after rinsing, indicative of improved stability. A two-layer model (PDMS on silane) provided an excellent fit to the reflectivity data (Curve 4, Fig.1). Contact angle measurements confirmed the presence of a hydrophobic surface after rinsing with water and hexane (Fig. 1B). Furthermore, the antimicrobial tests demonstrated that the efficacy of the formulation was improved due to the presence of the polymeric platform. Such structural information will help to understand the function-structure relationship in long-lasting antimicrobial efficacy of the films and inform optimization of formulations.

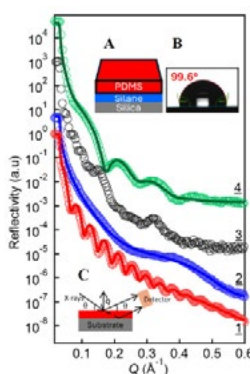


Figure 1. XRR data (symbols) and fittings (solid curves) of PDMS (1.0 wt%, 65 cSt) 1 pre-rinsed, 2 post-rinsed, and silane+PDMS, 3 pre-rinsed, and 4 post-rinsed. A) Schematic of XRR model, B) Contact angle of a water droplet on PDMS-silane coated silica, and C) Sketch of the XRR experimental setup.

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Magneto-plasmonic nanocomposites as selective and sensitive sensors for water remediation

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Environmental health is a major part of our lives; therefore, monitoring and addressing environmental pollution is essential. Surface-enhanced Raman scattering (SERS) is a highly sensitive analytical technique and a promising tool for detection of trace pollutants [1, 2]. As such, nanocomposites consisting of plasmonic and magnetic nanoparticles (NPs) are excellent candidates for water monitoring and remediation, offering the optical properties of plasmonic NPs (SERS) and facilitating target extraction from the environment using a magnetic field [2, 3]. Here, we present magnetic NPs decorated with Au NPs via chitosan and synthesized through a green route. To confirm SERS detection, highly charged porphyrins were chosen as model adsorbates. The nanocomposites were further functionalized with phenylboronic acid (PBA) to improve selectivity and tested for the SERS detection of other selected pollutants (e.g. amikacin). PBA has a unique ability to form reversible ester bonds with diol-containing molecules depending on the solution pH [4]. Therefore, such decorated magneto-plasmonic nanocomposites can be repeatedly used for the purposes of SERS detection and selective removal of pollutants from water.

Keywords:

Nanocomposites, magnetic nanoparticles, gold nanoparticles, SERS, phenylboronic acid.

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Functionalized cotton fibres for sustainable antimicrobial textiles

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Sustainable antibacterial textiles offer a compelling alternative to synthetic polymers in hygiene and personal care applications. Cotton fibres are a biodegradable, cellulose-rich material with inherent softness, breathability, and renewability. However, achieving durable antimicrobial function without compromising fibre integrity or consumer comfort¹ remains an open challenge. A promising solution is to use metal-organic frameworks (MOFs) such as ZIF-8. However, the MOF crystal growth mechanisms at the cotton fibre surface, and the effects of the fibre's chemical and physical hierarchy on this process, remain unclear. X-ray diffraction (XRD) measurements of cotton composites conflate fibre paracrystallinity, random orientation distributions, and coating heterogeneity into averaged signals that cannot resolve the underlying interfacial chemistry. To overcome this, we have adopted a multi-scale scattering approach to investigate the MOF crystal growth mechanism on model surfaces and on single cotton fibres. In particular, nano-focused XRD¹ provided unprecedented spatial resolution on the fibre crystal planes.

For our cotton fibre functionalization, ZIF-8 was grown *in situ* on non-woven cotton under mild, room-temperature aqueous conditions and subsequently functionalised with *curcumin*, a natural antimicrobial, and biopolymer layers of chitosan and hyaluronic acid.² Wide-angle X-ray scattering (WAXS) showed homogenous ZIF-8 deposition via the sodalite-phase Bragg peaks (Fig.1b)³. At the single-fibre level, nano-focused XRD with simultaneous X-ray fluorescence mapping revealed that ZIF-8 attachment, on the contrary, at this level was spatially heterogeneous, with the cellulose I (200) and (110) planes exhibiting a strong orientation dependence. The results on the single-fibre level with unprecedented spatial resolution thus unravelled the crystal structural details previously unreported on a macroscopic fabric level.

Complementary antimicrobial screening has revealed broad-spectrum activities of the functionalised fabrics against *E. coli* and *S. aureus*, attributed to the synergistic combination of ZIF-8 and *curcumin*. ZIF-8 mediates zinc ion-mediated toxicity against Gram-negative bacteria, whilst curcumin disrupts membranes of Gram-positive species^{2,4}. These findings demonstrate the antimicrobial efficacy of MOF-functionalised cotton and provide nanostructural characterisation at the single-fibre level; a resolution demanded by the material's hierarchical interfacial complexity. Together, they establish both a mechanistic framework for functional textile design and a scalable route to next-generation antimicrobial textiles for wound care, period products, and beyond.

Keywords:

ZIF-8, cotton functionalisation, nano-focused X-ray diffraction, single-fibre characterisation, antimicrobial textiles.

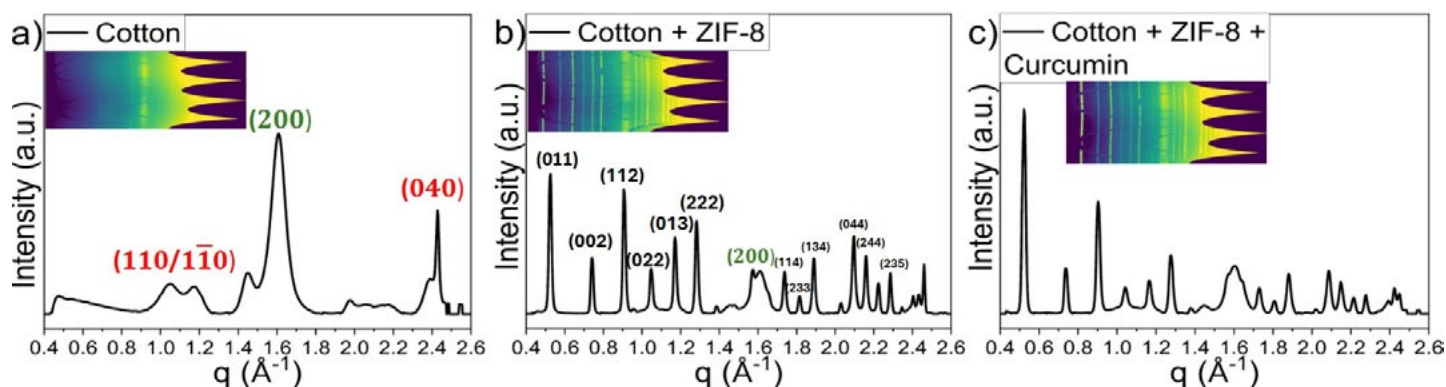


Figure 1 WAXS diffractograms of non-woven cotton: (a) unmodified cotton, (b) cotton with ZIF-8: Sodalite Miller indices indicated, and (c) cotton with both ZIF-8 and curcumin. Insets show azimuthally integrated 2D diffractograms.

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Predicting the size of surfactant micelles incorporating hydrophobic additives – quantitative model vs experimental data

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This is a study that predicts the size of spherical surfactant micelles in the presence of hydrophobic additives.

Surfactants are known to play a vital part in many processes in both fundamental and applied science. These compounds can self-assemble under aqueous conditions into molecular aggregates called micelles. ¹ Due to their structure, micelles are used in a range of different applications, such as in detergency, pharmaceuticals and nanotechnology, where they can act as simple delivery systems for small hydrophobic additives. Depending on the additive, these molecules can alter the physical properties of the surfactant, including their phase behaviour, surface tension and viscosity, and thus the final formulations' performance. ² It is therefore of great importance to understand and predict the effects of additives on the self-assembly of these systems.

We present a quantitative geometric model that can predict the size of spherical surfactant micelles in the presence of hydrophobic additives. This model was applied to predict the size of sodium dodecyl sulfate (SDS) micelles in binary mixtures (surfactant/water) and their swelling in ternary mixtures (surfactant/n-decane/water), as a function of their surfactant/additive/water volume fractions. Molecular parameters were extracted from the d-spacing of more ordered phases (lamellar and hexagonal). Results show that the experimental values are in good agreement with the model values, limited to predictions up to the maximum solubility concentration of the hydrophobic additive (MAC). This approach not only bridges theoretical modelling with experimental results but also provides a practical tool to estimate the effect of additives on the surfactant micelles more accurately, which in turn would help in the improvement of formulations for future surfactant-based products.

Keywords:

Surfactants, Micelles

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Characterization and Structural Analysis of Egg Yolk Plasma

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Egg yolk plasma is the primary contributor to the emulsifying and gelling properties of egg yolk due to its high content (85 %) of low-density lipoproteins (LDLs) (Anton, 2013). Although LDLs are generally considered a homogeneous population, their broad reported size range suggests potential structural heterogeneity that may influence functionality. In this study, egg yolk plasma was prepared under varying extraction conditions (0.1 and 0.2 M NaCl; 10.000×g and 40000×g) to investigate whether changes in ionic strength and centrifugal force reveal structural differences within the LDL population, and whether such differences translate into measurable functional effects. Structural differences induced by these variations were characterized using small-angle X-ray scattering (SAXS). In addition, temperature-dependent SAXS measurements (5-80 °C) were performed to investigate structural evolution during heating. The functional properties of plasma obtained under these different extraction conditions were subsequently evaluated and compared. Interfacial properties were assessed using drop tensiometry to determine adsorption kinetics and equilibrium interfacial tension, while heat-induced gelation and viscoelastic properties were analyzed by rheology. Compositional analysis showed that increasing ionic strength reduced total lipid content, while higher centrifugal force enriched the plasma fraction in neutral lipids and decreased the relative proportion of polar lipids. Despite these differences, particle size distributions consistently exhibited a dominant LDL population centered at 40-50 nm. SAXS measurements from the four samples revealed several characteristic features. The scattering data displayed smeared form-factor oscillations due to particle polydispersity, an increase in intensity at low q at higher temperatures, indicative of aggregation, and the development of a more pronounced high- q shoulder upon heating. Between 5 and approximately 65 °C, all data sets were similar, reflecting only minor changes in particle structure. Above ~65 °C, aggregation became increasingly significant, as evidenced by systematic changes at low q . The data were modeled using a polydisperse core-shell ellipsoid model that incorporates random-walk aggregation and an internal shell structure. Consistent with the SAXS results, all samples formed elastic gels upon heating (~80 °C), with plasma obtained at 40.000×g forming the stiffest gels. All samples showed a rapid decrease in interfacial tension, indicating quick adsorption of surface-active lipids and proteins from egg yolk plasma. At the interface, plasma prepared at 10.000×g exhibited lower equilibrium interfacial tension and higher interfacial viscoelastic moduli, suggesting more efficient interfacial stabilization, potentially due to higher phospholipid content and the presence of additional minor surface-active components.

Keywords:

egg yolk plasma, low-density lipoprotein, SAXS, interfacial tension, gelation

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Investigating physicochemical characteristics of artificial sebum for sustainable cleansing.

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Objective : Sebum, a complex mixture of lipids, plays a key role in protecting and lubricating the skin and hair. While sebum acts as a natural barrier against microbes and pollutants, its build-up or contamination can contribute to conditions like acne and dandruff. The aim of this work was to establish an understanding and develop new methods and knowledge about physicochemical properties of artificial sebum (AS) that underpin the cleansing technologies.

Methods : A novel micromanipulation method was developed and optimised for mechanical characterisation of AS thin films through scratch testing. The effect of temperature and humidity were evaluated using a combination of Differential Scanning Calorimetry (DSC) and Dynamic Vapour Sorption (DVS). Polarised Optical Microscopy (POM) allowed for evaluating polymorphism of AS.

Results : AS upon ageing reduced the cohesive energy from 0.3 mJ on the day of preparation to 0.04 mJ after 72 hours, which is due to the kinetic transformation of more unstable β' to β polymorph. DSC and POM analysis showed a change in crystallinity of AS upon ageing due to the change into the thermodynamically stable polymorphs. The addition of model air pollutants to AS resulted in lower mechanical strength and change in the polymorphism of AS, which made AS more solid-like at skin temperature therefore making it less likely to melt and remove. DVS analysis of polluted sebum after 24 h showed reduction in water sorption upon addition of pollutants suggesting that air pollutants affect water sorption and therefore moisturisation properties of sebum.

Conclusion : This work offers an in-depth understanding of the physicochemical characteristics of AS and its interactions with model air pollutants. It was established that the physicochemical properties of AS are dependent on the crystal structure of lipids, which also get affected by the addition of model air pollutants.

Sustainable colloidal carbon nanodots: from green synthesis to physicochemical-functional insights

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The increasing generation of agro-industrial and biowaste residues represents both an environmental burden and an opportunity for the sustainable design of functional colloidal nanomaterials [1]. In this context, we report a green waste-to-wealth strategy for the synthesis of antioxidant carbon nanodots (CNDs) derived from humic acids, sulfonated lignins, and spent coffee waste polyphenols. A mild bottom-up carbonization route is employed to obtain ultra-small CNDs with intrinsic colloidal stability, driven by the preservation of redox-active phenolic motifs at the particle surface, thus avoiding post-synthetic functionalization.

From a colloid and interface science perspective, the system is governed by a strong coupling between carbon core formation and surface chemical evolution, which ultimately controls interparticle interactions, dispersion stability, and functional performance. Comprehensive physicochemical characterization—including Cryo-TEM, X-ray diffraction, FTIR, XPS, electron paramagnetic resonance (EPR), UV–Vis absorption, fluorescence spectroscopy, and scattering techniques—confirms the formation of stable nanocolloids with sizes below 10 nm and heterogeneous but functionally rich surface chemistry.

The resulting CNDs behave as responsive colloidal interfaces, exhibiting excitation-dependent photoluminescence, robust resistance to aggregation, and efficient reactive oxygen species (ROS) scavenging. Importantly, ROS modulation is directly linked to surface-confined phenolic and heteroatom-containing functionalities, highlighting the role of interfacial chemistry in governing redox activity. Biocompatibility across human and cancer cell lines further supports their relevance for biointerface applications.

In addition, the nanodots display selective and reversible interactions with environmentally relevant metal ions (Pb^{2+} , Cu^{2+}), demonstrating their potential as multifunctional fluorescent nanoprobes for sensing in complex aqueous environments. Overall, this work illustrates how biowaste-derived precursors can be engineered into stable, functional carbon nanocolloids, bridging sustainable chemistry with interfacial nanoscience and advancing their application in environmental and biomedical colloid-based technologies.

Keywords:

carbon nanodots, biowaste valorization, ROS scavenging, chemosensing, sustainable nanocolloids

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Processing-induced structural changes in pea proteins and their impact on interfacial functionality and emulsion stability

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In the plant-protein sector, industrial processing is still primarily optimised to maximise extraction yield rather than to tailor functional properties relevant to food applications. Yet, in modern food design, emulsions are not only structural components but also key modulators of lipid digestion, which in turn can trigger physiological mechanisms related to satiation and satiety. The interfacial performance of plant proteins is therefore crucial for designing emulsions that behave predictably both in the product and throughout digestion. To support a shift toward functionality-driven processing, we investigated how three specific steps in pea-protein production (extraction conditions, thermal treatment, and drying) affect protein (micro)structure, interfacial behaviour, and ultimately oil-in-water (o/w) emulsion stability.

Salt extraction and alkaline extraction at mild pH produced proteins with comparable structural features, while extraction at pH 11 resulted in more extensive unfolding and aggregation. Despite this, pH 11 proteins also produced emulsions with small, stable initial droplet sizes and showed superior creaming stability. Drying techniques had only minor effects on protein conformation, whereas thermal treatment considerably increased aggregation and yielded emulsions with larger droplets and reduced stability across all extraction routes. These results demonstrate that processing-induced structural modifications strongly determine the interfacial properties of pea proteins and the resulting stability of o/w emulsions. Understanding these structure-process-function relationships offers valuable insights for developing plant-based emulsifiers that not only stabilise food emulsions but can ultimately be tailored to influence lipid digestion, satiety responses, and the delivery of lipophilic nutrients.

Keywords:

emulsion stability, pea protein, processing, extraction, protein structure

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From Biomass to Interface: Carob Pulp Sugar Extraction, Synthesis, Functional Characterization of new Cationic Sugar-based Surfactants

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The inevitable substitution of petroleum-based feedstocks is driving the scientific community towards the intelligent valorisation of biomass, such as carob pulp (*Ceratonia siliqua* L.), for the synthesis of new functional materials. As surfactants are among the most versatile and highly demanded chemicals worldwide, essential in pharmaceuticals, cosmetics, and detergents, shifting their production to renewable sources is a priority for sustainable chemistry^{1,2}. In this context, carob pulp emerges as a strategic Mediterranean resource; although often undervalued, its exceptionally high sugar content provides a robust molecular platform for developing sugar-based surfactants³. By leveraging the natural sugar scaffolds present in this agricultural by-product, it is possible to engineer high-performance amphiphilic molecules that match or exceed the interfacial properties of their fossil-based counterparts, effectively closing the loop in a circular biorefinery model.

This work focuses on sugar extraction using ultrasound-assisted aqueous-acid conditions, designed to promote the *in situ* inversion of carob sucrose. The resulting sugar-rich extracts were comprehensively characterised by UV-Vis, GC-MS, and HPLC-RID, and subsequently employed as precursors for the synthesis of novel cationic surfactants. To validate the efficacy of the biomass-derived products, their physicochemical behaviour was evaluated and compared with benchmark surfactants synthesised from analytical-grade sugars. Furthermore, the functional potential of these new surfactants was assessed through antimicrobial activity assays against *Escherichia coli* and *Staphylococcus aureus*.

Keywords:

Carob pulp; Cationic surfactants; Ultrasound-assisted extraction; Acid hydrolysis; Surface activity; Antimicrobial activity.

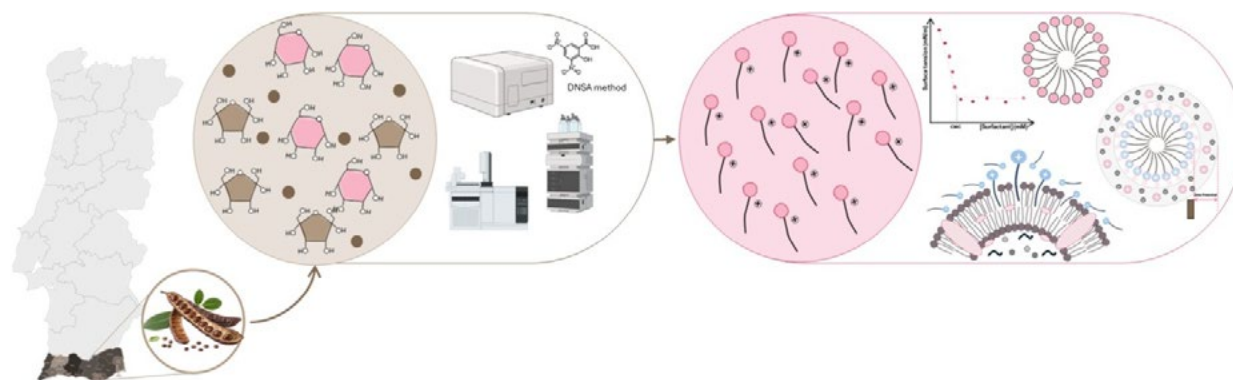


Figure 1. Synthesis and characterization path of new carob-derived cationic surfactants.

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Exploring Colloidal Kinetics Using Dynamic Light Scattering

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Colloidal systems undergo time-dependent transformations such as aggregation, dissociation, gelation, and phase separation, where mechanistic insight depends on resolving transient states on experimentally relevant timescales. Dynamic Light Scattering (DLS) is widely used for particle sizing, yet conventional single-angle, or sequential goniometer-based measurements can be difficult to interpret during non-equilibrium processes, particularly in the presence of intermittent contaminants, rare scattering bursts, or evolving heterogeneity that distorts correlation functions and compromises reproducibility [1-2].

This presentation introduces a real-time methodology for probing colloidal kinetics using DLScat (Swabian Instruments). The approach combines high-temporal-resolution correlation analysis with improved robustness against non-ideal measurement conditions. Simultaneous multi-angle detection (up to five scattering angles) provides internal consistency checks during time-resolved experiments and supports discrimination between genuine kinetic evolution and angle-dependent artifacts. In parallel, an adaptive spike-filtering algorithm suppresses transient scattering events in real time, reducing their influence on the estimated correlation function and enabling continuous tracking of dynamic changes.

Representative applications will be discussed, including salt-induced aggregation, protein self-association, and incipient gelation, in which the technique captures the evolution of characteristic size scales and polydispersity over time. Overall, our approach extends DLS from a predominantly steady-state sizing tool toward a more reliable platform for quantitative, time-resolved characterization of colloidal kinetics.

Keywords:

Kinetics, multi-angle dynamic light scattering, time-resolved measurements

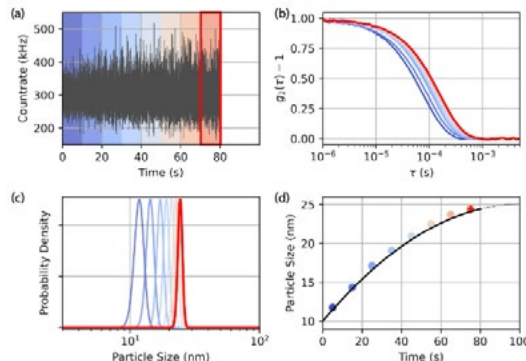


Figure 1. Simulated real-time kinetics from a 100 s DLS measurement, segmented into 10 s intervals and reprocessed. Results are shown in four panels: (a) count rate, (b) intensity autocorrelation function, (c) size distribution, and (d) particle size as a function of time.

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Foaming and emulsifying properties of commercial legume protein isolates as potential egg replacers: A comparative study

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Plant proteins are gaining attention as potential alternatives to egg proteins, yet their functionality in commercially available forms remains insufficiently characterized. This study investigates the foaming and emulsifying properties of commercially processed protein isolates from soy, pea, faba bean, lupin, and lentil, as well as their blends with egg protein ingredients as potential egg replacers. Protein composition, solubility, particle size distribution, and molecular characteristics of all protein sources were determined, followed by evaluation of foaming and emulsifying properties of individual proteins and their blends with egg albumen, egg yolk, and whole egg protein.

Among all the protein sources, faba bean isolate exhibited the highest foam stability, outperforming egg albumen, which was linked to its ability to form small, uniform bubbles and thicker lamellae. In contrast, pea and lentil isolates showed poor solubility and unstable foams, while soy isolate demonstrated relatively high solubility but only moderate foaming performance. Blending plant proteins with egg albumen improved foamability across all samples, with a particularly strong synergistic effect on foam stability observed for the lupin–egg albumen combination. However, blends with whole egg protein resulted in reduced foaming performance, likely due to lipid interference at the air–water interface.

In terms of emulsifying properties, lupin and pea isolates performed comparably to egg yolk, while faba bean showed moderate capacity. Soy and lentil isolates were less effective in emulsifying capacity, likely due to the presence of large aggregates. Blending with egg yolk or whole egg protein enhanced emulsion stability, and mixtures containing pea or lupin proteins reduced droplet flocculation and coalescence compared to egg yolk alone after 56 days of storage.

Overall, these findings emphasize the importance of solubility, composition, and interfacial behavior in determining the functionality of commercial plant protein isolates, which sheds light on how plant proteins can be better utilized in developing sustainable plant–egg ingredients with improved performance.

Keywords:

Plant protein isolates, egg protein ingredients, foaming properties, emulsifying properties, egg protein-plant protein isolate blends



Graphical abstract

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Oleogelation using dried protein particles

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Solid fats, such as palm oil or butter, are important ingredients in food products, as they play an essential role in providing texture and mouthfeel. However, the use of such fats is not desired from a health and sustainability perspective. Liquid oils, extracted from easily accessible oilseeds, are preferred, but oils cannot be used as a structuring and texturising agent in foods due to their liquid nature. Over recent years, research has shown the possibility of structuring liquid oil with protein particles to gain solid properties, these systems are called protein oleogels [1]. Protein oleogels are promising substitutes for solid fats, but the current oleogelation methods, such as the emulsion-templated and solvent exchange method, are indirect and require multiple steps [2]. Depending on the method used, it is also difficult to control the specific properties of the oleogels, as the protein content and structure cannot always be controlled. A simpler and adaptable method is the use of dried protein particles that can be directly dispersed in oil to create protein oleogels. Such a direct method requires a well-flowing particulate powder with small protein particles. When particles are small, more surface area is available for protein-protein interactions, and a more efficient network formation can be obtained. In contrast, when particles are large, as in current protein powders, no 3D protein network can be formed to create a stable protein oleogel. In our work, we explore a novel drying method, aimed at altering the properties and flowability of the obtained dry protein powder. This drying method included different solvents with low polarity, such as isopropanol and hexane, aiming to reduce attractive forces between proteins during the drying process by adjusting the solvent wettability and accompanying capillary forces. We found that the drying solvent affected the protein size, since particle agglomeration was prevented by drying from apolar solvents. The dried protein particles were directly dispersed in oil, resulting in protein oleogels. The stability of the oleogels created using this direct-dispersion method depended not only on the size of the particles, but also on other properties that were influenced by the drying procedure. Using confocal microscopy and rheology, we show the microstructure and properties of oleogels and discuss how the network formed is affected by the drying solvents used. The use of the direct-dispersion method simplifies the process of oleogelation and provides potential to adjust the properties of protein oleogels.

Keywords:

Protein oleogel, oil structuring, protein drying, organic solvents, oscillatory rheology

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Foamed lunar regolith simulant slurries for the in-situ production of porous construction materials

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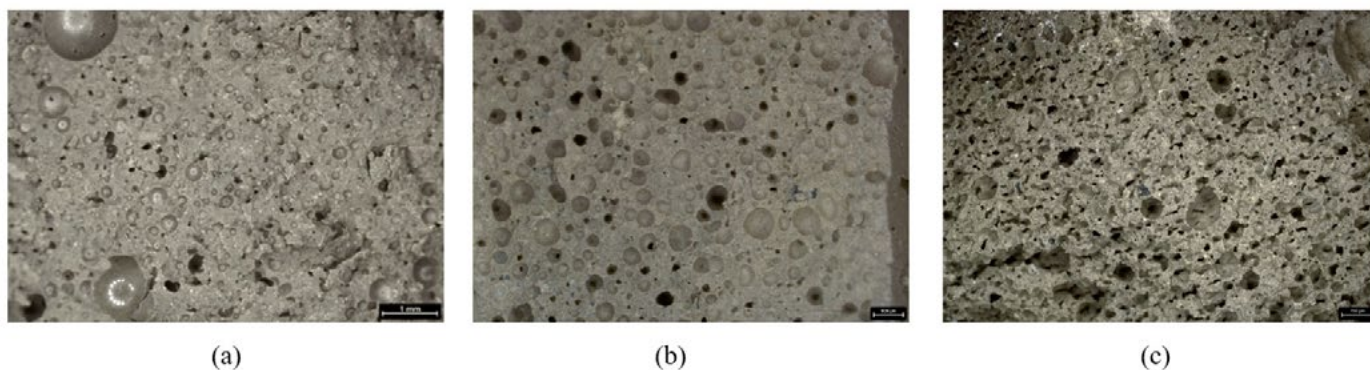
The development of advanced porous materials with tailored functional properties is becoming increasingly relevant in several applied fields, particularly in the context of human space exploration and long-duration space missions. The establishment of sustainable lunar outposts represents a crucial step toward future extra-terrestrial habitats, and it requires the use of local resources according to In Situ Resource Utilization (ISRU) principles in order to minimize the transport of materials from Earth [1].

In this framework, materials designed for lunar construction must be able to withstand extreme environmental conditions, including reduced gravity, severe temperature fluctuations, and continuous exposure to micrometeoroid impacts. This work focuses on the development and optimization of geopolymeric materials based on lunar regolith simulants with controlled porosity, aiming to achieve a balance between thermal insulation performance and mechanical strength [2].

Porosity within geopolymeric systems is introduced through different strategies, such as the use of surfactants and the addition of gas-releasing agents [3]. In particular, surfactant systems are employed to generate and stabilize foams within the slurry and define the final structure, while aluminum powder is used as a chemical foaming agent to produce hydrogen and induce controlled pore formation. The resulting materials can be further processed into structural components using advanced technologies, including additive manufacturing. The overall goal is to develop multifunctional, lightweight, and durable materials suitable for future lunar habitat construction. To this aim, the mechanical properties and morphology of the consolidated samples have been also investigated.

Keywords:

regolith foams, geopolymerization, porous materials



Foamed regolith geopolymer produced using: (a) TTAB foam; (b) aluminum powder; (c) aluminum powder and thickeners.

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Oil foams stabilized by polyglycerol fatty acid esters: Linking bulk self-assembly to interfacial and foaming properties

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Personal cleansing products must balance efficient removal of oily skin contaminants, such as sebum and makeup, with good sensory usability. As modern formulations become increasingly long-lasting and resistant, there is a growing need for systems combining high cleansing efficiency with mildness and pleasant texture. In this context, oil foams are attracting increasing interest for applications in cosmetics, food and pharmaceutical formulations, as they combine the strong solubilizing capacity of oils with the light texture and spreadability of foams [1]. However, oil foams remain poorly understood. Most reported oleofoams rely on crystalline surfactants or particles for stabilization, typically based on sorbitan esters or sucrose esters, often at high concentrations [2,3]. Although recent studies have shown that stable oil foams can also be obtained using molecular surfactants [4], the mechanisms governing foam formation and stability remain largely unclear, particularly regarding the role of surfactant self-assembly in the bulk oil phase and at the air/oil interface.

In this work, we investigate oil foams stabilized by polyglycerol fatty acid esters (PGs), a versatile class of non-ionic surfactants widely used in cosmetic formulations. Their well-defined and tunable chemical structure enables a systematic investigation of the relationship between molecular architecture and foaming properties. In particular, key structural parameters such as alkyl chain length, degree of unsaturation, and headgroup size can be independently varied.

A multiscale experimental approach is employed to elucidate the stabilization mechanisms of oil foams. Bulk self-assembly and phase behavior are characterized by small-angle X-ray scattering as a function of temperature, oil composition and surfactant structure. These results are correlated with interfacial properties probed by surface tension measurements and X-ray reflectivity, as well as with thin film stability and interfacial rheology. Finally, macroscopic foaming tests are performed to establish structure-property relationships across scales.

Our results reveal strongly contrasted foaming behaviors depending on both the oil phase and the chemical structure of the PGs. Foam formation and stability are shown to be directly governed by the nature of the surfactant self-assemblies present in the bulk oil phase, which are highly sensitive to oil composition. In particular, the size of the polyglycerol headgroup emerges as a key parameter controlling self-assembly pathways, interfacial mechanical properties and ultimately foaming performance. This work provides new insights into the rational design of oil foams and highlights the central role of bulk self-assembly in non-aqueous foaming systems.

Keywords:

Oil foams, Polyglycerol fatty acid esters, Nonionic surfactants, Bulk self-assembly

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Conductive Polymer Shell Formation in Gold–Polythiophene Hybrid Nanoparticles for Sinter-Free Printed Conductors

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Colloidal metal nanoparticle inks are widely used in printed electronics.[1,2] Many require high-temperature (>150 °C) post-treatments to reduce contact resistance and achieve sufficient electrical conductivity, limiting compatibility with flexible substrates.[3] Conductive ligand shells offer an alternative by enabling charge transport without sintering.[4] However, their formation is complex and strongly influences conductivity.[5,6] This work focuses on the pH-controlled formation of conductive polythiophene shells via ligand exchange and its impact on interfacial properties. We investigate the effect of pH on the exchange of cetyltrimethylammonium bromide (CTAB) on gold nanoparticles (60–75 nm) with the conductive polythiophene poly[3-(potassium-6-hexanoate)thiophene-2,5-diyl] (P3KHT), emphasizing the role of polymer conformation. Dynamic and static light scattering (DLS/SLS) and UV–Vis spectroscopy show that pH-dependent conformational changes critically affect colloidal stability and ligand exchange efficiency. At pH < 9, reduced electrostatic repulsion induces aggregation, hindering controlled shell formation. Raman spectroscopy indicates enhanced Au–P3KHT interactions under alkaline conditions, reflected by an increased Au–S/Au–Br peak ratio, consistent with improved polymer binding and surfactant displacement. The addition of 20 mM NaCl further facilitates CTAB removal by screening electrostatic barriers. X-ray photoelectron spectroscopy (XPS) reveals new S2p components at lower binding energies above pH 11, indicating stronger polymer–gold interactions. Preliminary electrical characterization shows enhanced conductivity for samples prepared under alkaline conditions ($\sigma = 6.1\text{--}9.5 \times 10^4 \text{ S m}^{-1}$), demonstrating suitability for sinter-free conductive inkjet inks.

Keywords:

Hybrid nanoparticles, gold ink, polythiophenes

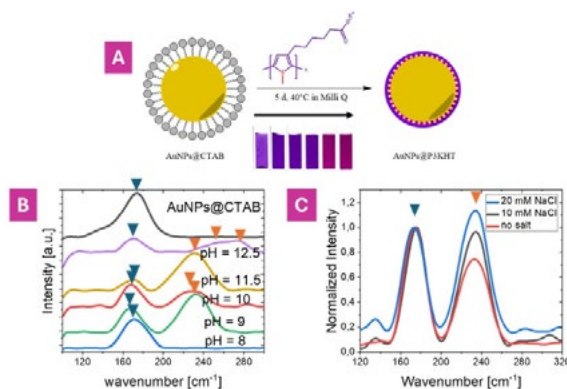


Figure 1: (A) Replacement of CTAB with P3KHT over ligand exchange in Milli Q at various pH. (B) Raman spectra of dry films of AuNPs@P3KHT after ligand exchange in different pH. (C) Raman spectra of AuNPs@P3KHT at pH 10.8 with different salt concentrations.

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Colloidal and Interfacial Effects of Impurities in Supercritical CO₂: Implications for Corrosion in CO₂ Dense Phase Pipelines (Carbon Capture and Storage)

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Carbon Capture and Storage (CCS) is being implemented at a large scale to mitigate the impact of CO₂ emissions on the climate. Currently, capital-intensive projects are being developed to capture CO₂ from major industrial emitters, transport it in dense-phase state, and store it in geological formations. However, impurities such as SO_x, NO_x, O₂, H₂O, and H₂S tend to react chemically [1] and produce small acidic droplets, potentially leading to severe corrosion issues in transport infrastructure.

To understand the colloidal aspects of the corrosion process, as a first step, we replaced CO₂ with surrogate solvents—benzene and tert-butylbenzene—possessing similar dielectric properties to CO₂ while conducting experiments at atmospheric pressure. Concentrated aqueous acid solutions at different concentrations were studied. The adsorption behaviour of ions and oxidation products at the water/oil interface was followed in time using profile analysis tensiometry. It was concluded that H⁺ behaviour at this interface is different from any other adsorbing ion [2]: it is the only sticky ion to adsorb less on water/oil than on water/air, and shows peculiar temperature dependence. The difference in the anion results in HNO₃ adsorbing on water/benzene interface, HCl has zero adsorption, whereas H₂SO₄ desorbs.

The coalescence stability of droplets was evaluated using the thin liquid film technique with the Scheludko-Exerowa cell, while their attachment to the pipeline walls was assessed by contact angle measurements and a modified cell for wetting films (water/oil/metal). Main outcomes from this study can be summarized as follows: (1) sulfuric acid–water droplets coalesce rapidly upon encounter in benzene and tert-butylbenzene, without an energy barrier; (2) the droplet interfaces are not sufficiently immobilized by Marangoni effects to slow down film drainage. Hence, the charging of the surface by ions such as H⁺, HSO₄[−], and NO₃[−] are not sufficient to stabilize the emulsion. As a next step, we plan to study the effects of organic impurities, either naturally present in CO₂ stream or introduced as additives, on emulsion stabilization and corrosion mitigation.

Keywords:

Carbon Capture and Storage (CCS), thin liquid films, adsorption, coalescence, corrosion.

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Microfluidic Formation of Lignin Nanoparticles: Influence of Processing Parameters on Colloidal Properties for Cosmetic Applications

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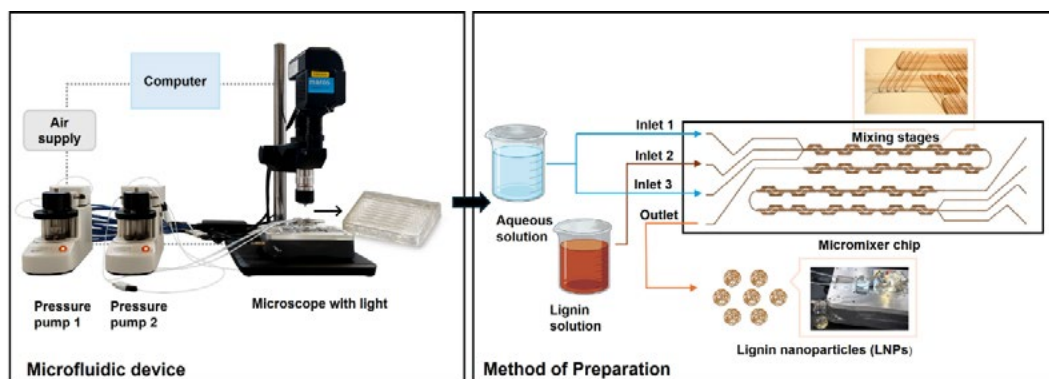
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The increasing demand for safe, sustainable, and high-performance ingredients in cosmetic formulations has intensified interest in bio-based nanomaterials. Lignin is a naturally abundant aromatic biopolymer with intrinsic multifunctional protective properties, including antioxidant and UV-absorbing potential for advanced skin care applications. In this work, lignin nanoparticles (LNPs) were synthesized from kraft lignin and its hydrophobically modified derivative using microfluidic technology to achieve precise control over particle formation. The influence of lignin molecular structure, concentration, solvent system, and flow-rate ratios on particle size, surface charge, and morphology was investigated using dynamic light scattering (DLS) and transmission electron microscopy (TEM). Optimized microfluidic conditions enabled the production of spherical, monodisperse nanoparticles with tunable sizes suitable for topical delivery. The functional performance of LNPs was evaluated through cosmetic-relevant assays, including antioxidant capacity, photoprotective potential, thermal stability, and encapsulation efficiency of lipophilic vitamins such as tocopherol. The release behavior of encapsulated active and its skin penetration potential were investigated using in vitro diffusion methods. The results highlight the potential of LNPs as safe and multifunctional nanocarriers for skin care formulations and sustainable alternatives to conventional cosmetic nanomaterials. Overall, this work provides a versatile microfluidic platform for the design and optimization of lignin-based nanocarriers and advances their application in next-generation skin care systems.

Keywords:

Lignin nanoparticles, lignin for cosmetics, microfluidics, nanoparticle size control



Preparation of Lignin Nanoparticles

Development of interfacial models to understand preservation through Neutron Reflection

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Evidence of humans using preservation techniques spans over 100,000 years, from the first evidence of wood polishing 750,000 years ago to use of beeswax as an antimicrobial in cosmetics ancient Rome [1,2]. However since the widespread acceptance of germ theory we have seen vast advances in preservative technology including chemical synthesis and refrigeration. Preservation is vital today for the prevention of disease and protection of human health but also to reduce production waste or recalls, which present both environmental and industrial costs. Despite the widespread use and importance of chemical preservatives today very little is known about the mechanisms of action on molecular scales, which is key preservative development and understanding risk.

In this work we study phenoxyethanol (PE), which is the most widespread preservative used in personal care products today. PE has been shown to cause some cytoplasmic leakage in bacteria, but this study has been the first to directly structural and mechanical changes induced at the membrane interface [3]. Safety and environmental concerns have encouraged development of boosting molecules, which show no efficacy alone, to work synergistically with PE enabling reduced concentrations in products. These include propylene glycol monocaprylate (PGMC).

This work has been an interdisciplinary study teasing out biocidal mechanisms of PE and PE+PGMC mixtures. These include microbiology work demonstrating improvement in PE efficacy against *E. coli* under addition of PGMC, and increased membrane depolarisation and leakage (Fig 1. A,B,C). Rheological study using the Langmuir Trough with phospholipid monolayer models of gram-negative bacteria inner membranes revealed PGMC creates a more elastic membrane enabling easier incorporation of PE and under mixture membrane become more rigid and easier to rupture (Fig .1 D). Neutron Reflection techniques using same membrane model directly observe the structural changes to model membranes revealing PE and more significantly PE+PGMC cause lipid loss from monolayer and PGMC causes PE retention under pressure fluctuations (Fig 1. E,F). We have also performed molecular dynamics simulations to tease out more details from this neutron work. Much work has been done to explore effects of antibiotic drugs on model microbe membranes using neutron techniques however this is the first work to explore the effects of preservatives, demonstrating neutron techniques as a very powerful tool in preservative science [4].

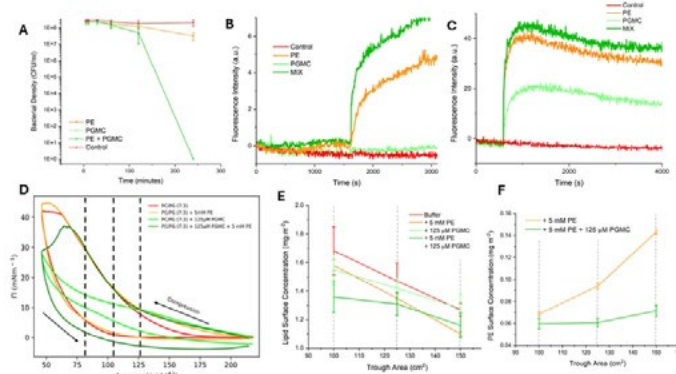


Fig 1. A. *E. coli* Dynamic killing B. *E. coli* NPN Uptake C. *E. coli* Membrane Depolarization (DiSC3) D. Langmuir Isotherms E,F. Surface Concentrations from Neutron Fitting

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To gel or not to gel? A curious case of molecular self-assembly in deep eutectic solvents

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Deep Eutectic Solvents (DES) are binary mixtures of a hydrogen bond donor (HBD) and a hydrogen bond acceptor (HBA), with a eutectic point (melting point) significantly lower (by around 100°C) than that of either components [1]. One of the main features of these hydrogen-bond rich non-aqueous media is the possibility to support amphiphile self-assembly [2-4]. However, different aspects of molecular self-assembly in DES are yet to be fully understood [2-4].

We have investigated the (surprising) role of the counter-ions in the self-assembly of a series of alkyltrimethylammonium surfactants – with either bromide (Br^-) or chloride (Cl^-) as counterions – in the DES choline chloride:glycerol (1:2) and compared the self-assembled nanostructures of the same surfactants in glycerol. We observed the formation of a gel of the chloride-counterion surfactants in DES, but *not* in glycerol. Vice versa, the bromide-counterion surfactants showed the tendency to form gels in glycerol, but *not* in DES. This peculiar observation was corroborated by the analysis of the birefringent textures observed by polarised light microscopy (PLM) and the viscoelastic response measured by rheology. Most importantly, small-angle neutron scattering (SANS) experiments unveiled the nanoscale organisation and its correlation with the bulk behaviour of the aggregated structures, showing clear differences in the size and shape of the surfactant aggregates in glycerol and in the choline chloride:glycerol DES. Collectively, these results demonstrate an interconnection between the solvent structure, the counter-ion identity, and surfactant self-assembly, opening new perspectives in tuning the properties of self-assembled materials within DES.

Keywords:

deep eutectic solvents, surfactant self-assembly, counterion effects, gelation, small-angle neutron scattering

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New and Original Strategies for Environmentally Friendly Solvent Media without Surfactants

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Surfactants are the matter of choice when hydrophobic, poorly water-soluble substances must be solubilised in or at least made compatible with an aqueous phase. However, surfactants can have some drawbacks, e.g., they may remain on surfaces or in the final product, induce or stabilise foaming, be environmentally undesirable etc. Then hydrotropes may do the job. Hydrotropes are small amphiphilic molecules that can also solubilise hydrophobic chemicals in water, however often at concentrations much higher than those of surfactants.

Nevertheless, they can have various advantages and hence are widely used in industry either as single solubilisers or in combination with surfactants.

We recently found that classical, healthy and even cheap natural oxidants can play the role of such hydrotropes. Further, they can even significantly enhance the solubility of molecules that are poorly soluble in water, not because they are oily, but rather because they tend to stack, e.g. indigo, caffeine, or several pesticides and pharmaceutical substances.

In this contribution, I will show various examples of such hydrotropes (and also solvotropes that solubilise molecules in oily environments) and their advantages in formulation. In this context, I will also discuss surfactant-free microemulsions and the value of the concept of so-called Natural Deep Eutectic Solvents that can be applied in an original way to fulfil the duty of enhancing solubilities.

Keywords:

Hydrotropes, Solubilisation, surfactant-free microemulsions, polyphenols

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Colloidal Polymer Nanoparticles for Heterogeneous Asymmetric Organocatalysis and Transition Metal Catalysis

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Embedding catalytically active organic and organometallic functionalities into polymer nanoparticles is a promising strategy for the design of efficient and sustainable heterogeneous catalysts. Functional polymer supports can enhance catalytic performance by improving access to active sites while increasing structural stability. In this context, miniemulsion polymerization provides a versatile and efficient route to nanoparticles with well-controlled size, morphology, and high specific surface area, all of which are key parameters governing catalytic activity. [1].

In this work, polymer nanoparticles were synthesized via miniemulsion polymerization and subsequently functionalized with a range of catalytic ligands, including proline derivatives, Schiff-base metal complexes, and xanthene-based fluorophores. The synthetic approach is based on the copolymerization of a structural monomer (typically styrene or methyl methacrylate) with a catalytically active functional comonomer. For proline-based systems, tailor-made polymerizable comonomers bearing the catalytic moiety were synthesized and incorporated into the polymer matrix [2]. An analogous strategy was applied to Schiff-base systems, where the ligand was coordinated to Mn(III) prior to polymerization. In the case of xanthene-based catalysts, rhodamine B was functionalized with 2-hydroxyethyl methacrylate (HEMA) via Steglich esterification to obtain a polymerizable ester derivative. The corresponding nanoparticles were prepared from styrene, divinylbenzene, and the rhodamine-derived comonomer.

After synthesis and functionalization, the nanoparticles were assessed in a set of representative model reactions to determine their catalytic performance. Proline-functionalized nanoparticles showed high diastereoselectivity in the intermolecular aldol reaction between *p*-nitrobenzaldehyde and cyclohexanone in aqueous media. Schiff-base systems also displayed efficient catalytic activity in the asymmetric epoxidation of styrene and indene, with reaction kinetics followed by chiral chromatography. In all cases, substrate conversions exceeded 90%, while the more sterically hindered catalysts afforded the highest selectivity and yields above 99% after 24 h. Additionally, xanthene-containing nanoparticles proved highly effective as photocatalysts in the dehalogenation of meso-1,2-dibromo-1,2-diphenylene.

An important advantage of these colloidal catalytic systems is their easy separation and recyclability, which underscores their strong potential for sustainable catalytic applications.

Keywords:

miniemulsion, colloid, asymmetric catalysis, nanoparticle

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Acknowledgements:

We acknowledge financial support from the Generalitat Valenciana (Consolidated Group Grant No. CIAICO/2023/172 and MFA/2022/064) and from the Ministry of Science and Innovation of Spain (Grant No. PID2023-152347OB-I00).

Lateral Equations of State of Surfactants at Interfaces: A Multiscale Perspective

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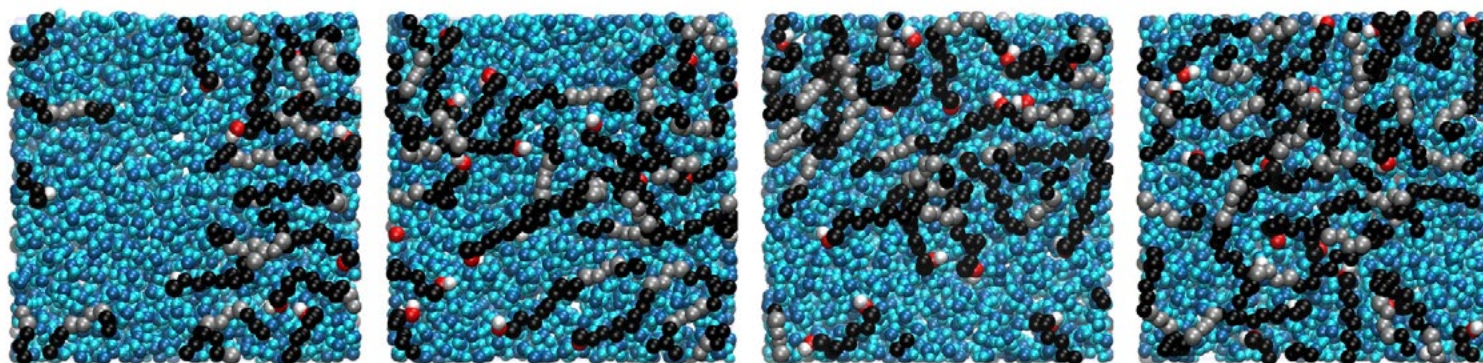
Surfactant molecules are commonly characterized by their lateral equation of state, which encodes the thermodynamic properties of the interface onto which they adsorb. This concept underpins a wide range of applications. For instance, the critical micelle concentration (CMC) of amphiphilic molecules in solution can be inferred from surface tension measurements. However, the underlying physics is intrinsically complex, as it involves the interplay between two coupled equations of state: one in the bulk phase, governing intermolecular interactions, and another at the interface, where competing attractive and repulsive surface interactions may arise. As a result, extracting unambiguous macroscopic properties from experimental observables remains challenging. For example, a plateau in surface tension may reflect either micelle formation in the bulk or saturation of the interface.

To address these issues, we perform classical molecular dynamics simulations within a multiscale framework to determine lateral equations of state as accurately as possible in representative systems. In the context of solvent ¹ extraction, the adsorption of a diamide extractant at the liquid–liquid interface is characterized in detail, revealing its coupling to aggregation processes in the organic phase. We also investigate bombykol, an amphiphilic pheromone ² potentially present at aerosol surfaces, to elucidate how interfacial behavior may influence long-range insect communication. Additional applications related to flotation ³ processes are currently under investigation.

Our results highlight that, whenever interfacial concentrations cannot be directly measured, the apparent lateral equation of state reflects a subtle balance between bulk and interfacial equilibria. This coupling complicates the interpretation of surface tension data alone, as distinct physical mechanisms—including interfacial phase transitions—may produce similar signatures. More broadly, this multiscale approach, combining colloid and interface theory with molecular simulation, provides a unified framework in which seemingly puzzling phenomena emerge as natural consequences of underlying thermodynamic constraints. For example, the frequently observed synergy in extractant mixtures can be rationalized by an increase in configurational entropy, while abrupt changes in surface tension may be interpreted as signatures of frustration effects within interfacial assemblies.

Keywords:

Surfactant, equation of state, surface tension, aggregation, saturation, molecular dynamics, pheromones, solvent extraction



Molecular Dynamics Simulations of Bombykol at the Air–Water Interface

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Stepwise Self-Assembly monolayer of Sodium Oleate on (111) Fluorite: Insights from Molecular Dynamics Simulations

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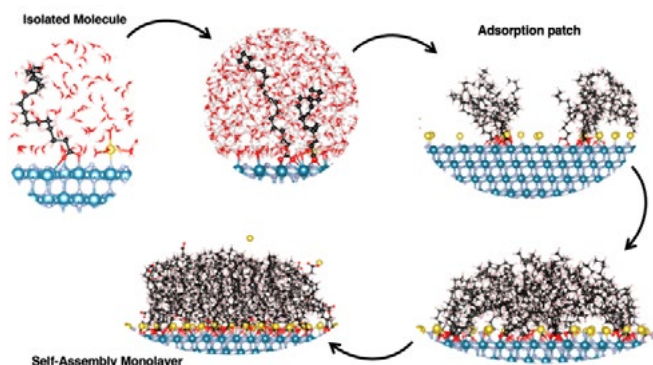
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Fluorite (CaF_2), the main natural source of hydrofluoric acid, is commonly purified by froth flotation using fatty acids as collectors and can be considered as the main representative of the calcium-bearing sparingly-soluble minerals [1,2]. The molecular origins of collector adsorption, intermolecular organization, and hydrophobization at the calcium-bearing minerals-water interface remain poorly resolved. Here, classical molecular dynamics simulations are used to uncover how sodium oleate adsorbs and self-organizes on hydrated fluorite (111) surfaces, from a single molecule to a full monolayer coverage. Benchmarking against previous DFT and AIMD results [3,4] confirms the reliability of the atomistic model. At low coverage, oleate binds strongly to surface calcium atoms, with adsorption energies around -266 kJ mol^{-1} , a dominant monodentate adsorption mode, and an angle between surface and molecule of 80° , all in line with the literature [5]. As the surface coverage increases, adsorption evolves into a cooperative process in which lateral chain-chain interactions promote the formation of increasingly ordered hydrophobic domains. Near monolayer completion, this competition between surface anchoring and intermolecular self-assembly leads to stable yet heterogeneous adsorption states. Remarkably, the theoretical adsorption thermodynamics show very good agreement with experimental adsorption enthalpies obtained from total organic carbon (TOC) measurements, bridging molecular simulation and experiments. Altogether, the results provide a compelling molecular picture of how collector adsorption and self-assembly control calcium-bearing minerals hydrophobicity, with direct implications for flotation performance and broader significance for interfacial self-organization in mineral processing systems.

Keywords:

Flotation, fatty-acids, self-assembly monolayer, solid-liquid interface



Evolution of the self-assembly monolayer formation.

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Antifoam dynamics of oil droplets in protein-stabilized aqueous thin films

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A drastic reduction in foaming functionality due to the antifoam activity of oil droplets can occur in protein-based foams, such as those generated from milk (analogues), protein extracts, or beer. Oil contents as low as 0.006 wt% caused notable foamability reductions in solutions covering a range of protein concentrations (0.5-1 wt%) [1]. General trends were observed across multiple protein and oil types, with reduced antifoam activity at either very low oil contents or at very high oil and/or protein contents. Dynamic conditions were found to be a prerequisite for antifoam activity in whipping tests, as only foamability and not foam stability was reduced [1]. The dynamic nature of the antifoam activity in protein-based systems was further supported by results showing that differences in susceptibility to antifoam activity across protein types correlate strongly with either adsorption kinetics at short timescales and/or high dilatational interfacial viscoelasticity [2].

Consequently, previously established insights to explain antifoam activity based on equilibrium surface tension values do not adequately describe the observed dynamics protein-based systems [3,4]. Instead, protein adsorption kinetics, the strength of the viscoelastic interfacial network and disjoining pressure between interfaces govern observed antifoam trends in protein-based foams. At 1 wt% protein, thin films with and without oil droplets are extremely stable in quasi-static tests at both small and large applied pressures. Only in dynamic tests with extreme thin film radius expansion rates (i.e. large pressure steps), increased rates of oil droplet entrainment and subsequent antifoam activity were observed, substantiating the dynamic nature of the antifoam effect in protein-based systems.

In conclusion, the unique dynamic nature of antifoam activity in protein-based foams was related to adsorption kinetics and viscoelastic interfaces, which is different from most of the previously established antifoam principles relevant to low-molecular-weight surfactants. Furthermore, the novel use of the thin film balance instrument granted new insights into those antifoam dynamics on the scale of a thin film, substantiating the dynamic nature of antifoam activity in protein-based foams.

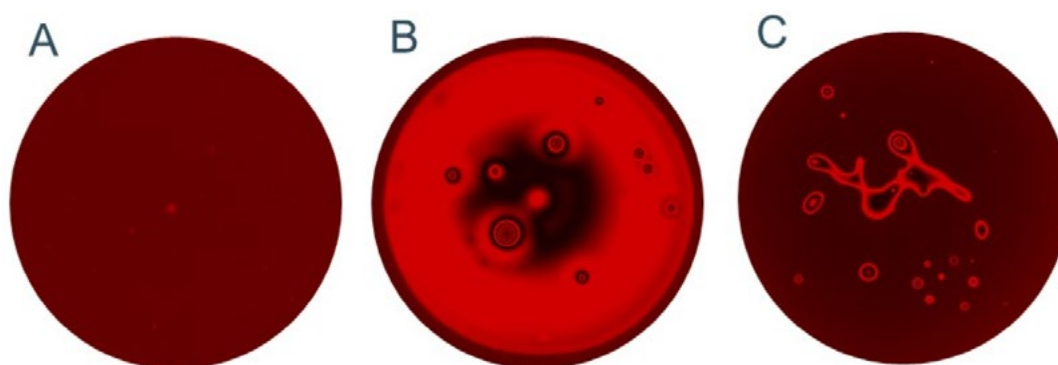


Figure 1: A: 10 minute old thin film with no entrained oil droplets at 1 wt% potato patatin protein, B: 10 second old thin film with entrained oil droplets at 1 wt% potato patatin protein, C: 10 minute old thin film with entrained oil droplets at 1 wt% potato patatin protein

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On the Calcium Binding Mechanisms of Acacia Gums (senegal and seyal): importance of solvation in the binding process

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The pronounced Ca^{2+} -binding capacity of acacia gum leads to both desirable and undesirable attributes in food applications, underscoring the need to understand its binding mechanism. We quantitatively characterized interactions between Ca^{2+} and demineralized *A. senegal* and *A. seyal* gums using dual-electrode potentiometric titration, isothermal titration calorimetry (ITC), and quartz crystal microbalance with dissipation (QCM-D). Potentiometric titration revealed clear pH dependence, with maximal Ca^{2+} binding capacities of 12.7 and 13.4 $\text{mg}\cdot\text{g}^{-1}$ at pH 7.0 (approximately one Ca^{2+} per two carboxyl groups) for *A. senegal* and *A. seyal*, respectively, and steadily decreasing binding toward pH 3.0. Ca^{2+} association triggered pronounced proton release at pH 5.0, due to binding-induced reductions in the pK_{obs} of glucuronic acids (GlcA). ITC showed moderate binding affinities (K_a in the range of 10^3 - 10^4 M^{-1}) and positive apparent enthalpies (ΔH_{obs}), possibly indicating entropy-driven dehydration that masks intrinsic exothermic complexation. ΔH_{obs} of *A. senegal* was significantly higher than that of *A. seyal* due to their distinct GlcA and/or 4-O-Me-GlcA profiles. Measurements at lower pH and across buffers demonstrated that ΔH_{obs} variations were governed by proton exchange and buffer protonation enthalpy rather than purely electrostatic attraction. Despite the large amount of bound Ca^{2+} , few inter-macromolecular associations of Acacia gums were observed upon Ca^{2+} binding. The results provide new insights into the formulation design of Acacia gum, as well as into the physicochemical basis of cation association in plant AGPs.

Investigations on the behavior of Thermo-responsive Block copolymers in Natural Deep Eutectic Solvents (NADES)

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Natural deep eutectic solvents (NADES) are a novel class of polar solvents that has the potential to become a non-toxic and cheap alternative to conventional organic solvents and ionic liquids. Amphiphilic self-assembly is very a well-established phenomenon for solutions of surfactants or amphiphilic polymers in water, allowing to functionalize them. ¹ Structure formation by surfactants in DES has been studied to some extent, ² but the solubility of polymers and in particular self-assembly of amphiphilic polymers is a topic that has been addressed to a very limited extent. ³

Guided by extensive solubility assessments of various homopolymers, we have recently developed a system of the copolymer poly(acrylamide)-b-poly(N,N-dimethylacrylamide) (PAm-b-PDMAm), which self-assembles in the NADES Reline in a thermo-responsive way, leading to marked self-assembly at higher temperatures (Fig. 1 a). The copolymer exhibits enhanced viscosity and shear-thinning in Reline (Fig. 1 b), which can be tuned by adjusting block lengths, offering a means to control NADES properties.

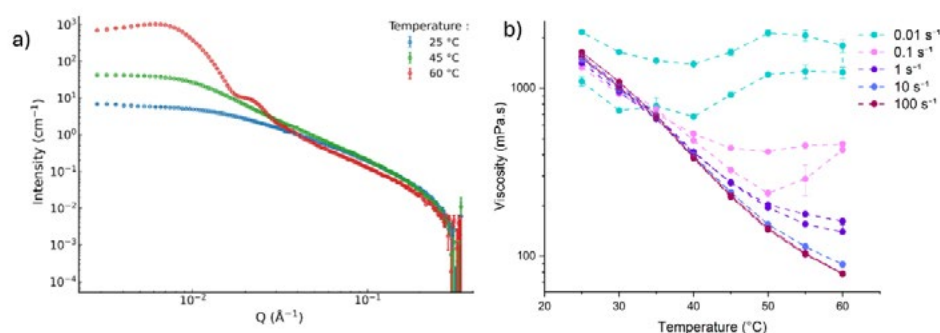


Fig. 1 (a) SANS profiles of PAm200-b-PDMAm300 (5% w/w) in Reline at 25 °C, 45 °C, and 60 °C. (b) Temperature-dependent viscosity of PAm200-b-PDMAm300 (5% w/w) in Reline at different shear rates.

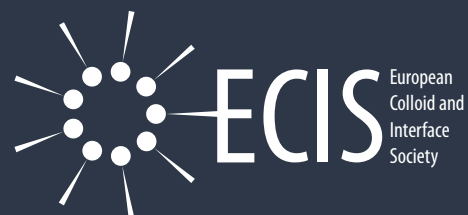
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Topic 3

Colloids at Interfaces, Membranes,
Films, Emulsions, and Foams

KEYNOTE



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Role of interfacial interactions in unlocking the full potential of plant-based nanomaterials

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Plant biomass-based nanoparticles, like nanocellulose and lignin nanoparticles, hold great potential for the development of lightweight, functional, biodegradable, and/or recyclable material solutions for a sustainable circular bioeconomy. However, to obtain optimal properties of the nanoparticles and materials made thereof, it is crucial to control the interactions both during particle production and in applications [1]. Herein we will focus on lignin, abundantly available as side streams from pulp industry and biorefineries, and nanoparticles made thereof (LNPs). Due to their nano-scale morphology and well-defined surface characteristics LNPs can introduce better processability, compatibility, functionality or stability compared to other forms of lignin. Furthermore, the spherical morphology and tunable size enable applications in totally new fields for example drug delivery or cosmetics [1]. However, owing to the heterogeneous and complex structure of lignin, its self-assembly mechanism and interactions remain unclear. In this presentation we will shed some light on these interactions and how they drive both the nanoparticle self-assembly as well as can be utilized in applications. Furthermore, we will show the synergistic effects of spherical LNPs and cellulose nanofibrils for emulsion stabilization and how this can be used to design strong, yet biodegradable composites [2] and biobased barriers [3]. We will also demonstrate how brown lignin can be turned into superhydrophilic, transparent colorless antifogging coatings by using modified LNPs [4] (Figure 1). These examples will reveal how controlling interfacial interactions enable attaining surface functionalities while retaining biodegradability and recyclability of the biobased materials. This approach contrasts with modifications depending on direct chemical modification or addition of synthetic materials.

Keywords:

lignin nanoparticles, Pickering emulsions, functional coatings



Fig.1 The figure shows application of LNPs; LNP and nanocellulose stabilized Pickering emulsion droplet, water resistant, yet biodegradable nanocomposite film and superhydrophilic antifogging coating.

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When nano-ions bind to microgels: from intra- to inter-cross-linking in suspension and at interfaces

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Microgels are colloidal particles made of swollen polymeric network, whose softness imparts many original properties both in suspension and at interfaces. In particular, poly(N-isopropylacrylamide) (pNIPAM) microgels adsorb at fluid interfaces and were found to stabilize Pickering emulsions and foams. ^[1] The stabilization effect is directly linked to their deformability at the interface, which has consequences on the interfacial elasticity of the drop surface. ^[2] Nanometric anions such as boron clusters and polyoxometalates (POMs) having a low charge density, belong to the class of superchaotropic ions, being prone to dehydration and coassembly with non-ionic systems. In particular, POMs were found to interact with pNIPAM polymers. ^[3] In the present work, we are delving into the interactions between POMs and pNIPAM microgels, investigating 1) how microgel structure impacts the association constant between polymers and nanoions, 2) how these interactions impact the microgel softness and thus, their interfacial behavior in emulsions. The concept is summarized in Figure 1. Interestingly, microgels could efficiently capture nanoions in the μM range, 3 orders of magnitude below the linear homologs. These nanoions act as internal physical cross-linkers and alter microgel softness. Moreover, they also create additional and reversible cross-linking effects between the microgels. Depending on the type of microgels and the pathway, the stability of microgel-stabilized emulsions could be enhanced or weakened ^[4].

Keywords:

Microgel, Nano-ion, Superchaotropic, Emulsion, Pickering

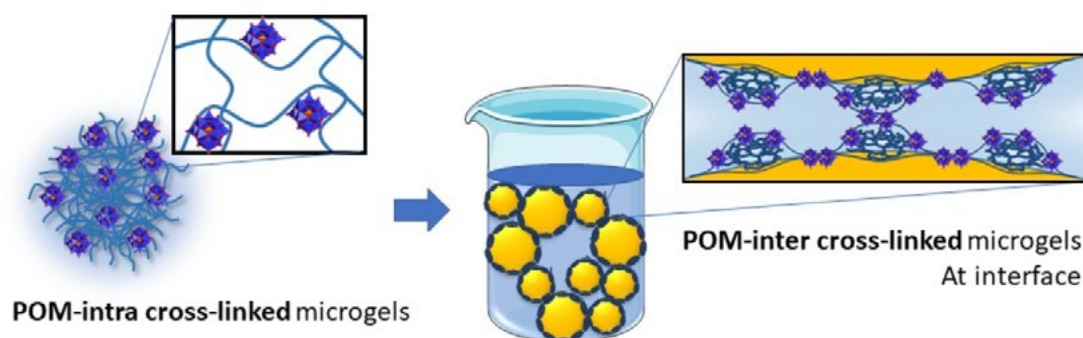


Figure 1. Scheme of a POM-cross-linked PNIPAM microgel (left) and inter-cross-linked microgels adsorbed at the oil-water interface of droplets in an emulsion (right).

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When Alcohols Break the Rules: Nonmonotonic Forces in Soft Membrane Stacks

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How do small solutes reshape interfacial forces in soft matter? Using lipid multilamellar vesicles, we show that short-chain alcohols drive membrane interactions beyond classical expectations. Combined SAXS and molecular dynamics reveal distinct responses: methanol induces continuous swelling and unbinding, whereas ethanol produces a striking nonmonotonic behavior, with collapse following initial swelling.

These trends violate standard free-energy-minimum descriptions. We show that, in the soft highly fluctuating regime, membrane spacing is governed by the full distribution of fluctuations rather than the free-energy minimum. While this resolves swelling, the ethanol-induced collapse points to additional interfacial stresses linked to solute partitioning and modified fluctuation forces.

These findings highlight how subtle interfacial chemistry can qualitatively reshape collective forces in soft assemblies.

Minimal Peptide Sequences That Undergo Liquid–Liquid Phase Separation via Self-Coacervation or Complex Coacervation with ATP

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The simple (self-)coacervation of the minimal tryptophan/ arginine peptide sequences W_2R_2 and W_3R_3 was observed in salt-free aqueous solution [1]. The phase diagrams were mapped using turbidimetry and optical microscopy, and the coacervate droplets were imaged using confocal microscopy complemented by cryo-TEM to image smaller droplets. The droplet size distribution and stability were probed using dynamic light scattering, and the droplet surface potential was obtained from zeta potential measurements. SAXS was used to elucidate the structure within the coacervate droplets, and circular dichroism spectroscopy was used to probe the conformation of the peptides, a characteristic signature for cation– π interactions being present under conditions of coacervation. These observations were rationalized using a simple model for the Rayleigh stability of charged coacervate droplets, along with atomistic molecular dynamics simulations which provide insight into stabilizing π – π stacking interactions of tryptophan as well as arginine–tryptophan cation– π interactions (which modulate the charge of the tryptophan π -electron system). Remarkably, the dipeptide WR did not show simple coacervation under the conditions examined, but complex coacervation was observed in mixtures with ATP (adenosine triphosphate). The electrostatically stabilized coacervation in this case provides a minimal model for peptide/nucleotide membraneless organelle formation. These are among the simplest model peptide systems observed to date able to undergo either simple or complex coacervation and are of future interest as protocell systems.

Keywords:

peptides, coacervates

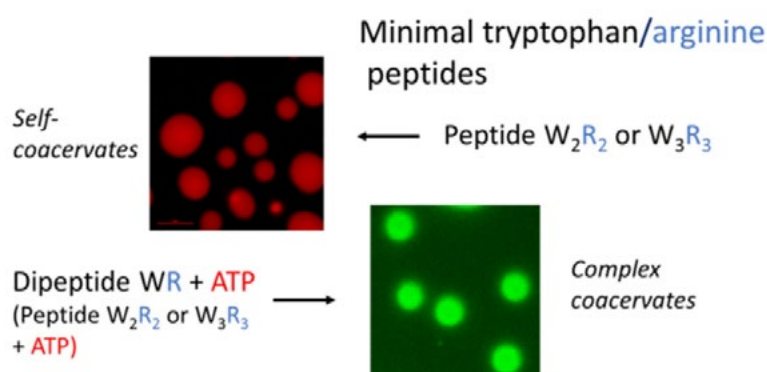


Figure 1. W_2R_2 and W_3R_3 self coacervates and $WR+ATP$ complex coacervates

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When Grains Generate Power: Electro-active Colloidal Interfaces for Triboelectric Energy Harvesting

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²*Institute of Materials and Surface Engineering, Faculty of Materials Science and Applied Chemistry, Riga Technical University*

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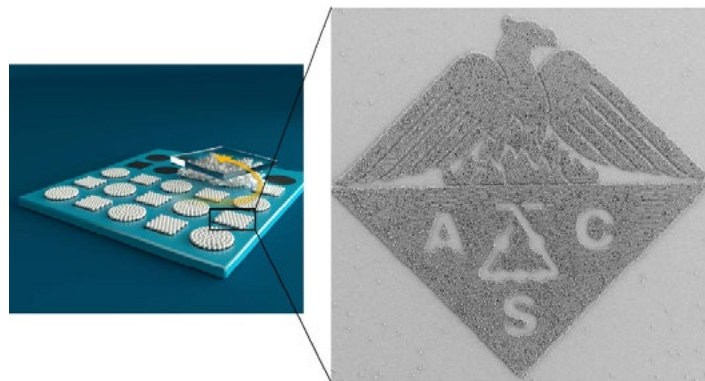
k.sotthewes@utwente.nl

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Electroactive interfaces formed from close-packed colloidal particles provide a novel pathway for designing soft energy-harvesting systems. In this talk, I will show how monolayers of polymer colloids can be rapidly assembled into hexagonally close-packed structures using a simple manual rubbing method with PDMS stamps, yielding well-defined colloidal interfaces on both conductive and insulating substrates [1]. The formation and stability of these assemblies are governed by tribocharging-induced electrostatic interactions, substrate stiffness, and particle–substrate contact mechanics, highlighting the central role of interfacial forces in colloidal ordering.

I will then demonstrate how these ordered colloidal monolayers function as electroactive interfaces in triboelectric nanogenerators (TENGs), where control over particle size, packing geometry, and surface chemistry enables enhanced and tunable energy harvesting [2]. Beyond their role in TENG performance, recent results reveal that close-packed PMMA colloidal interfaces exhibit a strong piezoelectric-like electromechanical response under mechanical loading, despite the absence of intrinsic bulk piezoelectricity [3]. This emergent behavior arises from contact electrification and stress-dependent charge redistribution at interparticle contacts, and can be observed even at the level of a single colloidal interface.

Together, these findings position close-packed colloidal assemblies as a versatile platform linking colloidal self-assembly, interfacial electrostatics, and emergent electromechanical functionality, with implications for energy harvesting, pressure sensing, and soft microsystems.



Self-assembly of colloids using the dry rubbing method

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Long-range interfacial repulsion across aqueous solutions of high ionic strength

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Since colloidal dispersions have a significant importance in our daily life, it is of special interest to get a deeper understanding of which interfacial forces govern their stability and how this stability can be tailored.

For aqueous electrolyte solutions, DLVO theory is a powerful and well-established framework to describe these interactions at low and intermediate ionic strengths. In contrast, the situation at high ionic strength is less understood, and the main methods for direct force measurements give inconsistent results. Whilst the surface force apparatus (SFA) provides clear evidence for a re-entrant behaviour of the repulsion in the highly concentrated regime (termed underscreening) for a wide range of different electrolytes [1], similar observations were not possible with the atomic force microscope (AFM) [2]. In this presentation, we will examine the reasons for these fundamental differences. We will show that approaching the experimental conditions of AFM measurements towards the ones of SFA could lead to similar results with both methods [3]. Specifically, in an attempt to explore experimental screening lengths across a wide suite of electrolyte concentrations, we demonstrate the experimental parameters dominating the occurrence of long-range repulsion: long equilibration times, large contact areas and slow approach velocities. We will discuss the reasons for the controversially discussed phenomenon of long-range repulsion at high ionic strengths.

Keywords:

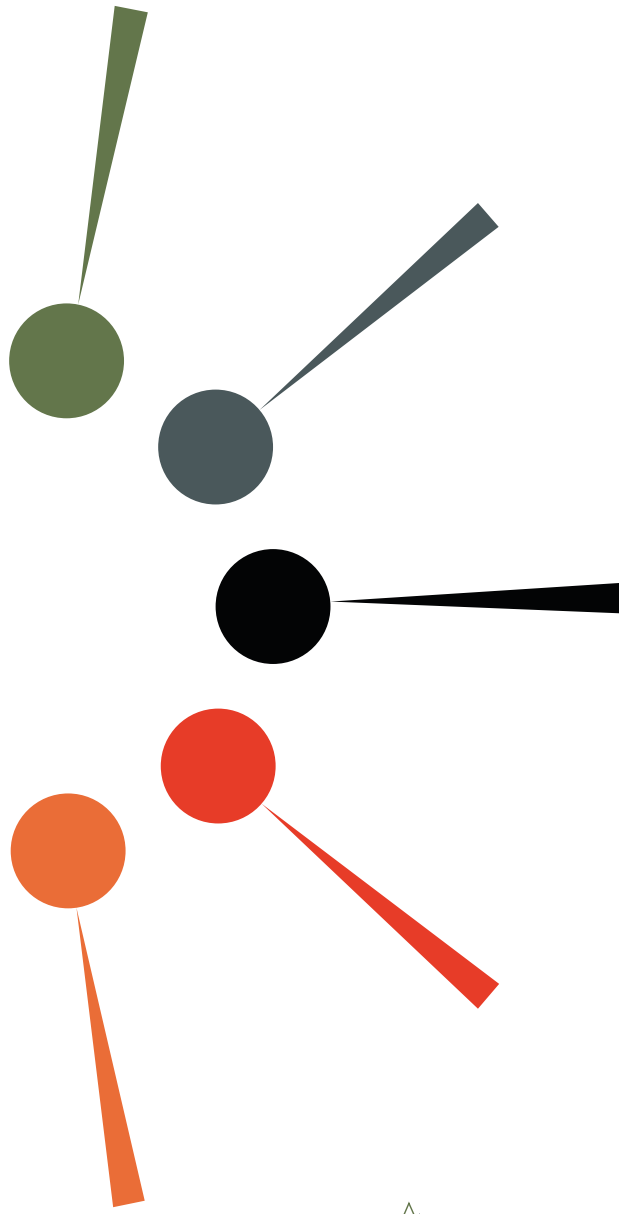
Interfacial forces, Colloidal Probe AFM, long-range electrostatic repulsion, underscreening

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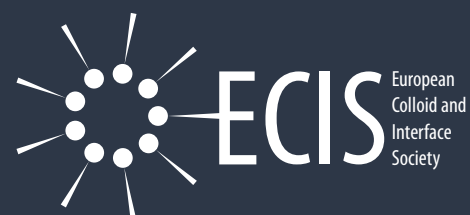
H.R. acknowledges the Alexander von Humboldt foundation.



Topic 3

Colloids at Interfaces, Membranes,
Films, Emulsions, and Foams

! ORAL



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Adhesive Nanoparticles Control Emulsion Properties via Tuneable Interdroplet Linking

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^b Physics and Physical Chemistry of Foods - Wageningen University, Wageningen, Netherlands,

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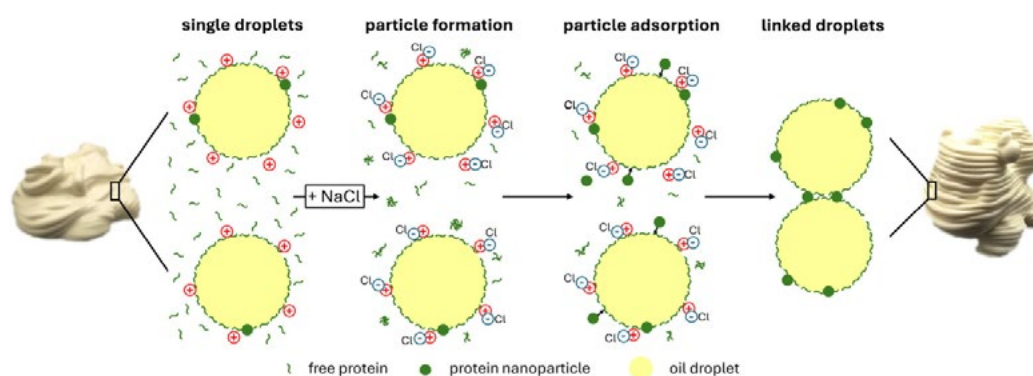
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Mechanical properties of emulsions are determined by the resistance of droplets against shear and, thus, interdroplet links are instrumental in providing emulsions with their desired properties. Here, self-assembled pea protein nanoparticles were probed for their attractive intermolecular interactions in forming interdroplet links. The mechanism for interdroplet linking was deduced by studying their adhesive effect across multiple length scales: nanoparticles adsorbed on a droplet are able to bridge two droplets, given that the two droplets can come into close enough proximity. The proximity requirement for interdroplet linking is easily met in jammed emulsions, or by reducing the electrostatic repulsion between droplets in dilute emulsions. This mechanism for interdroplet linking was validated with a theoretical model which identified bridging interactions in the thin film as crucial for providing the prerequisite adhesion energy. In practice, raising the ionic strength in jammed emulsions ($\phi_{oil} = 0.74$) still grants the emulsion with a moderate increase in G' (1.9 to 4.6 kPa), however, in dilute emulsions ($\phi_{oil} = 0.55$) interdroplet links transform the emulsion from liquid-like into a 3D-printable solid, increasing the G' 100-200 fold to 3.2 kPa. Our results demonstrate how promising protein nanoparticles are for tailoring the mechanical properties of emulsions through tuneable interdroplet linking, which opens the door for 3D-printing emulsions with intricate geometrical designs, like in soft microelectronics.

Keywords:

Adhesive Nanoparticles, Tuneable Droplet Linking, Thin Film Dynamics, 3D Printing, Microfluidics, Interfacial Rheology



Graphical abstract illustrating the mechanism for ion-driven interdroplet linking by protein nanoparticles and its effect on the mechanical strength of the emulsion.

Towards active bijels: Prussian-blue stabilized bicontinuous emulsions as electrode modifiers

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Bicontinuous interfacially jammed emulsion gels (bijels) are a class of soft materials composed of two interpenetrating and immiscible liquid phases arranged in a bicontinuous morphology, generated through spinodal decomposition. Their formation rely on the adsorption of colloidal particles at the liquid–liquid interface, where the particles become jammed and form a mechanically robust barrier between the two continuous domains. This structure is only achieved when the particles exhibit neutral wettability with respect to both liquid phases, thereby preventing preferential partitioning into either phase.

Due to their high interfacial area and interconnected transport pathways, they emerge as a promising platform for the design of functional materials in areas such as catalysis. However, most reported systems employ silica as stabilizing particles, while the use of electroactive nanoparticles remains comparatively unexplored.

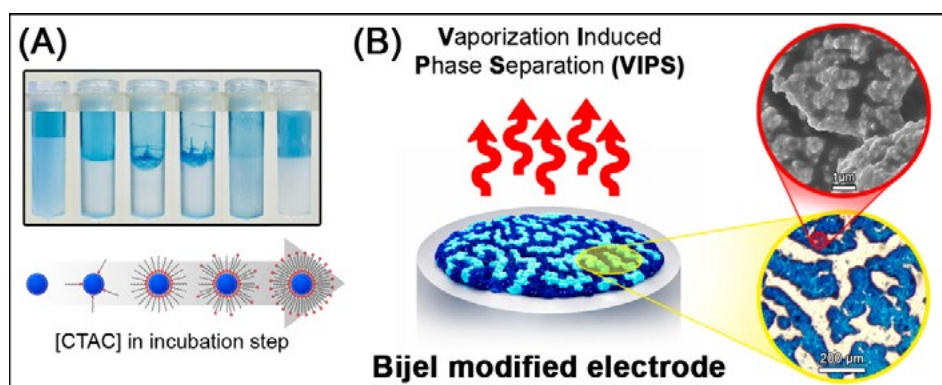
Prussian blue is a mixed valence coordination polymer consisting of Fe(III) and Fe(II) cations interconnected by cyanide bridges within a three-dimensional cubic crystalline lattice. It exhibits well defined electrochemical activity arising from intervalence charge transfer between Fe(II) and Fe(III) centers, which promotes electron transport through the Fe(II)–CN–Fe(III) framework. Under an applied potential, the material undergoes reversible redox interconversions, enabling its use in electroactive and charge transport related applications.

Citrate-stabilized Prussian blue nanoparticles (26 ± 7 nm) were synthesized by direct mixing of iron(III) chloride and potassium hexacyanoferrate(II) in the presence of citric acid at 60 °C and purified by dialysis. Surface hydrophobicity was tuned by incubating the nanoparticles with increasing concentrations of the cationic surfactant cetyltrimethylammonium chloride (CTAC) and the resulting interfacial behavior was assessed by zeta potential measurements and qualitative visual tests. The optimal condition was selected to enable interfacial stabilization of a bicontinuous structure formed between water and 1,6-hexanediol diacrylate through vaporization induced phase separation (VIPS) in a ternary mixture containing ethanol as a compatibilizing solvent.

When drop cast onto planar conductive substrates, the resulting bijel preserves interconnected bicontinuous channels, as confirmed by optical and scanning electron microscopy. These results demonstrate that Prussian blue nanoparticles can act not only as interfacial stabilizers, but also as electroactive building blocks for bicontinuous architectures, opening a route toward bijel based electrode coatings with coupled structural and charge transport functionality.

Keywords:

bijel, bicontinuous emulsion, nanoparticles at interfaces, Prussian blue, surface wettability



(A) Surface wettability modulation of Prussian blue nanoparticles with increasing CTAC content. (B) Bijel structured modified electrode surface fabricated through vaporization induced phase separation (VIPS).

Acknowledgements:

We greatly acknowledge the support from the Institute of Chemistry of the University of São Paulo, its Analytical Center, and São Paulo Research Foundation (FAPESP) (Grant#2024/19156-5).

Understanding the Structure of Bicontinuous, Particle-Stabilised Emulsions

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The stabilisation of emulsions with solid particles has been a cornerstone of soft matter science in recent decades, with particle-decorated droplets (Pickering emulsions) receiving particular attention. Bicontinuous interfacially jammed emulsion gels (bijels) are a natural extension of this concept, yet the rules governing their structure remain not fully understood. This is especially true for bijels formed through solvent-transfer induced phase separation (STrIPS) [1], despite their relevance as template materials for membrane separation [2] and catalysis [3].

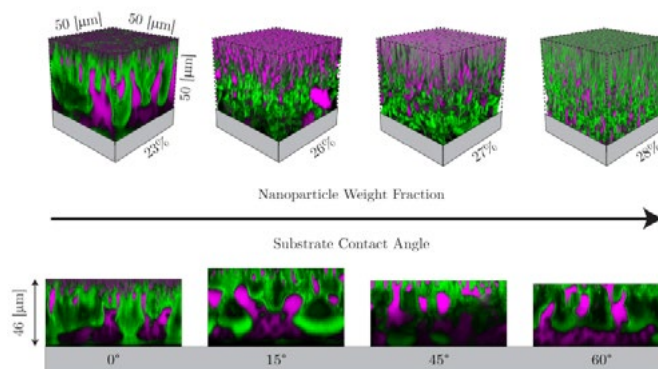
In this work, we determine two key factors that dictate the structure of STrIPS bijels. The first is the concentration of nanoparticles, which we investigate by mapping the 3D morphology of supported STrIPS bijel films through a combination of confocal microscopy and computer simulations. The resulting relationship between the size of the liquid domains and the particle concentration strongly deviates from that of a standard particle-stabilised emulsion, requiring a new model that better captures the specific formation conditions of STrIPS bijels.

Second, we cover the influence of substrate-directed phase separation on the morphology of supported STrIPS bijels. Computer simulations predict the formation of a distinct wetting layer during the STrIPS process, which is confirmed through confocal microscopy on experimental bijels. The composition of this wetting layer can be tuned by progressively increasing the hydrophobicity of the substrate material, ultimately driving a full inversion from water to oil.

Together, these findings provide a framework for the rational design of complex particle-stabilised emulsions with tailorable structures, such as STrIPS bijels.

Keywords:

Emulsions, Nanoparticles, Phase Separation



3D confocal reconstructions of supported STrIPS bijel films. Oil is indicated in magenta, water in black and nanoparticles in green. The top and bottom rows of images reflect the structural influence of the nanoparticle concentration and substrate wettability, respectively.

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CONTROL OF PARTIAL COALESCENCE IN SOLID-OIL-IN-WATER EMULSIONS AS A TOOL TO TUNE THE TEXTURE

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In cosmetics, as well as in food, many emulsions are made of oil that can solidify at low temperatures. After preparation in the liquid state, when cooled down, the drops exhibit surface rugosity that may lead to destabilization through partial coalescence also named edge piercing consisting of connecting drops together. This deleterious phenomenon is also an opportunity to tune the texture of the sample as illustrated in Figure 1, where it can be seen that the texture varies from hard and brittle, to liquid and to easily spreadable.

The objective of the present work was to determine the effect of three stabilizers on partial coalescence and therefore on the texture of cocoa butter-in-water emulsions [1]. The emulsions were initially prepared in the oil liquid state and allowed to crystallize for seven days. We show that the type of emulsifier is of utmost importance, everything else being unchanged: dairy proteins are too protective, inhibiting partial coalescence and the formation of a gel, lecithins are not protective enough to lead to interesting gels while buttermilk powder, comprising a mixture of both stabilizers, is very promising since a spreadable gel could be obtained thanks to connections between droplets.

Keywords:

O/W emulsions, solid oil, partial coalescence, edge-piercing, interface

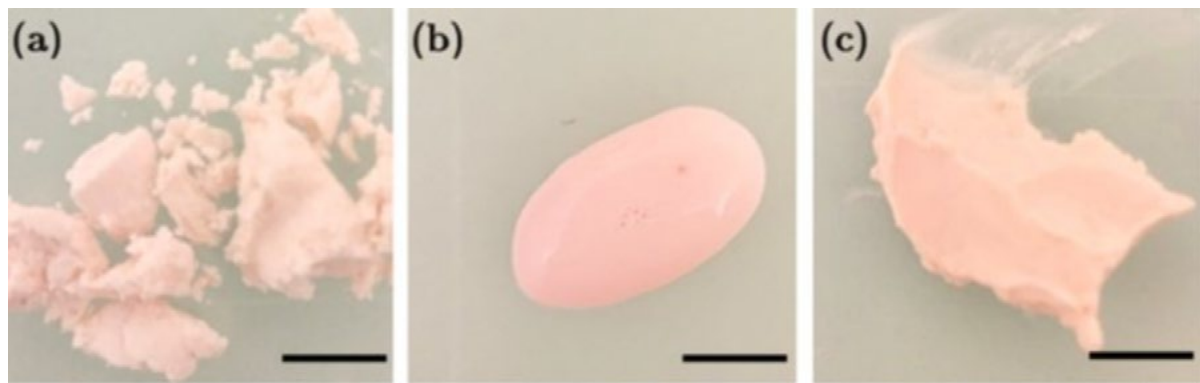


Figure 1: Photographs of solid oil-in-water emulsion obtained after 7 days crystallization stabilized with (a) vegetal lecithin, (b) a milk protein and (c) buttermilk powder. The scale bar represents 0.5 cm. The pink color is due to the addition of a dye for easier observation.

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Where Colloid Science meets Space Science: Synthetic Mimics for Nitrogen-based Polycyclic Aromatic Hydrocarbon Cosmic Dust

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We report the preparation of the first synthetic mimic for submicron-sized nitrogen-based polycyclic aromatic hydrocarbon (PANH) cosmic dust. Melting point phase diagrams were constructed for two binary mixtures comprising *N*-phenylcarbazole (m.p. 96 °C) with either *N*-ethylcarbazole (m.p. 71 °C) or *N*-propylcarbazole (m.p. 50 °C) to identify their eutectic compositions and temperatures, respectively. Each eutectic composition was then processed above its eutectic temperature via hot emulsification using a commercial water-soluble polymeric emulsifier: high-shear homogenization produced polydisperse molten PANH droplets of approximately 60-70 µm diameter. Each precursor emulsion was then subjected to high-pressure microfluidization to produce much finer submicron-sized PANH droplets. On cooling to 20 °C, these hybrid PANH microparticles were coated with an ultrathin overlayer of polypyrrole (PPy). This electrically conductive coating enabled the efficient accumulation of surface charge, which in turn allowed the electrostatic acceleration of such PPy-coated PANH microparticles up to the hypervelocity regime using a high-voltage dust accelerator. Firing a *single* 71:29 *N*-propylcarbazole/ *N*-phenylcarbazole microparticle into a gold target at 3.6 km s⁻¹ led to impact ionization and the *in situ* generation of an ionic plasma. Subsequent time-of-flight mass spectrometry analysis confirmed the formation of the characteristic parent cations for *N*-propylcarbazole and *N*-phenylcarbazole, respectively. Such laboratory-based experiments augur well for the unambiguous identification of PANH-based cosmic dust by next-generation impact ionization mass spectrometers to be deployed in current and future space missions.

Keywords:

polycyclic aromatic hydrocarbons, emulsions, cosmic dust, eutectic composition, polypyrrole, impact ionisation mass spectrometry, synthetic mimic

Dual jamming of bio-based CNC-stabilized bijel fibers via continuous solvent transfer induced phase separation

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Bicontinuous particle-stabilized emulsions are formed by mixing two immiscible liquids with a cosolvent, followed by inducing phase separation within the spinodal regime and kinetically arresting the evolving morphology with colloidal particles. Here, bio-based, rod-like cellulose nanocrystals (CNCs) are employed to stabilize bicontinuous emulsions through combined inter- and intra-phase jamming at a low particle loading of 3 wt.%, yielding characteristic domain sizes of approximately 10 μm . The use of 1-propanol as a cosolvent promotes CNC dispersion prior to and during solvent diffusion, enabling the continuous development of CNC-based bicontinuous emulsion gels in the form of segmented fibers (1–2 cm) and continuous filaments exceeding 25 cm in length. Crucially, surfactant-specific access to near-neutral wetting is identified as a practical control lever for CNC: stable bicontinuity is not achieved with CTAB, whereas robust filament formation is enabled by DDAB. The resulting porous, biphasic CNC network supports efficient crossflow mass transfer and provides a robust platform for interfacial chemical processes, opening an opportunity for sustainable material design.

Keywords:

Cellulose nanocrystals (CNCs), Pickering bicontinuous emulsions, interfacial jamming, solvent-transfer induced phase separation (STRIPS).

Acknowledgements:

This project was supported by the Canada Excellence Research Chair Program (Grant No. CERC-2018-00006); the Canada Foundation for Innovation (Project No. 38623); and the Pacific Economic Development Canada (PacifiCAN). M.Y. acknowledge the China Scholarship Council for funding her doctoral program. Imaging and image analysis for this work was performed in the University of British Columbia Super Resolution Microscopy Core (LSI Imaging Facility), RRID: SCR_023783. Some illustrations were created with BioRender.com.

Stimuli-responsive microgels-based capsules constructed from all-aqueous coacervate droplets

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Stimuli-responsive capsules are soft materials that combine confinement with dynamic control over permeability and transport. By responding to external triggers such as temperature, pH, or ionic strength, they allow reversible tuning of both structural and interfacial properties. An especially attractive strategy to design such systems relies on water-in-water emulsions, which provide ultra-low interfacial tension and fully aqueous environments. Here, we present a fully aqueous approach to fabricate stimuli-responsive colloidal capsules based on microgel assemblies at liquid–liquid interfaces.

All-aqueous phase separation typically arises when two water-soluble components are mixed, a phenomenon known as coacervation. In the case of self-coacervation, a single macromolecular species separates into micrometer-sized liquid droplets. Building on this concept, we exploit ampholyte polymer chains to generate highly stable micrometric coacervate droplets. Thermoresponsive poly(N-isopropylacrylamide) (PNIPAM) microgels adsorb at the coacervate interface and are subsequently interlinked by UV-initiated polymerization, forming a robust microgel membrane. After dissolution of the coacervate core, the capsules remain intact and display a permeable shell whose transport properties are governed by the microgel swelling state. The membrane exhibits size-selective permeability toward Brownian nanoparticles and can be dynamically modulated by temperature. Altogether, this system provides a versatile model platform to investigate adaptive interfacial assemblies and responsive transport in soft colloidal capsules.

Keywords:

Coacervates, microgels, all-aqueous emulsions

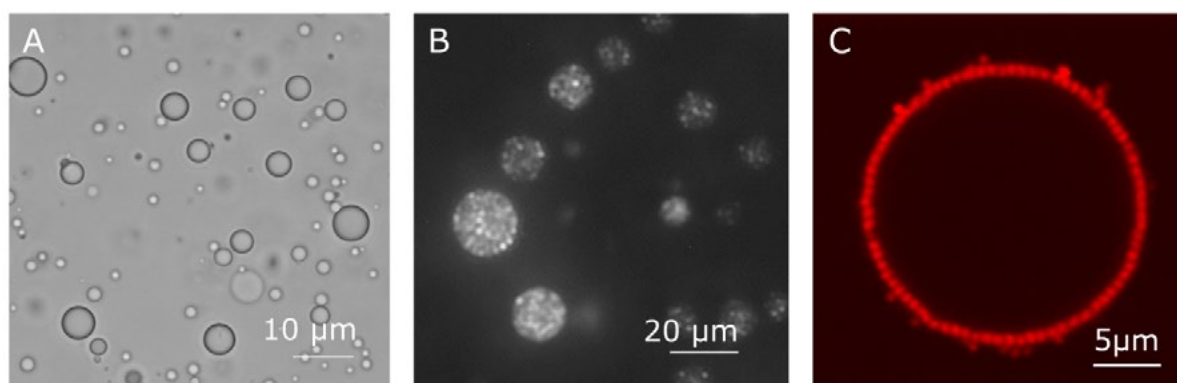


Figure 1: A) Optical microscopy image of coacervates. B) Fluorescent images of polystyrene latex sequestered in coacervates. C) Confocal image of microgels-based capsule through the coacervation templating method.

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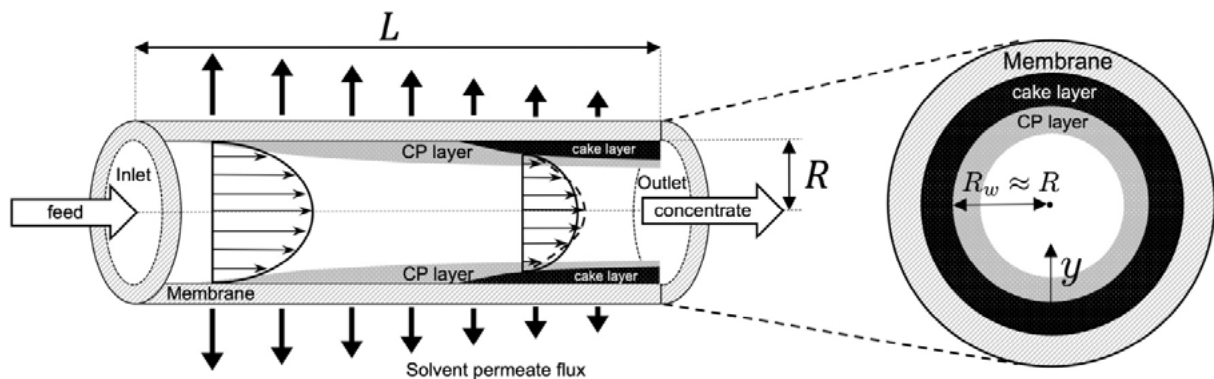
Modeling crossflow filtration: Effect of shear on particles-enriched polarization and cake layers

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Crossflow filtration (CF) is a pressure-driven separation and enrichment process for colloidal particles, in which a feed dispersion is continuously pumped through a cylindrical membrane channel permeable only to solvent. During the filtration process, particles accumulate at the membrane, forming a fluid-like, inhomogeneous concentration polarization (CP) layer and a solid-like cake layer. Both layers tend to lower filtration efficiency by increasing energy consumption per unit of colloid concentrate. Based on a newly developed accurate semi-analytic model for CF, we determine spatially resolved flow and particle concentration profiles in the transition regime between ultrafiltration (UF) and microfiltration (MF), where shear flow effects compete with Brownian particle motion [1]. Results are presented for model dispersions of non-permeable and permeable colloidal hard spheres [2,3], accounting for the shear-rate and concentration dependencies of collective diffusion and viscosity, as well as for a thin filter cake. Shear thinning of viscosity and shear-enhanced Brownian diffusion tend to improve filtration performance by increasing the critical permeate flux and transmembrane pressure at which cake formation sets in, and by lowering the cake coverage of the membrane surface. New findings include a non-monotonic shear-rate dependency of the dispersion flow across the CP layer, and a shear-induced significant upturn of the critical permeate flux at larger shear rates. The observed upturn resolves a long-standing so-called critical flux paradox related to the UF to MF transition regime. Our presentation bridges the gap between fundamental research on shear-affected colloidal transport properties and dispersion flow, and crossflow filtration as an important technological process.



Schematic view of inside - out crossflow filtration in a cylindrical membrane channel of length L and inner radius R

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Understanding interfacial stabilization in one-step W/O/W Pickering double emulsions using cellulose nanofibrils and oleic acid

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Double emulsions are complex systems consisting of emulsion droplets that contain smaller droplets inside, resulting in a three-phase structure with two interfaces. Compared with simple emulsions, double emulsions offer the advantage of encapsulating and controlling the release of both hydrophilic and hydrophobic active compounds. However, due to their high instability, double emulsions are typically prepared using large amounts of synthetic stabilizers and two-step methods.¹ To design more sustainable emulsions, cellulose nanofibrils (CNFs) are attractive candidates due to their renewability and biodegradability, although they typically form only simple O/W Pickering emulsions.² In this work, CNFs were combined with oleic acid to enable the one-step production of water-in-oil-in-water (W₁/O/W₂) double emulsions, using almond oil as the oil phase. Colloidal stability was monitored over time using optical and confocal microscopy, which showed that cationic and anionic CNFs effectively stabilized the external O/W₂ interface. Experimental results combined with classical molecular dynamics simulations revealed that oleic acid, naturally present in almond oil, stabilizes the internal W₁/O emulsion. Notably, anionic CNFs were more effective in preserving the double-emulsion morphology for over two months under ambient conditions. These findings highlight the potential of functionalized CNFs together with oleic acid as sustainable stabilizers for the development of double emulsions suitable for food, pharmaceutical, and cosmetic applications.

Keywords:

Cationic cellulose nanofibrils, oxidized cellulose nanofibrils, Pickering emulsions, double emulsions, molecular dynamics

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Acknowledgements:

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Emulsions of Hydrophobic Deep Eutectic Solvents Stabilised with Poloxamer Surfactants and Stearate Salts

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Deep eutectic solvents (DES) are novel solvents which have been applauded for their environmentally friendly nature and tunable behaviour. ¹ They feature a range of properties, depending on the molecules of which they are comprised, which allows them to have a wide range of applications. ² Despite many of the separate DES components being solid at room temperature, all DES form a room temperature liquid phase when mixed at their eutectic ratio.

This work explores a hydrophobic 'Type V' DES emulsion system, where a menthol : dodecanoic acid DES acts as the oil phase in an oil in water emulsion. These emulsions are stabilised through steric interactions of non-ionic block copolymer surfactants, namely poloxamer surfactants, at the droplet interface. The stability of these emulsion systems were found to be improved upon addition of the stearate salts of sodium, calcium and magnesium to the DES phase. This increased stabilisation is first quantified using droplet size analysis, then rationalised through the use of small angle neutron scattering techniques.

Type V DES are a subclass of these solvents, comprising of a simple mixture non-ionic hydrogen bond donors and acceptor pairs. At least one of the DES components is usually a terpene such as menthol or thymol, which can be extracted from mint and thyme respectively. ² As these terpenes can be naturally produced as secondary metabolites of plants, this could allow the DES formed from them to be feasibly produced on a large scale and to be considered a truly sustainable replacement solvent for the petrochemical-derived solvents commonly used today.

These mixtures are naturally hydrophobic, similarly to their parent molecules. They have much lower viscosity than other DES types and also feature low vapour pressure paired with high thermal stability, allowing them a large scope of potential application. Their inherent hydrophobicity has led to these solvents being explored as extractants for several species, from heavy metals to pharmaceutical actives. ^{3, 4} As these solvents can comprise of natural 'essential oils', this allows these solvents to also deliver their therapeutic or antibacterial properties if used in products which are to be applied to the skin, such as in medical or personal care products. ^{5, 6}

Keywords:

Emulsion, Surfactant, Interface, DES, Nonionic, Polymer

References:

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When membranes get crowded: interfacial constraints on protein binding and remodeling

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Cellular membranes regulate protein binding, remodeling, and signaling through complex interfacial interactions. Amphipathic proteins such as α -synuclein (α Syn) bind lipid membranes cooperatively, forming heterogeneous domains rather than uniform distributions. While this clustering is essential for membrane remodeling, it may also promote pathological aggregation associated with neurodegenerative diseases. However, the molecular determinants governing this behavior remain unclear.

Here, we investigate α Syn binding to model membranes and extracellular vesicles using circular dichroism, microscopy, cryo-TEM, and single-vesicle TIRF imaging. We show that macromolecular membrane crowding, introduced via polymer-grafted lipids, shifts the binding equilibrium without altering α Syn's α -helical structure. Larger polymers enhance membrane-induced folding and promote earlier binding saturation, consistent with stabilization of the membrane-bound state via excluded-volume effects.

At the vesicle level, binding is strongly cooperative and heterogeneous. Membrane crowding reduces accessible surface area, limits protein packing density, and suppresses curvature generation and remodeling, while regulating post-binding accumulation and spatial organization. Under physiological conditions and in biologically derived vesicles, binding affinity is reduced but heterogeneity persists, highlighting the role of lipid complexity and electrostatic screening.

Together, our results show that cooperative protein binding is governed not only by lipid composition but also by interfacial crowding and membrane accessibility, linking membrane organization to protein clustering and remodeling, with implications for cellular function and disease.

Keywords:

Cooperative binding, Interfacial crowding, α -synuclein, Protein–lipid interactions, Extracellular vesicles

Pickering or not Pickering? Deformation of lignin nanoparticles at the air-water and oil-water interfaces

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Lignin has long enjoyed plenty of attention in the development of new sustainable materials due to its high abundance, phenolic structure, and versatile applications. While lignin generally has a low solubility in water, converting it into nanoparticles (LNP) allowed its dispersion into water, enabling its use in water-based applications such as in oil-in-water emulsions. Given lignin's low solubility in water, LNPs have long been considered to behave like solid particles, effectively acting as Pickering emulsifiers whose emulsifying performance relies on their surface properties[1]. For this reason, we attempted to improve the emulsifying property of LNPs by coating them with hemicelluloses, which halted their aggregation in acidic pH[2, 3].

However, we found that unlike regular Pickering emulsions, the size of LNP had little influence on emulsion stability. Coating the LNPs also did not allow a stable emulsion to be formed at acidic pH; instead, the coated LNPs behaved similarly to unmodified LNPs, suggesting that the core lignin material was more important than the surface. Using a combination of X-ray and neutron scattering methods, we observed that despite being clearly solid and compact in water, the LNPs may deform upon adsorption. The extent of such deformation was dependent on the type of lignin (where softwood LignoBoost® lignin-based LNP was more resistant to deformation compared to BLN™-extracted hardwood lignin) and oil used in the emulsion (with isooctane emulsions having a thicker interfacial layer compared to hexadecane emulsions). Based on these results, we propose that as emulsifiers, LNPs should be treated more as polymeric microgels than solid particles, and call for further investigation into correlating the polymeric properties of lignin from different sources and extraction methods towards the functionalities of LNPs. Such knowledge will allow a more precise use of various types of lignin to tailor emulsion properties, hopefully facilitating a more widespread adaptation of lignin as future sustainable emulsifiers.

Keywords:

Lignin nanoparticles, Pickering emulsions, lignocellulose, lignin

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Dynamics and controlled assembly of solid lipid domains at interfaces

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Lipid monolayers are of significant interest due to their presence in several biological systems, where they perform essential protective and structural functions. In the respiratory system, the alveolar surface is lined with a pulmonary surfactant monolayer, which prevents the lungs from collapsing during breathing. This monolayer is primarily a mixture of neutral lipids and proteins, as well as phospholipids of which DPPC is the major component [1]. On the other hand, micron-sized pollutants deposited in the lung surfactant may alter its performance. Therefore, understanding the micro and macroscopic behavior of pure DPPC monolayers as a minimal model for biointerfaces as well as its interaction with micro-particles as a model for pollutants, hold considerable physiological relevance. Using a Langmuir-Blodgett trough coupled to an in-house optical microscopy setup (figure 1a), we vary the surface pressure while visualizing the lipid behavior thanks to the presence of a fluorescent lipid [2]. The DPPC monolayer undergoes phase transitions from gas to liquid to solid with increasing surface pressure, displaying a coexistence region where solid DPPC domains form within the liquid DPPC phase (figure 1b) [3]. In this work, we analyze the self-organization and dynamics of these lipid domains by characterizing their size, separation and area fraction while also measuring their dynamics as a function of surface pressure. We also observed the formation of solid domains in a case where aminated silica microparticles were deposited at the water/air interface. Different treatments of microparticles can promote (figure 1c) or hinder (figure 1d) the interaction between them and the solid DPPC domains. These observations will allow us to understand the monolayer's fluidity properties at a fundamental level and study the effect that model micropollutants have on the monolayer's phase behavior.

Keywords:

Phospholipids, monolayer, microparticles, phase behavior, lung surfactant

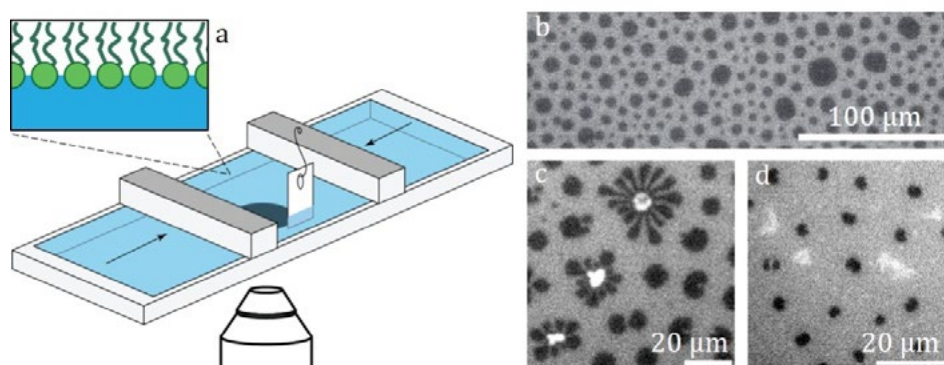


Figure 1: a. Diagram of the Langmuir trough. b. Solid DPPC domains immersed in the liquid phase in the water/air interface. Domains forming around (c) and far from (d) clusters of aminated silica microparticles.

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From Solution to Interface: Structural Evolution of pH-responsive O-Carboxymethyl-Chitosan Microgels with Varying Cross-linking

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Microgels are cross-linked soft-particle networks with colloidal dimensions that swell in a compatible solvent (Scheffold, 2020). Their high deformability, surface activity, tuneable size and composition, and responsiveness to external stimuli make them attractive stabilisers for stimulus-sensitive emulsions. When the polymer matrix is derived from renewable resources, the microgels gain added value for sustainable applications because of their biocompatibility, low toxicity and biodegradability. Consequently, their behaviour at fluid interfaces has attracted considerable interest in the food and pharmaceutical applications (Cai et al., 2025).

In this study we compare bulk swelling and interfacial responses of pH-responsive O-Carboxymethyl-chitosan (O-CMC) microgels with three cross-linking densities using scattering techniques, Langmuir–Blodgett isotherms, and atomic-force microscopy (AFM). At the air-water interface the particles adopt non-isotropic, partially flattened shapes that agree with the scattering data. Lower cross-linked microgels deform markedly more than highly cross-linked ones, indicating stronger interfacial spreading. Surface pressure-area isotherms show pronounced hysteresis during compression–expansion cycles, suggesting partial loss or rearrangement of the monolayer.

While bulk swelling is clearly pH-dependent, the present interfacial data do not reveal a strong pH effect. Future work will perform systematic pH-variation experiments at the interface to probe possible changes in packing, rigidity and monolayer stability.

Keywords:

Atomic Force Microscopy, Langmuir-Blodgett technique, Carboxymethyl Chitosan, Microgels

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Foam films stabilized by microgel particles : Insights from the dynamic thin film balance

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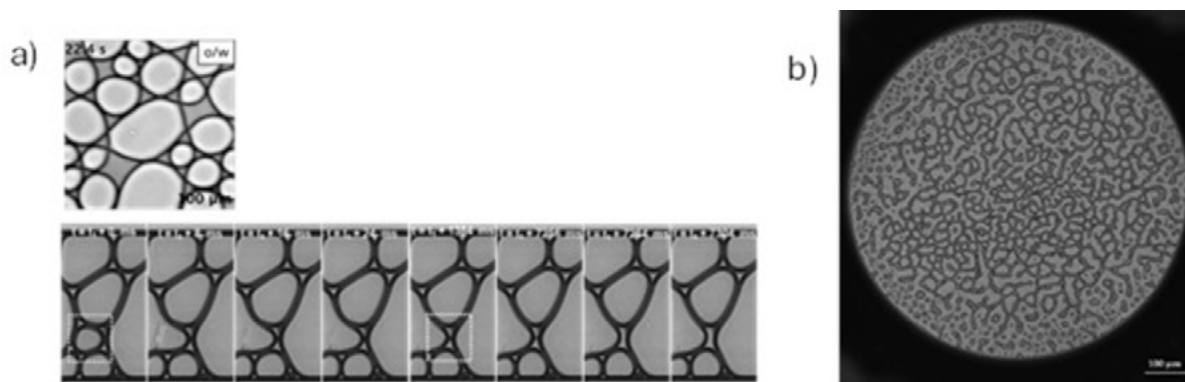
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Foams are multiphase materials that are prevalent around us, spanning diverse industrial, food and personal care applications, and also driving fundamental scientific questions. The thin films of liquid (TLFs) present between foam bubbles in proximity govern the lifetime beyond which bubble coalescence occurs. The dynamic thin film balance (TFB) is a versatile technique that uses precise pressure control to emulate thin liquid foam films created in a (bikewheel) microfluidic chip [1]. In this study we focus on Pickering foams stabilized by soft colloidal particles – PNIPAM core-shell type microgel particles that can deform at a fluid-fluid interface. Microfluidic experiments resulted in the generation of emulsion droplets and foam bubbles with bridged interfaces (Fig. a), specifically to control and closely observe bridging and to induce controlled de-bridging. Upon drainage of the simulated interstitial film, a highly heterogeneous film with an arrangement of dark and bright regions is formed. The film lifetimes have a distribution, skewed towards high lifetimes at higher pressures (≥ 20 mins) (Fig. b). The dark and bright regions correspond to uneven bilayer-like and monolayer arrangement of particles within the film, with the monolayer regions resulting in “bridged interfaces”. We show that the distribution of mono/bilayer-like regions within the film in fact depends on the pressure under which drainage occurs and that film stability correlates with the amount of monolayer regions. De-bridging induced by pressure reversal/reduction did not result in film rupture and the TLF remained stable despite multiple cycles of applied $\pm\Delta P$, to drain and thicken the film. Differences are observed in the rate of film expansion and retraction, that can be attributed to the presence of bridging/monolayer regions, that becomes a controlling step in liquid inflow towards the center of the film during film retraction. This hypothesis is evidenced by thickness differences estimated between these regions and by probing de-bridging behavior by reversal of the direction of applied pressure. We examine foam films stabilized by microgel particles at the thin film scale, at pressures relevant to realistic hydrodynamic conditions of drainage, and show that increasing the pressure that drives drainage beyond the typically employed range [2,3], results in *ab initio* defined interfacial structures, which in turn influence film stability. The pressure-dependent film structures affect significantly the subsequent film thickening.

Keywords:

thin liquid films, foams, microgel particles, bridging



(a) Bridged emulsion droplets & foam bubbles (b) Thin liquid film at the end of drainage (stabilized by core-shell microgel particles)

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From Bulk to Confinement: Slowing Dynamics in Bicontinuous Microemulsions

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The influence of hard and soft confinement on simple fluids, binary mixtures, and colloidal systems continues to attract considerable attention. Confinement encompasses a wide range of situations, from soft matter in proximity to solid interfaces to crowded, fluctuating environments and porous materials. Both theoretical and experimental studies have shown that fluid properties can change significantly when the confinement length scale becomes comparable to a characteristic length of the confined liquid. In complex, nano-structured fluids, additional structure-related length scales become important.

In the past, microemulsions have been extensively studied and carefully characterized, making them ideal model systems for soft systems with fluctuating membranes. For example, in the bulk, bicontinuous microemulsions exhibit an isotropic, periodic internal structure in which interpenetrating oil and water domains are separated by a fluctuating surfactant interface, forming a sponge-like morphology.

Here, we discuss how three-dimensional confinement, as realized by the mesoporous structure of controlled pore glasses, affects the phase behavior of such microemulsions, how these effects manifest in their dynamical properties, and how they compare to the corresponding bulk behavior.

A confined bicontinuous microemulsion is studied using neutron spin echo spectroscopy, a technique uniquely suited to probing thermally activated fluctuations in soft matter. In contrast, small-angle neutron scattering provides only the time-averaged structure of the fluctuating microemulsion.

Hydrophilic and hydrophobically modified controlled pore glasses serve as confining matrices, with pore diameters ranging from 10 to 100 nm. The pore sizes are selected such that, in one case, the characteristic oil and water domain size is significantly smaller than the pore diameter, while in another case it is larger.

As a first step, the bulk microemulsion is characterized using NSE and dynamic light scattering, allowing the determination of its intrinsic collective dynamics and the undulation dynamics of the surfactant film.

Under confinement, a pronounced slowing down of the intrinsic collective dynamics is observed across all investigated pore sizes compared to the bulk. The analysis indicates that enhanced interactions with the pore walls suppress long-wavelength fluctuations in the undulation mode spectrum.

Interestingly, the chemical nature of the pore surfaces appears to play only a minor role. The undulation behavior of the surfactant film remains largely unchanged in both hydrophilic and hydrophobic confinement.

Keywords:

microemulsion, dynamics, confinement, controlled pore glass

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Structure–mechanics coupling in particle-laden liquid-liquid interfaces

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Particle-laden liquid-liquid interfaces exhibit complex and tunable interfacial mechanics. The mechanical properties of these interfaces play a significant role in the formation and stability of Pickering emulsions. To date, most studies have focused on densely packed, monolayer interfaces, whereas less densely organized interfacial structures remain underexplored, despite their potential to exhibit pronounced mechanical properties. However, achieving robust elastoviscoplastic behavior at liquid-liquid interfaces remains challenging, particularly at sub-monolayer coverages. Single-component particle layers often fail to develop sufficiently connected interfacial networks, limiting their mechanical integrity under deformation [1]. In this work, we investigate how assembly pathways and interfacial composition govern the formation of mechanically robust interfaces.

One approach to address this challenge is the use of mixed particle interfaces, where differences in charge and surface properties enhance interparticle interactions and cooperative assembly [2]. By systematically varying the sequence of interface formation and particle addition, we observe a variety of interfacial (2D) assemblies, from local clusters to percolated networks, highlighting the role of bidispersity and the assembly protocol in controlling network connectivity.

The mechanical response of these interfaces is probed using interfacial shear and dilatational rheology across controlled surface coverages. Interfacial shear rheological properties are characterized by oscillatory time and strain amplitude sweeps using a double wall-ring geometry, while dilatational rheology is performed in a Quadro-trough to impose isotropic deformations and relate the response to microstructural changes [3]. Complementary imaging analysis provides insights into the evolving microstructure and its coupling to macroscopic viscoelastic properties.

These findings highlight the importance of particle composition, assembly protocol, and variations in particle interactions in controlling interfacial structure and, consequently, the rheological response of particle-laden interfaces.

Keywords:

Particle-laden interfaces, assembly mechanisms, interfacial microstructure, interfacial rheology

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Facetted liquid foam under free and force drainage

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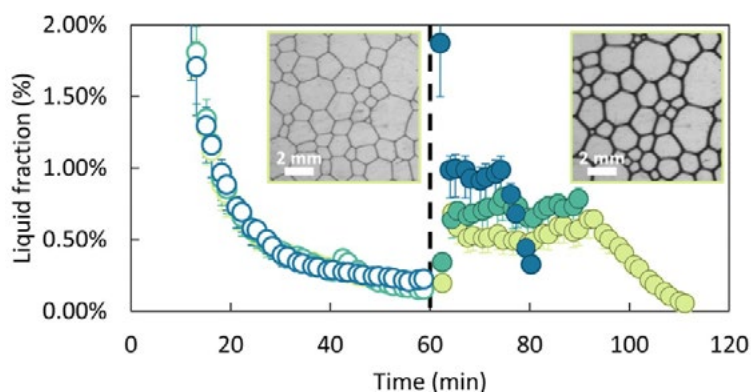
Surfactant-stabilized foams undergoing free and forced drainage were investigated by coupling optical imaging, conductivity measurements, and small-angle neutron scattering.[1] During free drainage, the Sauter mean bubble radius increases as $t^{1/2}$, while the liquid fraction rapidly decreases to below 0.5 vol%, after a transient regime characteristic of a coarsening foam.

During the forced-drainage sequence, at low flow rates of the injected solution, the liquid fraction increases again and reaches a steady value that depends on the imposed flow rate. At the same time, both the Sauter mean radius and the number of bubbles stabilize, indicating a strong reduction in the coarsening rate [2] and the maintenance of a stationary, swollen faceted foam structure. Small-angle neutron scattering, which enables the determination of the bubble film thickness as well as the specific surface areas of the films and Plateau borders, shows that these structural parameters also remain constant during forced drainage. These observations demonstrate that the structural characteristics of the foam under forced drainage (and not for foams under free drainage) are well described by equilibrium foam models reported in the literature, suggesting that hydrodynamic effects due to drainage are negligible at the low flow rates investigated.

Finally, this study provides, for the first time, a robust experimental comparison between aqueous polydisperse foam structures – under forced drainage - and theoretical models based on Kelvin cells.[3] These results open new avenues for exploring how hydrodynamics at higher forced-drainage flow rates affects foam structure, together with the role of surfactant chemistry and interfacial rheology in determining foam architecture.

Keywords:

Polydisperse foam, drainage, imaging, scattering, thin film, specific surface



Foam liquid fraction evolution versus time during the free drainage sequence on the left and during the forced drainage sequence at three different flowrates (followed by a free drainage) on the right

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Engineering lignocellulosic nanomaterials: from Pickering emulsions to air-dried high-performance foams

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As the main components of plant biomass, lignin and cellulose are natural, renewable and abundant polymers that, in the form of nanoparticles, are a promising and more sustainable alternative to fossil-based materials, in particular in the fabrication of solid foams [1]. Despite growing environmental awareness, preparing mechanically stable solid foams from renewable lignocellulosic building blocks remains challenging. Sufficient solid content is needed to produce foams that resist collapse, yet removing water from such systems at ambient conditions is difficult. Avoiding energy intensive processes such as freeze drying and supercritical drying while retaining foam integrity remains an open challenge, particularly for cellulose-based systems where high concentrations also hinder uniform dispersion. This study aims to reduce drying energy by designing an oil-in-water Pickering emulsion template that enables the fabrication of high-performance dry foams at room temperature without surfactant and cross-linker, and with a scalable process. Lignin nanoparticles (LNPs) served as Pickering stabiliser for an oil-in-water emulsion with a volatile hydrocarbon as the oil phase. As the oil evaporated, it generated pores, while cellulose and polyvinyl alcohol provided structural and mechanical integrity. By tuning cellulose content, this method resulted in high mechanical stability (0.63 MPa compressive stress at 50% strain), low thermal conductivity ($36 \text{ mWm}^{-1} \text{ K}^{-1}$) and promising sound adsorption properties [2]. These properties were comparable to those of fossil-fuel-based rigid polyurethane. In addition, we investigated how the surface chemistry of the LNPs affected the type of emulsion obtained. Unmodified LNPs with water contact angle in oil of 82° favor oil-in-water emulsions, whereas chemically modified LNPs with water contact angle in oil of 106° produce water-in-oil, as confirmed by microscopy, electrical conductivity, and surface free-energy analysis. Our findings establish a practical, low-energy platform for manufacturing high-performance renewable-foams from widely available plant resources. Furthermore, the type of emulsion can be tuned by changing the surface chemistry of lignin nanoparticles.

Keywords:

Air-dried foam, lignocellulose nanoparticles, Pickering emulsion, wettability

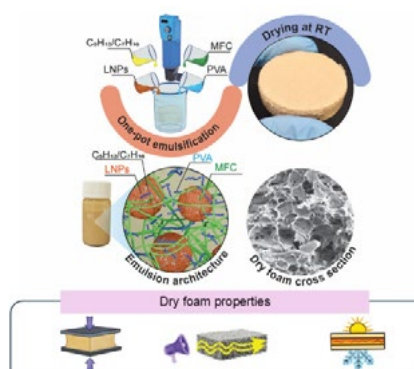


Illustration on air-dried foam production

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Acknowledgements:

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Impact of particle-size polydispersity on colloidal crystallization and thin-film structures

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The synthesis of colloids is frequently challenged by the difficulty of producing monodisperse particles. Size disparity in colloidal particles can disrupt order in their assemblies, ultimately leading to a complete suppression of crystallization. In this talk, I will present a systematic experimental investigation into how size polydispersity affects the 2D and 3D structures of colloidal crystals grown as thin films through vertical drying. Surprisingly, we do not observe a gradual decline in 2D local order but two sharp drops at 8% and 12% polydispersity, indicating the presence of both 2D and 3D crystallization regimes in the system. By showing that assembly quality improves from the bottom up, we suggest that 3D crystallization in our system resembles epitaxial growth. We also examine whether this crystallization process involves size fractionation. To broaden the picture, we explore how polydispersity influences crystallization within bulk samples. These insights help define the limits for achieving ordered colloidal crystals and shed light on assembly mechanisms in vertical drying of thin films, where direct observation of the crystallization process is experimentally challenging.

Keywords:

colloids, self-assembly, polydispersity, thin films, crystallization

Influence of Lipid Shape and Headgroup Charge on Bilayer Behavior

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To better understand bilayer property dependency on lipid electrostatics lipid head group's internal degrees of freedom need to be taken into account. The most general shapes and charge distributions of lipid head groups are considered: rigid rod-like, flexible segments and triangular head groups. The lipid monolayer is in contact with an electrolyte solution composed of monovalent ions. The system is considered by means of a generalized classical Density Functional Theory model and Simulations. Starting from the free energy of the system the calculus of variation was used to derive Euler-Lagrange equations which were solved numerically by Finite element method [1-4].

Results show that there are mainly two distinct regions of the electric double layer: (1) the interfacial region, with thickness less than or equal to the length of the fully stretched conformation of the lipid head group, and (2) the outside region, which follows the usual screening of the interface. The lipid head group structure substantially impact the potential profile of the layer. The strongly charged monolayer induces a non-monotonous conditional probability density and tendency of head groups more perpendicular to the surfaces. The weakly charged surface causes more constant conditional probability density. The flexibility of head groups switches the perpendicular to more parallel orientation of head groups due to possibility of intermediate positive charge to be in the vicinity of negatively charged plane of phosphate groups and terminating negative charge to be extended more in the solution. Simulations confirm the results of the model [4].

Finally, a phase-separated multi-component phospholipid plane with one half consisting of charged lipids and the other half of non-charged lipids in contact with an electrolyte solution composed of monovalent ions will be considered. Results show that in the vicinity of the transition from the uncharged to the charged part a sigmoidal transition to an increased concentration of counterions is observed [5].

Keywords:

Lipid head group structure, Electric double layer, Phase separation

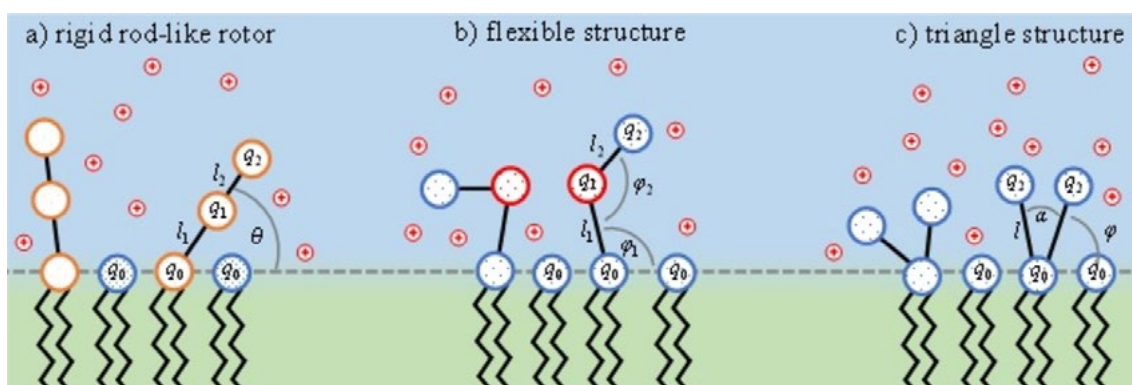


Figure 1. Schematic presentation of the lipid monolayer, where head-groups with the spatial charge distribution are in contact with the aqueous solution [4].

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Stabilization of water-in-water emulsions by macromolecular complexation at the interface

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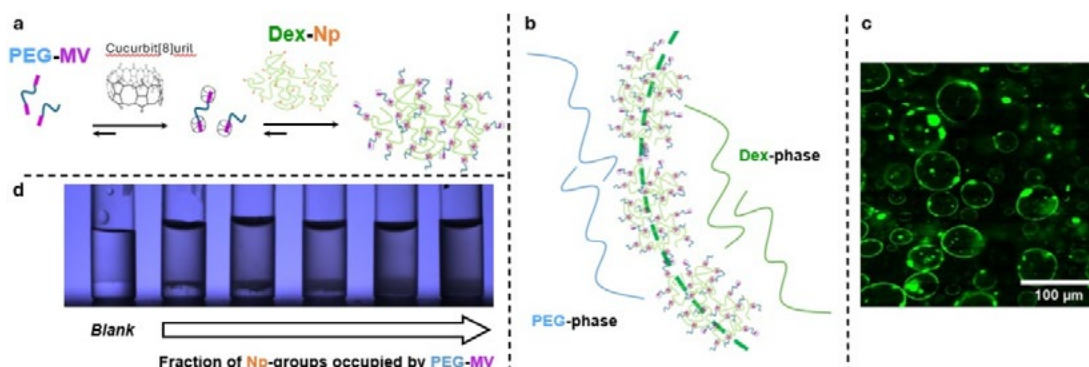
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Aqueous biphasic dispersed systems, referred as water-in-water emulsions, constitute a distinct type of colloidal systems in which two immiscible aqueous phases coexist. These systems are formed thanks to the incompatibility between two polymers dissolved in water, such as dextran (Dex) and poly(ethylene glycol) (PEG), arising from their low entropy of mixing. The capacity to encapsulate active ingredients and regulate substance release, while being composed of fully biocompatible components, holds great potential for application of such systems in food science, encapsulation and drug delivery [1]. Stabilizing these unconventional emulsions constitutes a great challenge because their interfaces are ill-defined in terms of hydrophilic/hydrophobic domains and are thicker than in common oil/water emulsions [2]. Consequently, classical surfactants are generally ineffective, and stabilization mainly relies on solid particles, although the underlying mechanisms remain unclear [3].

In this context, the project deals with the development of a novel strategy to stabilize such water/water (W/W) interfaces by using macromolecular stabilizers, that possess an affinity for both the PEG- and Dex-rich phases, and therefore are located at the droplet surface similar to ordinary surfactants at water/oil interfaces. This strategy is based on the formation of complexes between PEG and Dex chains bearing methyl viologen (MV) and naphthol (Np) guest moieties, correspondingly, *via* host-guest inclusions in the presence of a host, *i.e.* cucurbit[8]uril (CB[8]) [4] (Figures a-b). The proposed method allows to tune the structure of such amphiphile-like stabilizers, and therefore, their affinity to the W/W interface (Figure d). By combining confocal microscopy (Figure c), small-angle neutron scattering, and isothermal titration calorimetry, we access the structure of the formed complexes in the bulk and at W/W interface, and demonstrate their efficiency and robustness in stabilization of water-in-water emulsions.

Keywords:

Water-in-water emulsions, bis-hydrophilic stabilizer, interfacial host-guests complexation



Figures a) Formation of the host-guest macromolecular complex b) sketch of the interfacial complexation occurring in W/W emulsions; c) confocal microscopy image of such W/W emulsions highlighting the positioning of the complex at the interface; d) W/W emulsions at $t = 2$ h as a function of the ratio

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Acknowledgements:

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Nanoscale Landscapes: Unveiling the Lateral and Vertical Architecture of Microgels at Fluid Interfaces

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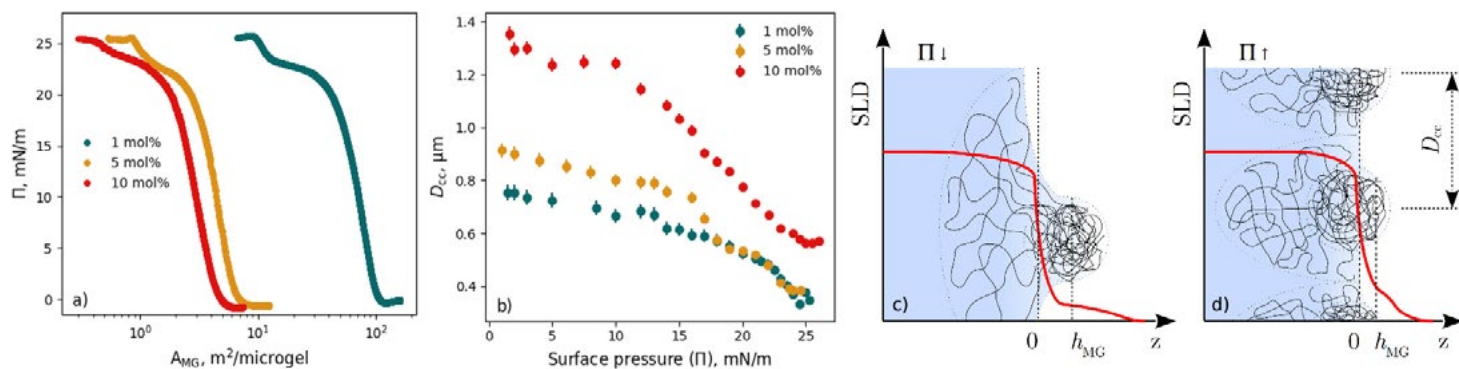
Microgels are soft, three-dimensional colloidal networks comprised of cross-linked polymers, whose surface activity [1] and mechanical properties [2] can be precisely tuned via cross-linker density. In the bulk phase, particularly when composed of thermoresponsive polymers like poly(oligoethylene glycol methacrylate), these microgels exhibit stimuli-responsive behaviour, allowing their size and surface charge density to be controlled via temperature modulations. However, transitioning these particles from the bulk to an interface alters their physicochemical behaviour [3].

Here we map the structural evolution of polymer microgels as they transition from bulk solutions to distinct interfacial environments. At the solid-water interface, *ex situ* atomic force microscopy (AFM) reveals decorated microgel surfaces can impart functional, stimuli-responsive elasticity. In contrast, adsorption at the fluid air-water interface induces significant structural deformation relative to the bulk state, causing the core-shell particles to flatten dramatically into a two-dimensional core-corona (or “fried-egg”) morphology.

Accurately capturing these disparate behaviours requires tailored characterisation. While AFM provides essential, high-resolution structural insight at solid substrates, it is inherently limited when evaluating long-range lateral structure over delicate fluid boundaries. To address this, *in situ* specular and off-specular X-ray reflectivity (XRR) is utilised to directly probe the air-water interface without doping or transfer-induced artefacts. This technique successfully resolves the long-range vertical and lateral ordering of the microgels as a function of surface pressure [4]. Furthermore, by directly comparing this *in situ* XRR data with *ex situ* AFM measurements, we explicitly confirm and quantify the structural transfer effects that occur during Langmuir-Blodgett deposition, highlighting the critical need for *in situ* methodologies when evaluating interfacial microgel behaviour.

Keywords:

microgel, reflectometry, X-ray, air-water interface, structure



(a) Langmuir isotherms and (b) corresponding centre-to-centre distances (D_{cc}) of microgels at the air-water interface as a function of surface pressure and cross-linker concentration. Visualisation of microgels at the air-water interface are also shown for (c) low and (d) high surface pressures [4].

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Universal Double Emulsions Made Simple

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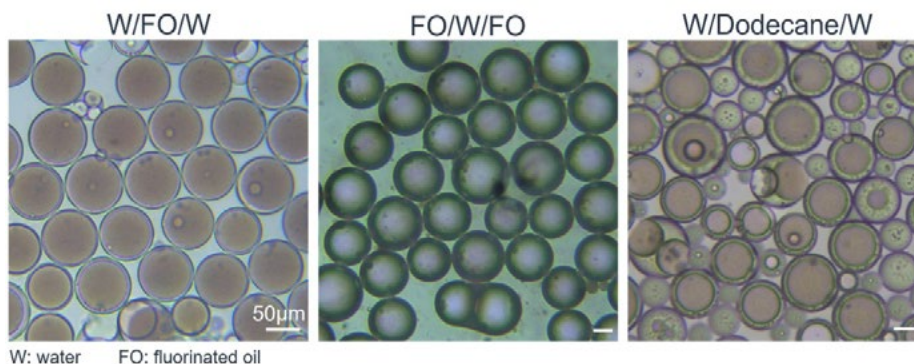
Double emulsions are defined as a fluid encapsulated within another immiscible fluid, dispersed in a continuous phase. This configuration is used for encapsulation, controlled release, or templating of advanced materials. While many applications require only the presence of an internal phase regardless of its structure, in some cases, it is important to have defined inner cores. In particular, single-core double emulsions are useful as very defined model systems, for example, to study confinements and crystallization processes [1,2], or for cell culture and tissue engineering [3].

The most widely used method for producing well-defined single-core double emulsions relies on sophisticated microfluidic devices. While microfluidics allows for precise control of the design of double emulsions (4), it requires the design of complex devices and laborious surface functionalization. A simple double emulsification method has been previously proposed, but it is limited by the density differences between the involved phases, which constrain the range of applicable formulations [2].

Here, we present a universal, scalable, and simple technique to generate single-core double emulsions using a syringe-based emulsification method. Our approach eliminates the need for complex equipment, and it is independent of the density gradients of the involved phases, enabling a broad range of fluid configurations. We investigate the method's tunability of droplet size and demonstrate its scalability capacity. This work offers a practical alternative to microfluidic methods for the production of double emulsions and provides a simple pathway towards the production of double emulsions using accessible, low-cost techniques.

Keywords:

double emulsion, single-core, microfluidics, organic solvent, fluorinated oil



Multiple double emulsions configurations. Double emulsions from left to right: water/fluorinated oil/water, fluorinated oil/water/fluorinated oil, and water/dodecane/water.

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MicroRNA-Induced Structural Changes in Reconstituted HDL Probed by Synchrotron SAXS

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Reconstituted high-density lipoprotein (rHDL) nanoparticles, discoidal assemblies of apolipoprotein A-I (apoA-I) and zwitterionic phospholipids, have emerged as promising endogenous-mimetic carriers for nucleic acid therapeutics targeting atherosclerosis. The capacity of rHDL to associate with and deliver microRNAs has been demonstrated in foam cell models of atherosclerotic plaque, with miRNA binding saturating at a 1:1 miRNA:apoA-I molar ratio [1]. Despite this therapeutic potential, the structural consequences of nucleic acid association with the rHDL disc remain poorly characterised at the colloidal level. Molecular dynamics simulations predict that single-stranded miRNA adsorbs at the headgroup region of zwitterionic phospholipid bilayers via hydrogen bonding and electrostatic salt bridges, an interaction mode strongly enhanced by divalent cations such as Ca^{2+} and Mg^{2+} , which adsorb onto the bilayer surface and electrostatically recruit the negatively charged miRNA backbone [2] [3]. Whether these atomistic predictions translate into measurable structural remodelling of intact rHDL nanodiscs under physiologically relevant ionic conditions is an open question.

Here, we address this gap using synchrotron small-angle X-ray scattering (SAXS) to characterise the structural response of rHDL (apoA-I / DPPC:LysoPC:EC, 75:20:5 mol%) to single-stranded miRNA addition across different concentrations of the divalent salt Ca^{2+} or Mg^{2+} . SAXS patterns of rHDL alone were modelled with a core-shell bicelle elliptical belt model; miRNA alone was described by a flexible cylinder consistent with its hairpin secondary structure; and rHDL–miRNA mixtures were fitted using a combined plugin model in which disc radius and head-region thickness were refined as free parameters. Systematic miRNA addition produced statistically significant increases in both particle core radius and lipid head thickness, with the miRNA-induced signal exceeding concentration-handling noise in all buffer conditions. Crucially, the magnitude of the radius and lipid head thickness increase with divalent cation concentration, consistent with cation-mediated enhancement of miRNA adsorption at the lipid headgroup interface. These results provide direct structural evidence that rHDL nanodiscs are remodelled upon miRNA addition, with changes in particle radius and headgroup layer thickness consistent with miRNA adsorption at the lipid surface, an effect progressively enhanced by increasing divalent cation concentration.

Keywords:

reconstituted HDL, nanodisc, microRNA, RNA-lipid interaction, divalent cations, SAXS, structural biology

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Influence of Supramolecular Structure on Hydrogel Strength

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Biological materials lend some of their material properties on their supramolecular structure. As a result, a small amount of molecular building blocks are responsible for a large variety of macroscopic behaviors [1]. Inspired by biology, hydrogel designs have started to include hierarchical structures [2,3]. However, adapting the supramolecular structure of hydrogels without impacting their molecular structure remains a challenge. One method to achieve this aim is by templating the hydrogel in another material, but this can limit the accessible suprastructures [4].

Here, we vary the supramolecular structure by templating the hydrogel in a bicontinuous interfacially jammed emulsion gel (bijel). Bijels self-assemble via interfacial jamming of nanoparticles during spinodal phase separation of two immiscible liquids [5-7]. By varying the wettability of the nanoparticles, we vary the bijel template structure without impacting the chemical composition of the hydrogel. In particular, we using this technique we can achieve a variety of structures; from non-porous with nanoparticle intrusions, to encapsulated pores, to bicontinuously porous.

We correlate structural information gathered from confocal laser scanning microscopy and scanning electron microscopy with the stress-strain relationship of the hydrogels. Because the manner in which we create the supramolecular structure of the hydrogels keeps the chemical composition constant, we can directly map the changes in hydrogel strength to its supramolecular structure. Thus, showing the importance of controlling not only molecular structure but also the supramolecular structure of materials.

Keywords:

Hydrogel, Bijel, Supramolecular structure, Particle stabilized emulsions

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Thin nanocellulose coatings as tunable selective layers for membrane separation

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Nanocellulose coatings offer hydrophilic, hygroscopic and chemically modifiable surfaces that can be applied as the selective layers in porous membranes.[1, 2, 3] However, they have inherent trade-off between permeance and rejection that depends on the nanocellulose dimensions and chemistry, coating thickness and nanocellulose-water interactions.[4] We investigated this trade-off by controlling the coatings' nanocellulose composition, applied coating thickness and membrane pre-wetting before filtration. Specifically, we used a pilot-demonstrated method[1] to fabricate nanocellulose-enabled ultrafiltration membranes by cast-coating dilute suspensions of chemically unmodified cellulose nanofibers (CNFs) and negatively charged TEMPO-oxidized CNFs (TCNFs) onto commercial polyethersulfone support (Figure 1). We identified with least-squares regression modelling that the permeance increased with decreasing coating thickness and that the dry-installation of the membranes without pre-wetting enhanced their size exclusion rejection capacity. Further characterization supported these trends and guided the selection of membranes for roll-to-roll pilot production that could be industrially implemented in the future. The pilot scale membranes had molecular weight cut-offs of 4-9 kDa and pore size distributions around 5 nm, which reflected the nanocellulose fiber width. The piloted membranes' specific permeances ranged from 100 to >300 L m⁻² h⁻¹ MPa⁻¹. While thicker coatings decreased the permeance, they also increased the membranes' negative surface charge, enabling electrostatic salt rejection in addition to steric sieving. Overall, thin coatings provided higher permeance and steric rejection performance (~90% for polyethylene glycol with theoretical particle sizes ≤5 nm), whereas thicker coatings resulted in lower permeance but improved electrostatic rejection (~50% of Na₂SO₄). The nanocellulose-enabled membranes matched or exceeded the performance of commercial ultrafiltration references and tolerated at least 2 MPa pressures and pH 2-12.

Keywords:

nanocellulose, water purification, ultrafiltration, pilot scale, coating

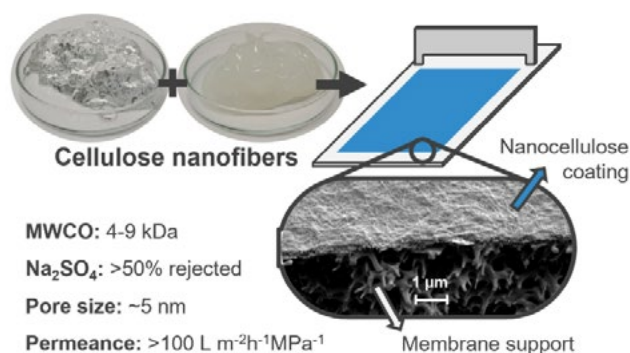


Figure 1. Nanocellulose-enabled membranes were manufactured by cast-coating CNFs on a porous support.

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Colloidal Routes to Thermoregulating Coatings from Phase Change Materials Polymer Nanocapsules

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Phase change materials (PCMs) regulate heat flows by storing and releasing latent heat during phase transitions, enabling passive thermoregulation [1–3]. Confinement within polymer shells prevents leakage upon solid–liquid PCMs. In this context, the integration of encapsulated PCMs (ePCMs) into coatings relies on precise control over capsule morphology, encapsulation efficiency, colloidal stability, and processability during film formation. Reducing capsule size to the nanoscale facilitates their incorporation into coatings while tuning heat storage dynamics and thermoregulating performance [2].

Polymer nanocapsules of organic PCMs were prepared by miniemulsion techniques, in which PCM-containing droplets act as nanoreactors for shell formation. Two strategies were employed to induce polymer growth at the droplet interface: conventional miniemulsion polymerization and interfacial polymerization. In the former, polymerization proceeds within monomer-swollen droplets, leading to shell formation through phase separation, whereas in the latter, the reaction is confined at the droplet boundary by the interaction of complementary precursors across the interface. The resulting colloidal dispersions were used to fabricate coatings via casting–solvent evaporation, preserving capsule integrity.

The influence of encapsulation on particle size and morphology was assessed, reflecting the interplay between interfacial stabilization and polymerization kinetics. Differential scanning calorimetry and thermogravimetric analysis confirmed successful PCM confinement, with encapsulation efficiencies above 90%. Thermoregulating performance was evaluated using a semi-adiabatic two-chamber setup, where heat transfer across the sample is governed by conduction and latent heat contributions. The incorporation of nanocapsules results in a measurable temperature-damping response, attributed to the presence of the ePCM and its effect on heat transport across the film.

Keywords:

Nanoencapsulation, Miniemulsion polymerization, Phase change materials, Heat storage, Thermal regulation

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Engineering Protein-Based Colloids

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Protein-based colloids provide a uniquely programmable platform for materials design. Because proteins are genetically encodable, their interactions, stability, and function can be rationally engineered, enabling applications across optics, health technologies, and environmental sensing. Within this landscape, fluorescent proteins (FPs) have emerged as powerful genetically defined optical modules that rapidly expanded from biological labels and sensors into synthetic materials. However, their broader materials use is often limited by fragility under non-native conditions. To address this challenge, a genetically encoded macro-oligomerization strategy was developed to strengthen FP–FP interactions through electrostatic control, yielding assemblies that remain stable for months in organic solvents and other harsh environments and can be embedded into non-aqueous polymer matrices. In parallel, computational protein engineering enabled the creation of highly supercharged FP variants that preserve photoluminescence and thermal stability while supporting controlled self-assembly with partner proteins in solid materials. Living biomaterials were also explored through the engineering and downsizing of bacterial spheroplasts, improving their interfacing with synthetic polymers and enabling more controlled interactions between living compartments and man-made matrices. More recently, the controlled production of cell-sized microbeads has enabled the encapsulation of bacteria, generating modular living–synthetic units whose composition and responsiveness can be tuned. Together, these advances illustrate how proteins can serve not only as structural building blocks of materials but also as functional components for applications in areas such as food technology and security.

Keywords:

Protein engineering; Protein-based colloids; Fluorescent proteins; Living biomaterials

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Contaminated phyllosilicates colloids separation by particulate flotation foams for excavated or in-situ soils decontamination

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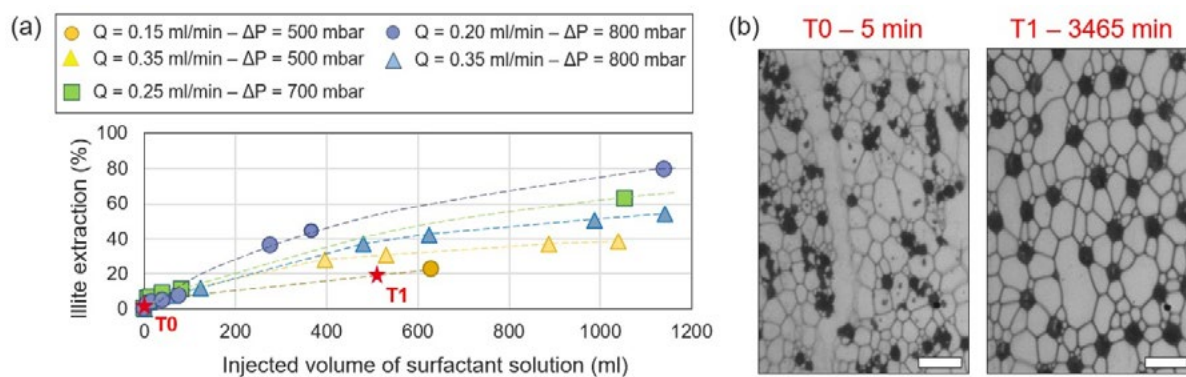
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Both colloidal phyllosilicates and organo-mineral clay-humic complexes microparticles are able to adsorb permanently in soils various chemical pollutants or even radionuclides, inducing long-term contaminations over several decades. The main contaminants fixed on these microparticles resist to water lixiviation such as metallic cations (lead, copper...) or, in the case of nuclear accidents, cesium-137 (¹³⁷Cs) with a half-life of 30.1 years. All these contaminated microparticles (1 to 100 µm) are most often located in the top of clay-sandy soil (0-30 cm depth) with low permeability coefficient (10⁻⁵ to 10⁻⁶ m/s). Two treatment strategies to decontaminate the soils are studied by CEA.

First, to treat large contaminated top soil areas (from 100 m² to 10 ha), the first step requires to excavate the topsoil (0-30 cm) to separate the finest granulometric part containing major contamination. More particularly in the case of radioactive Cs soil decontamination, CEA developed these latest years an environmentally friendly process with flotation foams operating in continuous mode that limits the production of secondary wastes and reduces the high volumes of contaminated soil [1]. The flotation foam process allows the selective extraction of the smallest phyllosilicates particles containing cesium in a flotation foam column. Soil is suspended in water (10 to 15% by mass) and CEA found that cationic TTAB surfactant is the best to selectively absorb on negatively charged phyllosilicate particles increasing their hydrophobicity. Ascending air bubbles injected at the bottom of the column capture selectively the hydrophobic phyllosilicate particles or aggregates and transfer the contaminated particles in a stable foam generated at the top column. The drying residue of the foam concentrates the contamination in a reduced volume divided by 3 to 7. Last year, a new foam flotation column was designed to use on real radioactive soils and confirmed the recovery of a major part of Cs in the foam residue with TTAB.

Secondly, for smallest surfaces called hot spots (<100 m²), one innovative method developed more recently is to generate ascending flotation foam flow directly in the soil through aspiration [2]. Over the last two years, CEA has studied the detachment and transport of foam-raw illite micrometric particles in model porous media made of glass beads. The *in-situ* generated foam properties are first evaluated with a non-ionic surfactant thanks to image analysis and conductance measurements (Foamscan® device, Teclis Instruments) under varying foam generation parameters (foaming solution flow rate Q and pressure gradient ΔP). The geometry of the porous medium, coupled with various flow rates and pressure difference, deeply influences the foam characteristics (liquid fraction, lamellae apparent thickness, bubble density) which may then result in different particles transport and extraction efficiencies. This method is relevant to precise the role of surfactant, i.e. TTAB, on the transport of adhered microparticles by lamellae thanks to surface charge modification.



(a) Recovery curves for illite particles in 0.5 mm glass beads-packed column under different conditions of in-situ foam generation. (b) Snapshots at different recovery times. Grains, illite aggregates (first snapshot) and lamellae appear in black, the porous area is in light gray. Scale is 0.5 mm.

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How phospholipids stabilize macro and nanoemulsions?

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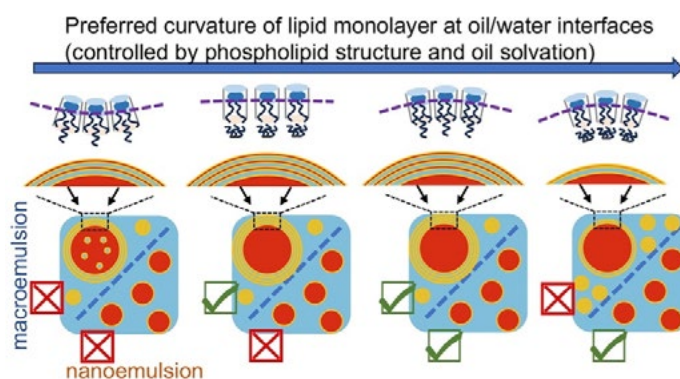
Delivering an emulsion intravenously for nutrition or drug delivery requires droplets to remain metastable at the sub-micronic scale in high ionic strength conditions. There is a large interfacial area to cover with a surfactant monolayer in these nanoemulsions and the amphiphilic species must be non-toxic. Phospholipids are thus industrially used to meet these constraints. However, their low preferred curvature, which sensitively depends on molecular structures and interactions, is not favorable for stabilizing emulsion droplets. We have investigated this problem to find a rationale for choosing formulation conditions leading to metastable emulsions, based on a fine understanding of interfacial properties and structure.

Four phase diagrams were established for ternary aqueous systems containing either DOPC or POPC as the phospholipid and hexadecane or miglyol 812 as the oil. Droplet interfaces were probed using small-angle neutron scattering and the amount of adsorbed lipid was determined using separation and Raman spectroscopy. The metastability of both nano and macro emulsions was systematically assessed over weeks using light scattering.

We show that a lipid monolayer stabilizes nanoemulsion droplets and display excellent metastability if the preferred curvature is positive and large enough, even without any added charges or at high ionic strengths. In contrast, macroemulsion droplets are stabilized with a lipid multilayer, which should possess a positive preferred curvature but also a good enough interfacial anchorage, which is lost upon increasing the preferred curvature. Overall, we provide a mechanistic description through which we can understand the impact of molecular changes in the formulation on emulsion metastability, through the analysis of the lipid film preferred curvature, layering, and interfacial anchorage. These results demonstrate how a virtuous circle can be established between fundamental soft matter approaches and industrial applications in complex formulations.

Keywords:

Parenteral, Emulsion, Self-assembly, Curvature, Metastability



Interplay between spontaneous curvature of the phospholipid monolayer and emulsion metastability

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Dissecting the Interactions of Superchaotropic Ions

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Polyoxometalates (POMs), among other large, multiply charged ions, associate with neutral polar surfaces, surfactants, and small nonionic molecules. [1] They favourably interact with nonionic surfactant foam [2] and micelles[3]. The unusual properties of these ions are explained by the “superchaotropic effect”. We have recently presented a classification of ions, which extends the Hofmeister scale and is based on ion size and charge [4]. However, many details of the molecular origin of this effect are not well understood.

Here we present all-atom and coarse-grained MD simulations of the interactions between $\text{PW}_{12}\text{O}_{40}^{3-}$ Keggin ions and oligoethylene glycoles. We quantify the interactions between Keggin ions and tetraethyleneglycol and between two Keggin ions by potentials of mean force and dissect the results into different contributions to the total free energy. Our results demonstrate the importance of contributions originating from water solvent, and help towards an understanding of the molecular driving forces of nanoion interactions.

Keywords:

Nanoions, Hofmeister effects, chaotropic effect

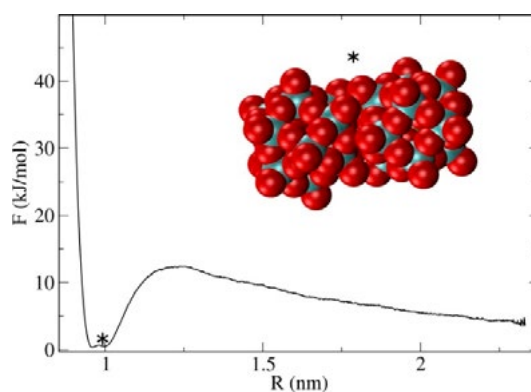


Figure 1: Potential of Mean Force between two Keggin ions from atomistic MD simulations. The snapshots shows a representative conformation of two ions at the distance of minimum free energy.

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Hybrid alginate beads embedding lipid mesophase nanoparticles: pollutant trapping validation

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While mesophase emulsions are well known in the field of drug delivery, lipid-based dispersed nanostructures have not yet been developed for water treatment applications. Our goal is to develop a composite material containing nanostructured emulsions capable of trapping external moieties such as emerging pollutants. In particular, we aimed to investigate the driving forces responsible for pollutant absorption.

Structured emulsions were formulated using eco-friendly precursors: squalane as the oil phase and monolinolein as the structuring lipid. The particles were stabilized by a triblock copolymer. An ultrasonic probe was used as a fragmentation tool, producing small particles with diameters in the 250–300 nm range. The internal structures were tuned by varying the lipid-to-oil ratio and were fully characterized using scattering techniques (SAXS).

The absorption kinetics of endocrine-disrupting compounds (bisphenol, phthalates, parabens, etc.) were investigated, showing that absorption rates correlate with both the type of internal structure and the interfacial area within the droplets. Trapping efficiencies were determined indirectly by monitoring pollutant concentration as a function of contact time between the mesophase dispersions and the pollutant solution reservoir, using UV spectroscopy and liquid chromatography.

To obtain a material that is easy to handle and suitable for water treatment applications, the mesophase particle dispersions were encapsulated in a biopolymer matrix based on sodium alginate. Using a dripping technique, the final material was prepared in the form of macroscopic colloidal beads. Since pollutants can directly access the internal emulsion droplets through the polymer network, the capture ability of the lipid mesophase particles is preserved. As observed for the structured emulsions, the absorption properties of the composite material depend on the lipid content and therefore on the nature of the internal structures and the interfacial area. We have shown that the absorbed pollutant affects the interfacial curvature in the monolinolein/squalane/water system.

Keywords:

emulsions, lipid mesophases, pollutant trapping

Highly stable aqueous foams with nanocelluloses and pectins

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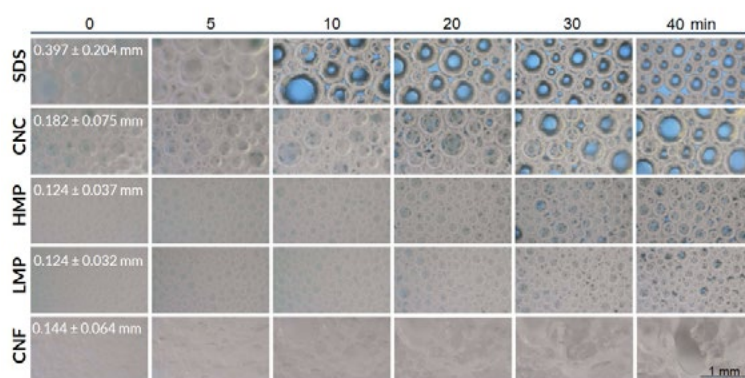
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Aqueous foams are dispersions of gas in a liquid phase, widely employed in food, cosmetic, and cleaning applications. Despite being thermodynamically unstable, their lifetimes can be significantly extended by adding colloidal species such as polymers and nanoparticles, which mitigate the effects of drainage, coarsening, and bubble coalescence [1,2]. Foam stabilizers used in industrial formulations are typically derived from petroleum sources or animal proteins, which are associated with environmental problems and allergies. In this study, plant-based biopolymers, including cellulose nanocrystals (CNCs), cellulose nanofibrils (CNFs), and high- and low-methoxyl pectins (HMP and LMP), were incorporated into aqueous foams with 0.5% (m/m) sodium dodecyl sulfate (SDS). Dispersions with varying biopolymer concentrations (0.25–1.5%) were prepared, yielding negatively charged colloidal systems that exhibited pseudoplastic rheological behaviour. Foams were generated by mechanical agitation and evaluated for foamability, bubble size distribution, and half-life ($t_{1/2}$). Increasing biopolymer concentration led to reduced foamability and smaller bubble sizes, attributed to higher viscosity and consequently lower air incorporation. At 1.5% biopolymer content, the average bubble diameter decreased from 397 μm for SDS-only systems to 182 μm (CNC), 144 μm (CNF), and 124 μm for both HMP and LMP. Foam stability was enhanced by CNFs and both pectins, with $t_{1/2}$ increasing from 3.15 h, in the absence of biopolymers, to 233 h with CNF. In contrast, CNCs did not significantly improve foam stability, indicating that viscosity alone does not govern stabilization. These findings suggest that biopolymers may influence the interfacial organization of SDS molecules and the dynamics of coarsening processes. Moreover, mixtures of biopolymers consistently produced longer foam lifetimes than individual components at equivalent concentrations, evidencing cooperative stabilization effects. Additional cross-linking with calcium ions further improved foam durability across all systems at 1.5% biopolymer content, resulting in mechanically robust cross-linked gels. Overall, this work demonstrates a sustainable strategy for tailoring foam stability using plant-derived colloids, offering for potential application in cosmetics.

Keywords:

Foams, Nanocellulose, Pectin, Foam half-life



Structure of plant-based biopolymer foams over time by optical microscopy.

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Acknowledgements:

FAPESP through the Young Investigators Grant (2023/09659-7), and the Research, Innovation and Dissemination Center for Molecular Engineering for Advanced Materials – CEMol (Grant CEPID N° 2024/00989-7). GGS thanks the scholarship FAPESP 2023/14118-5.

Application of nanoparticle-surfactant composites for the foam and emulsion stabilization

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Nanoparticle–surfactant composites represent a versatile and promising class of materials for regulating interfacial phenomena in dispersed systems. Their physicochemical behavior is governed by adsorption processes, electrostatic and hydrophobic interactions, and structural reorganization both at the interface and in the bulk. Surfactant molecules adsorbed on nanoparticle surfaces alter surface tension, rheological properties, and interfacial stability, while nanoparticles themselves influence micellization, aggregation, and the overall organization of surfactant assemblies.

A particular focus of this study is the role of silica nanoparticles combined with surfactants of different nature. Experimental results demonstrate that these composites significantly enhance foam stability by reinforcing interfacial films, reducing liquid drainage, and slowing coalescence. In emulsions, nanoparticles act as stabilizers via Pickering-type mechanisms, creating more robust and long-lasting structures. This dual ability to stabilize foams and emulsions highlights their multifunctional character.

From an application perspective, the stabilization effects of nanoparticle–surfactant composites are especially relevant for enhanced oil recovery (EOR). Improved foam stability enables better mobility control in porous media, while stronger emulsions facilitate more efficient displacement of residual oil. Beyond EOR, such systems hold promise in other industrial processes where interfacial control is critical, including detergency, food formulations, and environmental remediation.

Controlling assembly at the air-water interface through protein-nanoparticle pairing: the effects of protein structure, flexibility and NP interaction.

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Controlling the assembly of nanostructured layers at fluid interfaces is key to nanoscience given their role in functional materials and biological systems. How nanoparticles (NP) adsorb, pack and organise at the interface affects the performance, stability, mechanical response and functionality of the interfacial layer. However, achieving rational control over these processes remains a challenge. A common approach to tuning NP interfacial behaviour is to use surface-active ligands that modify particle wettability and interparticle interactions [1]. Thanks to their amphiphilicity, structural heterogeneity and conformational adaptability, proteins can form complex, dynamic interfacial films, making them particularly attractive yet under-explored interfacial modifiers [2].

We systematically investigated the interaction between model negatively charged silica NPs and three model proteins that, while sharing a negative state at neutral pH, differ in structure and flexibility: bovine serum albumin, β -lactoglobulin and β -casein. Using a combination of bulk-sensitive (circular dichroism, fluorescence spectroscopy, dynamic light scattering) and interface-specific (dynamic surface tension, grazing incidence small-angle X-ray scattering and compression isotherms at the air–water interface) techniques, we established a direct link between protein–NP interactions in bulk solution and the structure, packing, and mechanics of the resulting interfacial layers and demonstrated that NP interfacial assembly can be rationally controlled through protein–NP pairing.

Beyond providing fundamental insight into hybrid interfacial systems, these findings are directly relevant to the design of protein–NP building blocks for applications where controlling interfacial assembly at the molecular level is the key to unlocking system performance.

Keywords:

Fluid interfaces, protein–NP interaction, protein structure, protein stability, mixed protein–NP films, adsorption

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Macro- and nano-scale electrostatics govern self-assembly, interactions, and self-healing at charged aqueous surfaces

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Understanding how the electrostatic interactions influence the structure and properties of aqueous surfaces is of fundamental importance in many fields spanning emulsion/foam stabilisation, catalysis, materials science, and biochemistry. Yet, the role played by the ionic strength and charged species is poorly understood.[1] Here, we apply a macro and nanoscale structural and electrostatic characterisation to elucidate how the ionic strength and the cation charge modulate the organisation and electrostatic response of negatively charged silica nanoparticles at the water surface.[2] We identify a self-regulation mechanism whereby the steady-state inter-particle distance is dictated by a characteristic mesoscopic electrostatic potential and a fixed single-particle repulsive energy, irrespective of ion identity and ionic strength. Changes in the electrolyte composition set the nanoparticle surface excess, which adjusts to compensate for changes in the interfacial dipolar strength. Furthermore, the behaviour of the monolayer under mechanical deformation demonstrated the onset of composition-dependent short-range inter-particle attractions as the ionic strength or the cation charge increased. Such attractions also determine the monolayer relaxation mechanism upon compression. In the presence of strong attractions, the monolayer relaxes via the formation of two-dimensional clusters; vice versa, when nanoparticles repel each other, the relaxation leads to the formation of isolated nanoparticles at the surface. We will demonstrate that the two relaxation mechanisms markedly influence the monolayer's self-healing capabilities upon mechanical compression. This provides further tools to build aqueous surfaces with tailored structure, properties and dynamical response to stimuli.

Keywords:

Interfacial electrostatics, Ion effect, Electric double layer, Dipolar interactions, Interfacial screening

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Temperature Induced Electrical Percolation in Mixed Reverse Microemulsions

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The doping of most widely used sodium bis (2-ethylhexyl) sulfosuccinate (AOT) reverse microemulsions interface with surfactants of different nature alters elastic rigidity of the interface, changes water solubilization capacity and microviscosity of the confined water, also affects percolation of electrical conductance, etc. Such flexibility of microemulsions is very important for various biological and technological applications of these mixed aggregated systems.

The goal of the proposed work was to study the influence of additives of surfactants of both monomeric and polymeric type, ((viz. nonionic polyoxyethylene (4) lauryl ether (Brij-30), tyloxapol, pluronic F-127, triton X 100, anionic sodium cholate (SC) and cationic promethazine (PMZ) and chlorpromazine (CPZ) hydrochlorides)) on the electrical percolation threshold and sizes of water droplets in mixed reverse microemulsions with conductivity measurements and dynamic light scattering method.

Electrical conductivity of the reversed mixed micellar solutions was measured with conductivity meter Orion Star A215. The average hydrodynamic radius (R_H) of the water droplets was determined by dynamic light scattering (Zetasizer Nano ZS, Malvern Instruments, UK) equipped with a He-Ne laser operating at 633 nm and at a measurement angles of 173° . The activation energy of temperature induced electrical percolation was calculated for each investigated microemulsion.

Electrical percolation in mixed (AOT and Brij-30, AOT and SC) microemulsions with a fixed value of the molar ratio of surfactant to water ($W=20$) takes place at relatively lower temperature than for reversed microemulsion based on sodium bis (2-ethylhexyl) sulfosuccinate alone. In contrast to this, quenching of percolation is observed in case of additives of cationic surfactant PMZ in temperature induced mode of electrical percolation. Tyloxapol and pluronic F-127 occupy an intermediate positions between the above-mentioned additives according to percolation suppression ability, however, the percolation threshold in the presence of pluronic ($T_p=50^\circ\text{C}$) exceeds that of tyloxapol ($T_p=40^\circ\text{C}$), and in the presence of triton X 100 (a tyloxapol monomer), percolation begins at an even lower temperature ($T_p=35^\circ\text{C}$).

The revealed changes in both: a) retardation or early occurrence of percolation and b) sizes of water droplets under the influence of additives of surfactants of different nature may be will useful to clarify the fine mechanisms of electrical percolation phenomenon in reverse microemulsions as they widely are applied in mimicking of biomembranes, membrane conductance of electrical impulses, mass transfer in organisms, etc.

A Predictive Hydrodynamic Criterion for Pickering Foam Formation by Hybrid Eulerian Multiphase Population Balance Modeling

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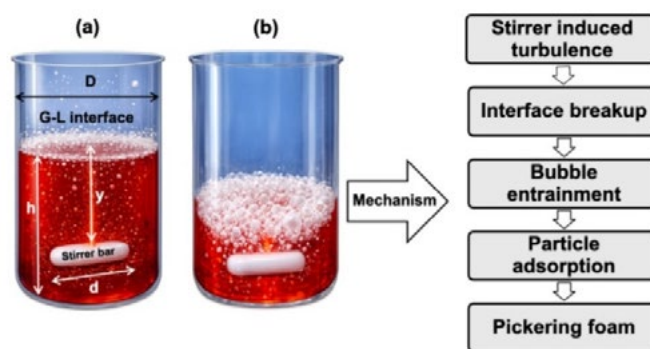
Particle-stabilized (Pickering) foams offer a versatile platform for intensifying gas-liquid-solid reactions by combining high interfacial area with the ability to anchor catalytic particles at gas-liquid interfaces.^{1,2,3} Despite their promise, the rational design and scale-up of Pickering foam reactors remain limited by the absence of predictive criteria linking hydrodynamics to foam inception.

Here, a predictive hydrodynamic criterion for the onset of Pickering foam formation in stirred reactors is established. By integrating systematic foaming experiments with a hybrid Eulerian multiphase computational fluid dynamics–population balance modelling framework, a critical instability threshold is identified. Foam formation is shown to emerge when the normalised stirrer–interface position exceeds 0.7 and the stirrer-to-reactor diameter ratio surpasses 0.5. This transition corresponds to a near-interface Weber and Froude-number regime in which turbulent inertial stresses overcome interfacial tension and gravity, leading to bubble entrainment that is subsequently stabilised by particles. This coupled model framework quantitatively captures bubble size distributions and accurately delineates foam and no-foam regimes across a wide range of reactor configurations, enabling the construction of a generalised dimensionless foamability map.

These findings provide a unified and predictive framework for understanding and controlling Pickering foam formation, offering a robust foundation for the scale-up and design of intensified multiphase catalytic reactors and other technologies exploiting structured gas-liquid interfaces.

Keywords:

Pickering foam, interfacial catalysis, population balance model, gas entrapment, bubble



Schematic and step by step mechanism of the foam formation in tube reactors depending upon stirrer-interface proximity. (a) No foam when the stirrer is away from the G-L interface (b) vigorous foaming when the stirrer is close to the interface. D : tube diameter; d : stirrer bar length; h

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Disintegration of colloidal lignin in emulsion interfaces as monitored and triggered by atomic force microscopy

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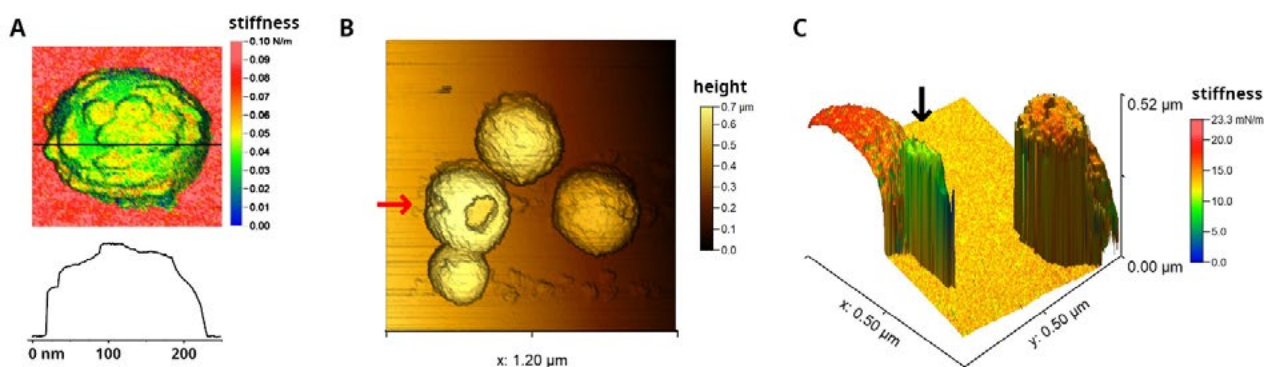
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Recently, we analysed Pickering droplets and their stabilising lignin nanoparticles (LNP) for their topography, stiffness, and adhesion using Atomic Force Microscopy (AFM). The measurements were done for ultrasonicated emulsions in nanoresolution under water.[1] We also showed that the droplets were moved and merged, and soft nanoparticles flattened in the interface (Fig. 1A), when they were contacted with increased interaction forces. There were also indications of thin interfacial films adding to the stability of the droplets, which is now backed with neutron scattering data.[1,2] Building on this, we now study the behaviour of colloidal lignin on emulsions that have been prepared with a low-energy microfluidic method.[3] Soft bioparticles often are presumed to be intact, well-attached to the Pickering-Ramsden interface, and separate from each other. However, we observed lignin aggregates (Fig. 1B) and particles detaching from the aggregations during the imaging (Fig. 1C).[4] Furthermore, we gained even stronger evidence of a thin layer stabilising the emulsion interface despite the mechanically gentler emulsification method. These results challenge the common presumption of having Pickering-Ramsden as the only stabilisation mechanism for emulsions with colloidal lignin and biobased particles in general. Besides presenting results, I will discuss general opportunities and pitfalls in AFM analysis of Pickering emulsions

Keywords:

Atomic force microscopy, emulsion, Pickering emulsion, lignin, colloidal lignin, interfacial particles, liquid-liquid interface



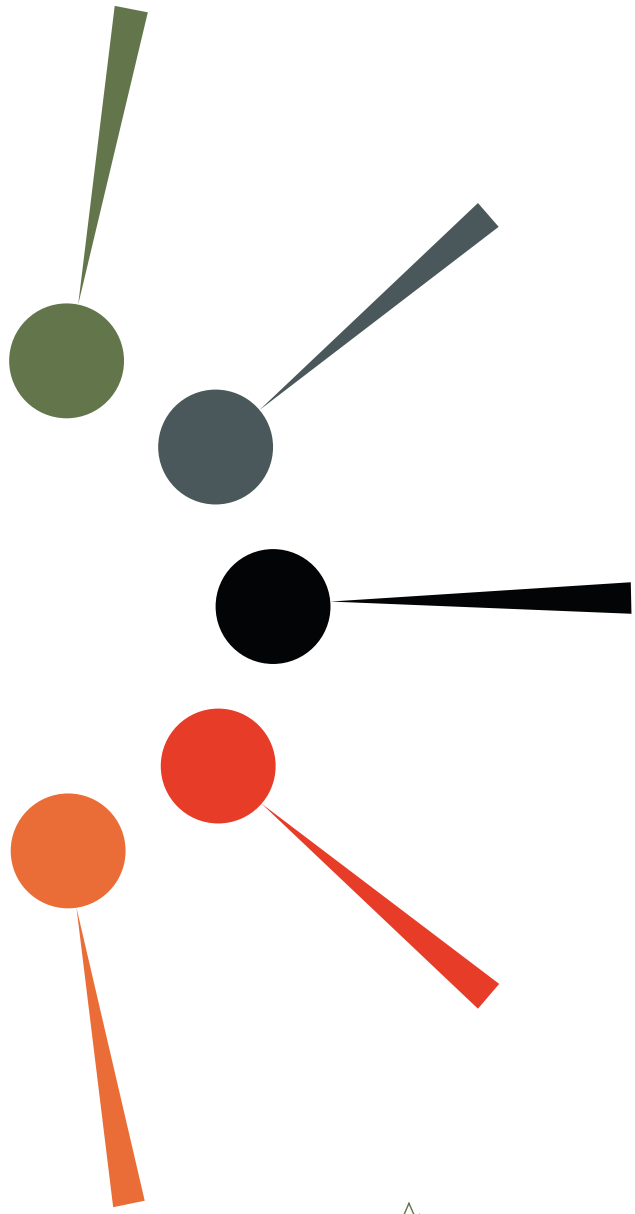
AFM micrographs of oil droplets under water. A: Flattened LNPs on a nanodroplet.[1] B: A hollow lignin particle on a microdroplet was chipped (red arrow), and bumps formed on the interfacial film at high contact forces.[4] C: A lignin particle detached (black arrow) from an interfacial aggregate.[4]

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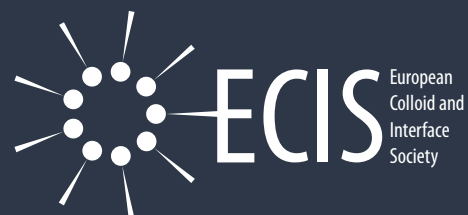
This work has received funding from ERC Consolidator grant (ID: 863808, "PARTIFACE") and Marie Skłodowska-Curie grant agreement (No. 956248).



Topic 4

Micro-, Nano-, Optofluidics, and
Rheology of Complex Fluids

! KEYNOTE



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DE GRANADA

Connecting recovery rheology to structural rearrangement in capillary suspensions

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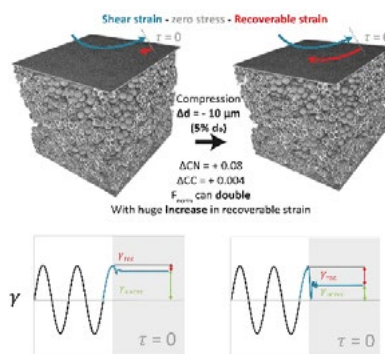
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Capillary suspensions, particle gels in a bulk fluid with small amounts of a secondary immiscible fluid forming liquid bridges at particle contacts, demonstrate unique behavior due to the strong capillary forces. Recovery rheology offers new tools to understanding the material response to deformation and distinguishing between contributions from different physical mechanisms. By measuring strain evolution after stress removal, the total strain can be decomposed into recoverable and unrecoverable components. Unlike conventional materials where the recoverable strains consist of instantaneous elastic recoil with slow relaxation, obscuring the true elastic response, capillary suspensions exhibit distinctive strain decomposition under oscillatory shear. Kinetic arrest imposed by capillary bridges constrains particle mobility during stress-free periods. Since capillary suspensions maintain their deformed network configuration over experimentally relevant timescales, enabling clean separation of elastic response originating from bridge stretching and bending, these can be used as an ideal model system to correlate the relevant physical processes to the network microstructure.

Using iterative zero-stress recovery under oscillatory shear combined with rheo-confocal microscopy, we isolate the elastic recoil of the capillary network and correlate macroscopic strain recovery with particle-scale displacements and liquid bridge morphology. Below the flow point, particles demonstrate more collective movement, and the rate at which recoverable strain is acquired increases dramatically, approaching the oscillatory cycle beginning. As amplitude increases towards and beyond the flow point, this behavior progressively disappears with trajectories becoming increasingly smooth and particle displacements becoming more local. This systematic evolution reflects the interplay between network elastic deformation and structural rearrangement onset and establishes a correlation between elastic response and recoverable microstructural deformation during the yielding transition in capillary suspensions.

Keywords:

Capillary suspensions, Recovery rheology, capillary force, yielding



Slight changes to the network caused by compression can lead to drastic changes in the recovered strain

An Optofluidic Microplatform for Quantifying Structure–Stress–Flow Coupling in Complex Fluids under Extensional Microflow

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Microfluidic extensional flows provide a powerful route to investigate how complex fluids deform, orient, and relax under processing-relevant conditions. This is particularly relevant for colloidal and interfacial soft-matter systems, where the macroscopic flow response is governed not only by solvent viscosity, but also by flow-induced reorganization of internal microstructure, including self-assembled aggregates, semiflexible macromolecules, and anisotropic supramolecular networks[1]. In such systems, interfacial interactions, electrostatic coupling, and structural anisotropy give rise to nonlinear rheological behavior and flow-dependent optical and nanoscale structural responses that are absent in simple liquids. However, quantitatively linking these responses to the local microfluidic flow field remains a major experimental challenge[2].

Here, we present an integrated optofluidic microplatform that combines contraction–expansion microchannels with spatially resolved flow birefringence, in situ SAXS, and μ PIV to probe structure–stress–flow coupling in complex fluids under well-defined extensional microflow. The platform integrates complementary optical and scattering measurements within matched microfluidic geometries, enabling direct access to birefringence maps, anisotropic SAXS patterns, and local velocity fields under identical flow conditions. In combination with μ PIV-based flow reconstruction and numerical analysis, the system provides a quantitative framework to correlate local deformation rate, optical anisotropy, and nanoscale structural orientation throughout the microchannel.

The approach is especially suited to colloid and interface systems whose behavior is controlled by self-assembly and interparticle or intermolecular interactions, such as surfactant-based wormlike micelles and charged biopolymer solutions. It makes it possible to resolve where and how flow-induced alignment develops in contraction–expansion regions, how orientational order evolves under strong confinement and high deformation rates, and how local structural anisotropy couples to the underlying kinematics. More broadly, the platform establishes a versatile experimental tool for microfluidic rheology and optofluidic characterization of complex fluids, and offers a general route to investigate flow-induced orientation, stress generation, and microstructural reorganization in colloidal and interfacial soft-matter systems.

Keywords:

microfluidic rheology, extensional flow, structure–stress–flow coupling

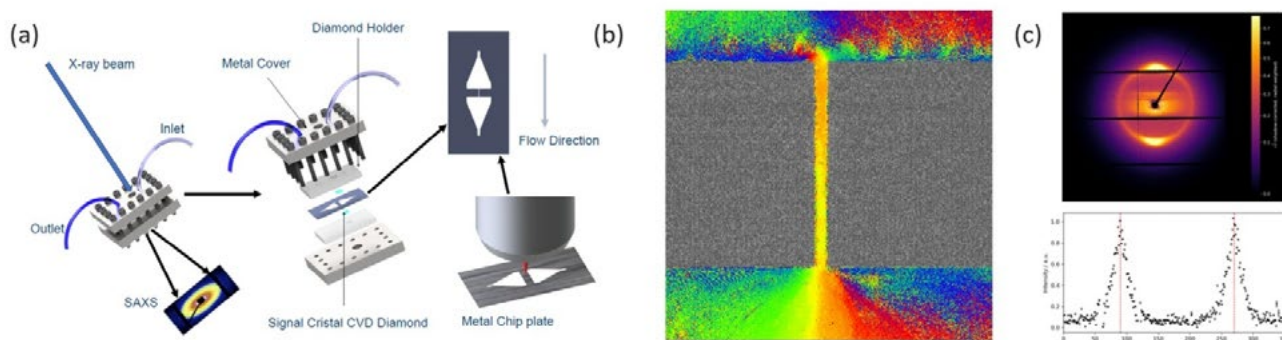


Fig. 1 Integrated microfluidic platform for birefringence and SAXS measurements under flow. (a) Microfluidic SAXS chip design. (b) Flow birefringence map. (c) Anisotropic SAXS response.

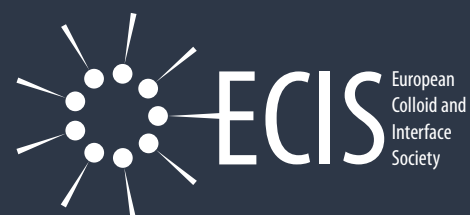
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Topic 4

Micro-, Nano-, Optofluidics, and
Rheology of Complex Fluids

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A 3D-PRINTED MICROFLUIDIC APPROACH FOR FABRICATING MICROCAPSULES IN AQUEOUS ONE-PHASE SYSTEMS (AOPS)

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Fully aqueous microcapsules are attractive for encapsulation applications because they offer mild processing conditions, good compatibility with aqueous formulations, and avoid the use of organic solvents. So far, the most established strategies for water-in-water (w-w) capsule fabrication relied on aqueous two-phase systems (ATPS). These systems enable compartment formation through phase separation, but they also restrict formulation design because capsule generation depends on preserving immiscibility between the two aqueous phases. Here, we propose an alternative route based on aqueous one-phase systems, where water in water capsules are formed directly from miscible polymer and surfactant streams. This approach preserves the benefits of fully aqueous processing while broadening the range of materials and formulations available beyond conventional ATPS based designs.

In this study, we present a needle-assisted 3D-printed microfluidic platform for the direct formation of w-w capsules from polymer-surfactant systems [1, 2]. By bringing the aqueous streams into controlled contact within a tailored flow geometry, the device eliminates the need for a separate templating phase. Its 3D-printed design also allows channel dimensions and device architecture to be readily adapted for different formulation systems, enabling reproducible production of microscale capsules with storage stability of up to six months.

Capsule formation is driven by polymer-surfactant coacervation [3, 4], which generates a shell around the inner aqueous stream and achieves encapsulation. Surfactant addition further improves colloidal stability and reduces aggregation during storage. SEM and AFM results showed that the capsule shell remained continuous and intact across both the microscale and nanoscales. In addition, particle accumulation tests using 1 μm polystyrene particles dispersed in the inner stream showed that, after storage, the particles accumulated along the inner surface of the capsule shell while the surrounding continuous phase remained clear. These observations indicate that the capsules maintained their encapsulation integrity and effectively confined the particles within the shell boundary.

Overall, this work establishes a practical strategy for generating stable and tunable w-w capsules in an aqueous one-phase environment. While further optimisation is required to minimise ancillary build up of PS complex precipitation in the microfluidic channel, the integration of controlled microfluidic assembly and polymer-surfactant complexation provides a versatile platform for developing all-aqueous capsule systems with potential applications in personal care, food, and drug delivery.

Keywords:

microencapsulation, microfluidics, coacervation, microcapsule, aqueous one-phase system (AOPS)

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Rhamnolipid Coacervate Microdroplets via Microfluidics: Generation, Morphology, and Interfacial Properties

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Rhamnolipids are microbial glycolipid biosurfactants composed of one or two rhamnose units linked to β -hydroxy fatty acid chains. Commercial samples exhibit significant chemodiversity, consisting of mixtures of mono- and dirhamnolipids with variable chain length and unsaturation [1,2]. Their amphiphilic architecture promotes spontaneous self-assembly in aqueous media leading to supramolecular structures such as micelles and anisotropic aggregates whose properties depend on concentration, pH, and ionic strength [1,2].

Under specific solution conditions, surfactant solutions may undergo liquid–liquid phase separation (LLPS), generating dense liquid phases known as coacervates, where solute-rich droplets coexist with a dilute continuous phase [3,4]. In surfactant systems, coacervation can be triggered by variations in ionic strength, as salt addition screens electrostatic repulsion between charged headgroups and enhances intermolecular association.

In this work, rhamnolipid-based coacervate droplets were generated under high ionic strength conditions using microfluidics. Experiments were performed with a Dolomite flow-focusing junction chip, where the rhamnolipid solution flowed through the central channel while saline solutions were injected from two lateral channels. Hydrodynamic shear at the junction breaks the central stream into discrete droplets, enabling precise control of droplet formation. The microfluidic setup produced monodisperse coacervate droplets in the micrometric range with controlled morphology and reproducible size distribution. The systems were investigated using optical and confocal microscopy to observe droplet morphology and dynamics, while electron paramagnetic resonance (EPR) provided information on internal organization. ζ -potential and rheology measurements further characterized interfacial properties and interparticle interactions, enabling the establishment of structure–property relationships.

Keywords:

rhamnolipids; coacervates; microfluidics; biosurfactants

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Light induced motion manipulation of micro-sized colloids in external flow - aggregation, fractioning and analysis

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All in one: What connects the interfacial sensitive fractioning and population-based interface analysis of micro-sized colloids between the mimicking blood clogging with inorganic particles. All those features are possible by light induced motion manipulation of micro-sized colloids in external fluid flows via microfluidics. This is possible with a photosensitive azobenzene containing surfactant, where the more surface-active *trans*-isomer adsorbs stronger on interfaces in comparison to the less surface active *cis*-isomer counterpart. This yields under illumination into dynamic exchange between *trans* - and *cis* -isomers making interfaces upon illumination phoretically/osmotically active – its phoretic strength is proportional to illumination parameters and more important also to interfacial properties.

In this sense sedimented colloids can be brought into a vertical displacement from solid-liquid interfaces. We show that this control of light induced chemical activity yields either to model representative of controlled blood coagulation for inorganic particles[1] or into simple and versatile population-based analysis[2] and fractioning of equally sized particles[3,4] varying only by their interfacial properties (porosity, material, surface coating or surface charge).

Keywords:

active colloids, photosensitive surfactants, interface based fractionation, population based porosity analysis, aggregation, microfluidics

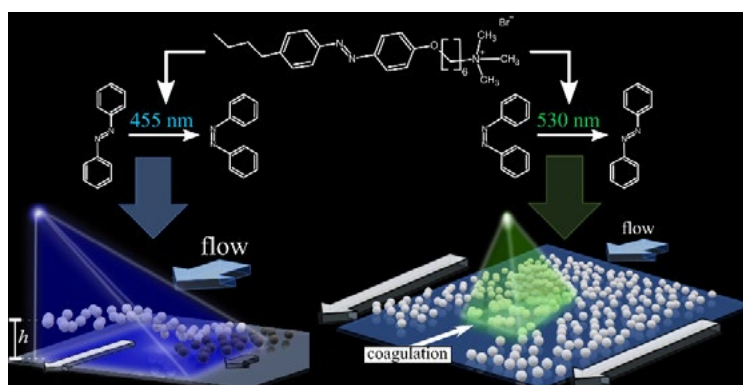


Figure 1. Light-induced control of microscale colloids with azobenzene surfactants. Blue light induces particle levitation and altered motion, enabling fractionation[3,4] and population-based porosity analysis [2]. Green light induces aggregation, causing localized, remotely controlled clogging.

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Rapid microfluidic osmotic compression of proteins to establish equations of state and phase diagrams

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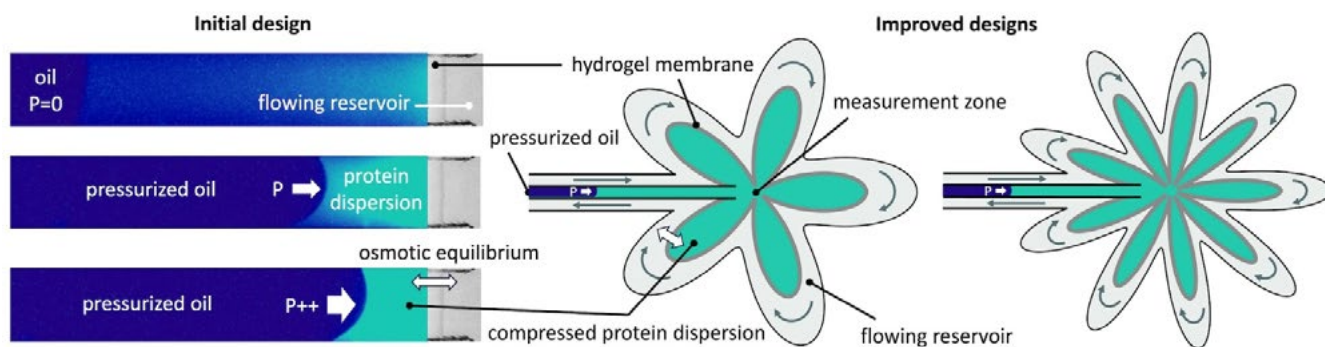
Understanding protein-protein interactions is essential for predicting and controlling the phase behavior of biomolecular systems, with direct implications for protein formulation, stability, and crystallization. However, stabilizing proteins in solution or, conversely, promoting their crystallization remains largely empirical.

Here, we will show how to design a microfluidic chip integrating a PEGDA hydrogel membrane synthesized in situ to perform osmotic compression experiments on small proteins. Compared to a previous design for larger colloids [1,2], these new membranes imply a smaller cutoff and a larger surface area. Different designs of membrane shape will be discussed.

Equations of state (osmotic pressure Vs. concentration) can be measured by fluorescence or Raman spectroscopy, for fixed pH and chemical potential of ions. These parameters are fixed precisely by maintaining a continuous thermodynamic equilibrium between the reservoir and the dispersion through the membrane. Changing the composition of this flowing reservoir can be performed in real time to observe the immediate response of the dispersion. A proof of concept is proposed with the well-known lysozyme protein.

Keywords:

microfluidics, membrane,
osmotic compression, proteins, phase diagrams, equation of state



Initial design (left) with a flat membrane synthesized across a straight channel and improved designs (center and right) with a membrane and flowing reservoir geometry optimized to accelerated osmotic compression

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Optothermophoresis-induced patterning of gold nanoparticles on solid substrates

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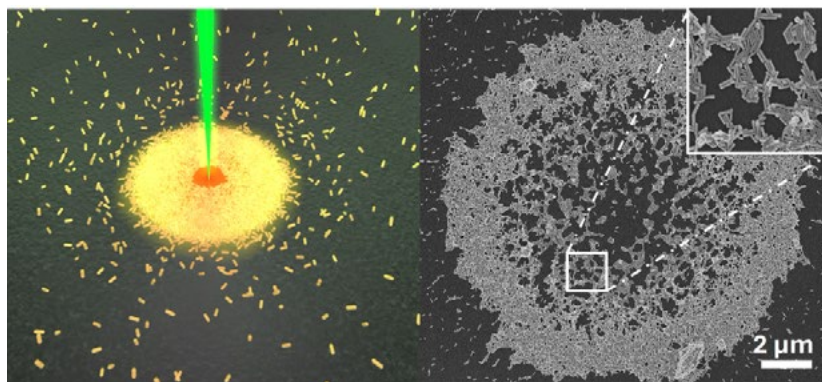
Colloidal assembly of nanomaterials into defined patterns is critical for integration of nanotechnology with solid-state devices. Optical control provides a simple and template-free means of patterning colloids into submicron features. In this talk, a rapid and versatile strategy for the assembly of gold nanoparticles on unmodified glass substrates driven by opto-thermal gradients will be presented [1,2].

By using both gold nanospheres and nanorods capped with cetyltrimethylammonium chloride (CTAC), we demonstrate rapid nanoparticle deposition within seconds at surfactant concentrations up to an order of magnitude below the critical micelle concentration (CMC). Rather than conventional depletion mechanisms, the assembly is consistent with a bridging flocculation mechanism governed by polymer-mediated particle-particle and particle-substrate interactions. The resulting structures can be tuned by varying solvent composition or nanoparticle shape. While spheres assemble in water, gold nanorods require the addition of a co-solvent, highlighting the influence of particle morphology and surface chemistry on the assembly process.

We further extend this approach by replacing polymer ligands with small thiol molecules capable of forming self-assembled monolayers (SAMs). The thiol chain length strongly influences the morphology of the assemblies, with longer chains promoting highly ordered hexagonal arrangements and shorter chains leading to more disordered structures. These findings provide new insight into opto-thermally driven colloidal assembly under non-equilibrium conditions and establish a simple route for the rapid fabrication of tunable plasmonic substrates with potential applications in surface-enhanced Raman scattering (SERS).

Keywords:

optothermophoresis, plasmonic nanoparticles, assembly, SERS



Patterning of gold nanoparticles using laser-induced thermal gradients

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Core@Shell Nanomaterials as Conductive Inks for Flexible Printed Electronics

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Bimetallic core@shell nanomaterials have attracted significant attention as functional components of conductive nanoinks, enabling reduced noble metal consumption while maintaining high conductivity [1, 2]. The performance of printed nanomaterials depends on multiple factors, including ink formulation (nanomaterial type, size, shape, stability, and rheology), substrate properties (surface energy, wettability, and roughness), and the printing method. Typically, conductive structures are formed through three stages: nanoink preparation, deposition, and post-printing treatment such as drying and sintering.

In this work, we developed two approaches for fabricating conductive coatings based on nanoinks composed of copper@silver nanowires (NWs) and nickel@silver nanoparticles (NPs). Both types of core@shell nanostructures were synthesized via a galvanic displacement process, yielding air-stable Cu@Ag NWs (~100 nm in diameter and 15–20 μm in length) and Ni@Ag NPs with an average size of ~220 nm.

The obtained nanomaterials were used to fabricate conductive films using scalable deposition techniques and low-temperature post-processing. Uniform Cu@Ag NW networks were achieved after sintering at 100 °C in a vacuum oven, while Ni@Ag NP-based coatings required a combined chemical and UV–Vis-assisted sintering process to ensure effective particle coalescence. The resulting films exhibited comparable electrical conductivity on the order of 10^4 S/m, attributed to favorable morphology and efficient interparticle connectivity.

These results demonstrate that core@shell nanoinks based on Cu@Ag or Ni@Ag nanostructures enable the fabrication of conductive coatings at low temperatures, making them suitable for heat-sensitive substrates such as polymers or paper. This approach offers a promising pathway toward cost-effective, scalable production of conductive elements for next-generation printed and flexible electronic devices.

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Temporal Decoupling of Viscosity Growth and Particle Aggregation in Shear-Induced Gelation

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Aqueous suspensions composed of silica nanoparticles and poly(ethylene oxide) (PEO) exhibit a reversible gelation phenomenon known as "shake-gels." These suspensions remain in a flowable, sol-like state at rest but temporarily transition to a gel-like state when agitated by hand or subjected to shear flow. Under steady shear at a constant shear rate, the viscosity increases abruptly after an induction period, resulting in gelation. Despite extensive research, the dynamics of gelation, particularly the relationship between the rheological response and internal structural evolution, remain poorly understood.

To elucidate the gelation dynamics, time-resolved rheo-USAXS (ultra-small-angle X-ray scattering) measurements were performed on aqueous mixed suspensions composed of silica nanoparticles and PEO under a constant shear rate. This technique enabled the simultaneous acquisition of temporal evolution of viscosity and scattering profiles reflecting particle-scale structures (**Fig. 1(a)**). When steady shear was applied, a sharp increase in viscosity was observed accompanied by gelation. Simultaneously obtained scattering profiles revealed that the dispersed particles became aggregated cluster structures. Notably, the increase in viscosity occurred prior to discernible changes in scattering intensity (**Fig. 1(b)**). This temporal dissociation suggests that a polymer-mediated network structure, which cannot be observed by USAXS, increased the viscosity of suspensions. This study is the first to demonstrate that viscosity growth occurs before particle aggregation during shake-gel gelation. This finding provides new insight into the stepwise development of gel network structures.

Keywords:

Rheo-USAXS, Shake-gel, Shear thickening, Silica nanoparticles, Poly(ethylene oxide)

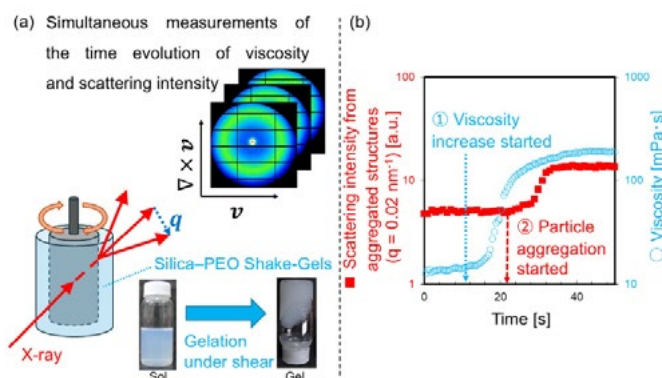


Fig.1 (a) The outline of the time-resolved Rheo-USAXS. (b) Viscosity increases preceded particle aggregations.

Acknowledgements:

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Resonance Shear Measurements Reveal a New Perspective on Boundary Lubrication

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Resonance shear measurements have provided new insights into the behavior of lubricant oils under boundary lubrication conditions [1-5]. Lubricant oils are widely used in machinery to reduce energy loss and wear, and one major direction in lubricant development has been to lower viscosity in order to reduce friction in the hydrodynamic regime. However, low-viscosity oils often show increased friction and wear in the boundary lubrication regime. This limitation is commonly attributed to direct contact between surfaces once the lubricant is squeezed out of the gap.

Our recent studies show that certain lubricants actually remain confined between surfaces even under conditions corresponding to boundary lubrication, and their effective viscosity can increase by up to three orders of magnitude compared with their bulk values. These findings suggest a new view of boundary lubrication: the high friction observed for low-viscosity oils may arise not from surface contact, but from highly confined lubricant layers whose molecular ordering dramatically increases effective viscosity. We also find that such ordering can be disrupted by introducing branched molecules [3-5].

In this presentation, we will discuss how various lubricant systems behave under confinement, including (1) phenyl ether lubricants and their mixtures [2], (2) isostearic acid[3], and (3) mixtures of isostearic acid with PAO (poly- α -olefin) or hexadecane[4]. Implications of this new perspective for the design of next-generation lubricants will also be addressed [1, 4, 5].

Keywords:

surface forces measurement, resonance shear measurement, lubricant oil, hydrodynamic lubrication, boundary lubrication, confined liquid

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Rheological and microstructural characterization of non-Brownian hydrogel suspensions

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Non-Brownian suspensions, as out-of-equilibrium systems, exhibit a strong coupling between their rheological properties and their microstructure. The latter is strongly influenced by particle characteristics. In particular, it has been shown that, in dilute non-Brownian suspensions, the pair distribution function is directly related to the surface state, notably the roughness, of the constituent particles.

In this work, we investigate this coupling between rheology and microstructure for non-Brownian suspensions of hydrogel particles. The particles are commercial hydrogels Aquakeep 10SH-NFC (kobo products, Unipex) beads swollen either in water or in a water–glycerol mixture, with a Young’s modulus ranging from 10 to 100 kPa. After sieving, the particles have a mean diameter of 300 μm and are dispersed in the fluid in which they were swollen. They are volume-labeled with a fluorophore (Nile Blue A). The suspensions are sheared in a transparent cylindrical Couette rheometer. The shear plane (velocity–velocity-gradient plane) is illuminated by a 30 μm thick laser sheet, which makes the intersected particles appear as bright disks. The laser sheet is mounted on a scanning system that allows its vertical position to be varied, providing a series of 2D images separated by a distance dz . From these image stacks, a three-dimensional reconstruction of the suspension is obtained (Figure 1).

An AI-based algorithm is used to detect the particles and to compute both the local volume fraction and the 3D pair distribution function for volume fractions ranging from 5% to 70%. The resulting pair distribution functions differ markedly from those measured in suspensions of more rigid spheres. Finally, the local rheology is investigated by particle tracking. We demonstrate the critical importance of measuring the local volume fraction in order to derive constitutive laws that accurately describe the rheological behavior of non-Brownian hydrogel suspensions.

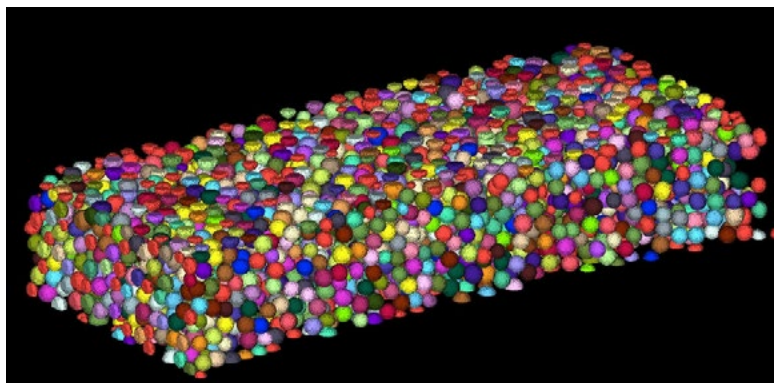


Figure 1. Three-dimensional reconstruction of the Aquakeep particle suspension at a volume fraction of 45%.

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Acknowledgements:

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Enhanced adsorption-limited process for model surfactants in the EDGE microfluidic device

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In numerous industrial processes such as spraying, foaming, or emulsification, interfacial dynamics are crucial for efficiency and stability. Interfacial tension is governed by the adsorption of surfactants at the interface. Understanding these transient dynamics requires quantifying the relationship between interfacial tension, adsorbed surfactant amount, and subinterface concentration, along with diffusion coefficients, adsorption timescales, and convective effects. However, no single experimental method currently captures all these parameters simultaneously.

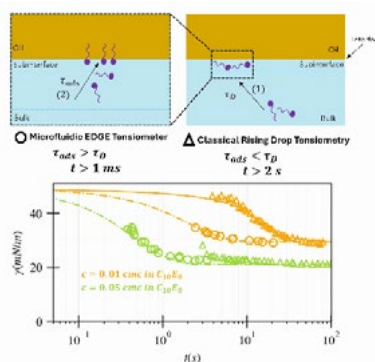
With classical tensiometers, it is difficult to study mass transport occurring below a few seconds, and diffusion is typically the limiting process. Adsorption and diffusion are therefore coupled, making it impossible to quantify kinetic parameters independently. Microfluidic devices offer a complementary approach, providing experimental conditions where adsorption-limited processes are enhanced while diffusion is no longer the limiting mechanism.

We studied the dynamic interfacial tension of two model surfactants, and SDS, at the water/hexadecane interface, combining a microfluidic EDGE tensiometer and a classical pendant drop tensiometer to cover timescales from 10 ms to 200 s¹. Diffusion parameters were extracted from pendant drop data using the Ward and Tordai² framework, while adsorption kinetics were characterized in the EDGE device through the rigorous thermodynamic model of Diamant and Andelman³ — which we show to be the limiting mechanism for in these conditions.

This combined approach allowed us to accurately interpret the full evolution of interfacial tension and to extract key physical parameters governing surfactant mass transport: diffusion coefficients, adsorption and desorption rates, and equilibrium isotherms. The resulting framework provides a unified and experimentally grounded methodology for measuring and modeling interfacial dynamics, with direct relevance to industrial processes involving rapid interface formation.

Keywords:

Interfacial tension, surfactant mass transport, microfluidics, adsorption kinetics, millisecond timescale



Dynamic interfacial tension captured by the EDGE microfluidic device compared to the classical tensiometry technique. Scheme of the adsorption process.

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Hierarchical Structuring and Rheology of Lignin–Polylactic Acid Blends for Additive Manufacturing

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Lignin is the second most abundant polymer on Earth and holds great potential for the future development of new, sustainable materials [1]. However, as a complex polyphenol both structure and properties are highly dependent on not only the source, but also the extraction method [2]. Here, chemically distinct lignins extracted from wood have been incorporated with polylactic acid (PLA) in fused deposition modelling (FDM), revealing that lignin chemistry will influence the compatibility with PLA, and the resulting melt behavior and mechanical properties. Rheological measurement revealed an increase in both storage and loss moduli with the addition of lignin, particularly in the low frequency regime, indicating the formation of a weakly connected aggregated network. The incorporation of lignin further promoted a higher zero shear viscosity, at high shear rates a pronounced shear thinning behavior was observed, enabling the extrusion during FDM. Microscopy and X-ray scattering measurements of the 3D printed materials revealed that lignin not only introduce a structural heterogeneity in the printed materials, but also results in a multiscale aggregation, with lignin domains spanning from submicron to micron length scales. The lignin aggregate size and distribution depended on the lignin chemistry, demonstrating its role on governing hierarchical organization within the PLA matrix. These insights show that lignin induce a multiscale structure that enhances low-frequency elasticity while maintaining processability through a shear-induced network breakdown, supporting the development of lignin-rich FDM materials that reduce PLA content while maintaining performance in additive manufacturing.

Keywords:

additive manufacturing, lignin, melt rheology

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Droplet elasticity reduces the contact time on superhydrophobic surfaces

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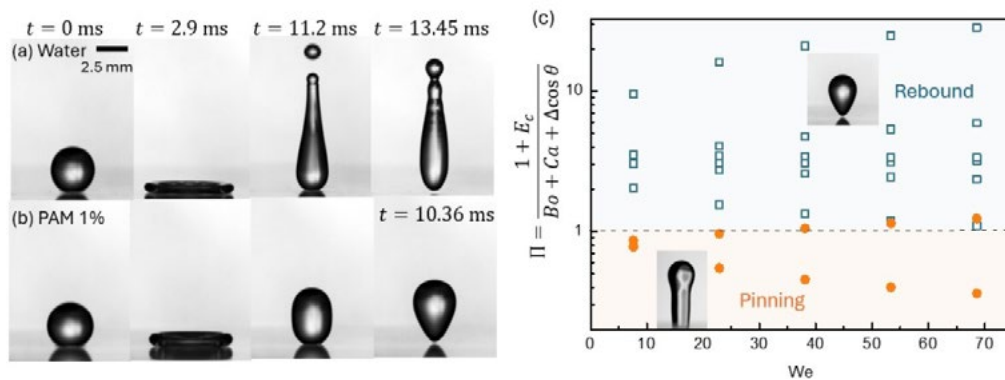
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Droplet impact is a ubiquitous phenomenon in nature and industrial applications. Extensive research exists on the impact dynamics of Newtonian droplets, while the non-Newtonian scenario remains poorly explored. In this context, viscoelastic droplets have been proposed as an alternative to suppress droplet rebound. Although this is helpful for droplet deposition techniques, it can lead to surface damage on superhydrophobic surfaces. In a previous study, we demonstrated that at very high impact speeds, droplet rebound is actually possible due to the balance between elastic and adhesion forces [1].

In this work, we investigate the impact dynamics of shear-thinning viscoelastic droplets impacting at low speeds on superhydrophobic surfaces. Notably, besides complete rebound, viscoelastic droplets with viscosities up to 10,000 times that of water reduce the contact time on the surface by more than 20%. We attribute this effect to the elastic energy released as kinetic energy during droplet retraction, as previously proposed for yield-stress fluids [2]. We propose a theoretical model to explain this outcome based on the retraction of slender viscoelastic ligaments, where elastic stresses contribute to capillary stresses in the retraction process. Our experiments are complemented by numerical simulations that also demonstrate contact time reduction. We further derive a rebound criterion obtained from an energy-balance approach, which is in good agreement with experiments.

Keywords:

Complex fluids, Superhydrophobicity, Elasticity, Contact line dynamics.



(a) Water droplet impacting a superhydrophobic surface at an impact speed of 1 m/s. (b) Polyacrylamide droplet impacting at the same speed. (c) Rebound criterion based on the Elastocapillary, Bond, and Capillary numbers, together with the contact angle hysteresis to predict outcomes vs. Weber number.

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Acknowledgements:

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Tailoring gold bipyramids for photothermal applications

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Plasmonic nanoparticles with five-fold symmetry offer an important advantage over their single-crystalline analogs due to their superior structural stability. The concentration of Au seeds is the sole factor determining the size and/or aspect ratio, and thus the optical properties of the nanoparticles. As a result, varying nanoparticle volumes while keeping their optical spectra unchanged remains a synthetically non-trivial task. We expand the chemical space for the synthesis of highly monodisperse penta-twinned gold bipyramids, achieving yields approaching 100%. In particular, we found that the combination of bromide ions and seed concentration allows for tailoring the dimensions and aspect ratio of gold bipyramids [1], enabling modulation of nanoparticle volumes while keeping their optical spectra unchanged. By exposing the nanoparticles to a constant position of the plasmon band under NIR laser irradiation, we found that larger AuBPs exhibited lower efficiencies, due to increased scattering contributions [2].

Keywords:

Precision Nanochemistry, Gold nanoparticles, Thermoplasmonic

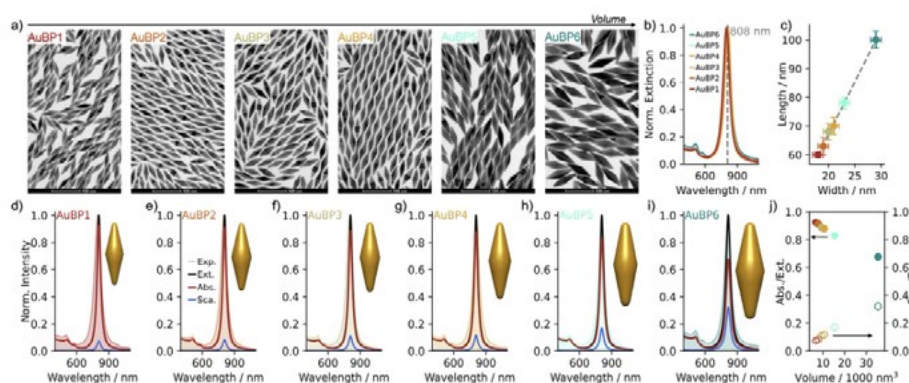


Figure 1. a) TEM images of AuBPs with increasing volume and constant aspect ratio. b) UV-Vis-NIR of samples with the maxima of LSPR at 808 nm. c) Length vs. width. d–j) Optical properties of AuBPs showing the increase of extinction contribution with increasing volume.

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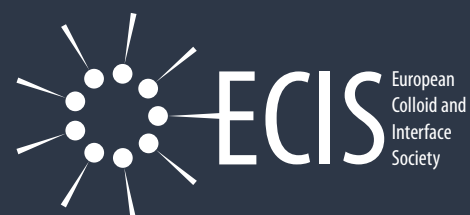
Acknowledgements:

This work was supported by the grant PID2022-141017OB-I00 and PID2022-137363OA-I00 funded by MCIN/ AEI/10.13039/501100011033 and by “ERDF A way of making Europe” and project HRZZ-IP-2022-103456 by the Croatian Science Foundation. Authors acknowledge the financial support received from the IKUR Strategy under the collaboration agreement between the Ikerbasque Foundation and Materials Physics Center on behalf of the Department of Science, Universities and Innovation of the Basque Government.

Topic 5

Wetting Phenomena,
Superhydrophobicity, Capillary,
and Surface Interactions

KEYNOTE



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Adsorption of a charged natural polysaccharide: role of pH and counterion on surface forces and film thickness

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In cosmetics, applications such as hair conditioning rely on the adsorption of polyelectrolyte films onto the charged surface of hair fibers, whose mechanical properties are central in determining the final sensorial perceptions. A current challenge for the cosmetic industry is to design high-performance products employing bio-sourced polyelectrolytes, with the aim of achieving eco-sustainable processes and products. Such design requires a deep understanding of the physico-chemical parameters controlling the adsorption and conformation of polyelectrolyte chains onto a charged substrate. We have used the Surface Force Apparatus (SFA) to investigate experimentally the effect of pH and counterion on the intersurface forces resulting from adsorption of chitosan onto negatively charged mica surfaces. Chitosan with 17% degree of acetylation and either acetate or lactate counterions was dissolved at 0.1 mg/mL in water with 100 mM of NaCl and pH adjusted to 3, 7 or 10. SFA measurements of the normal force vs intersurface distance were carried out, after chitosan adsorption onto the mica substrates and rinsing, in pure aqueous buffer with the same pH and salt content.

We find that, at pH 7, intersurface forces are repulsive and independent of the counterion. The range of such forces, on the order of 10-15 nm and larger than the Debye length at 100 mM of NaCl, is compatible with steric repulsion between chains forming a film whose thickness is about the Flory radius R_F of the chains. Repulsive forces measured at pH 3 are found to be comparable in range with pH 7. Surprisingly, we observe a twofold and reversible change in the range of repulsion when changing the pH between 3 and 10 (Fig. 1 A), with repulsion setting in at 20-30 nm at pH 10, suggesting a strong swelling of the adsorbed layer under basic conditions. This swelling at large pH is supported by numerical simulations of adsorbed chitosan chains, which demonstrate a spread of the monomer density profile and a decrease of the density peak at a distance of $\sim R_F$ (Fig. 1 B).

Our study, combining force measurements and numerics, sheds light on the role of pH on adsorbed chitosan and suggests that the thickness of the adsorbed film is mainly controlled by the near-wall monomer density.

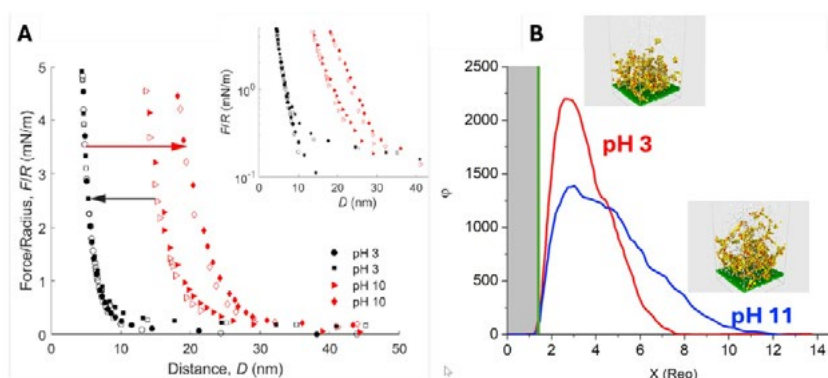


Fig. 1 – (A) Force vs distance curves obtained upon approach (full symbols) and separation (open symbols) at pH 3 and 10. (B) Monomer density profiles from numerical simulations of adsorbed chitosan

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Water drops sliding over arrays of Janus micropillars: A new mechanism of drop charging

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When water drops slide over a smooth hydrophobic solid surface, negative charges are spontaneously deposited at the rear of the drop, and the drops gain a positive charge. This phenomenon is known as slide electrification. Here, we demonstrate an alternative mechanism of spontaneous charge separation in sliding drops. Therefore, arrays of Janus micropillars were fabricated by photolithography. Each micropillar has a hydrophilic top created by reactive ion etching (RIE) and aminopropyltriethoxysilane (APTES) deposition, while the walls and substrate were hydrophobized by perfluorooctyltrichlorosilane (PFOTS). Drops on these arrays show high apparent contact angles, remain in the Cassie state, and still contact the hydrophilic top faces. Sliding drops acquire charge, with polarity and magnitude governed by top-surface chemistry, including $\text{NH}_3^+/\text{NH}_4^+$ formation and PFOTS removal after plasma exposure, and dense NH_2 groups formation from thermally activated APTES vapor deposition. Unlike flat surfaces, high-speed reflection microscopy reveals tiny satellite droplets left on each pillar that evaporate within one second. Consequently, charge separation occurs within the liquid phase between the primary drop and deposited satellites, rather than directly at the contact line.

“Probing Soft Matter: Long-Range Forces and Shear-Induced Phenomena in Compliant Systems”

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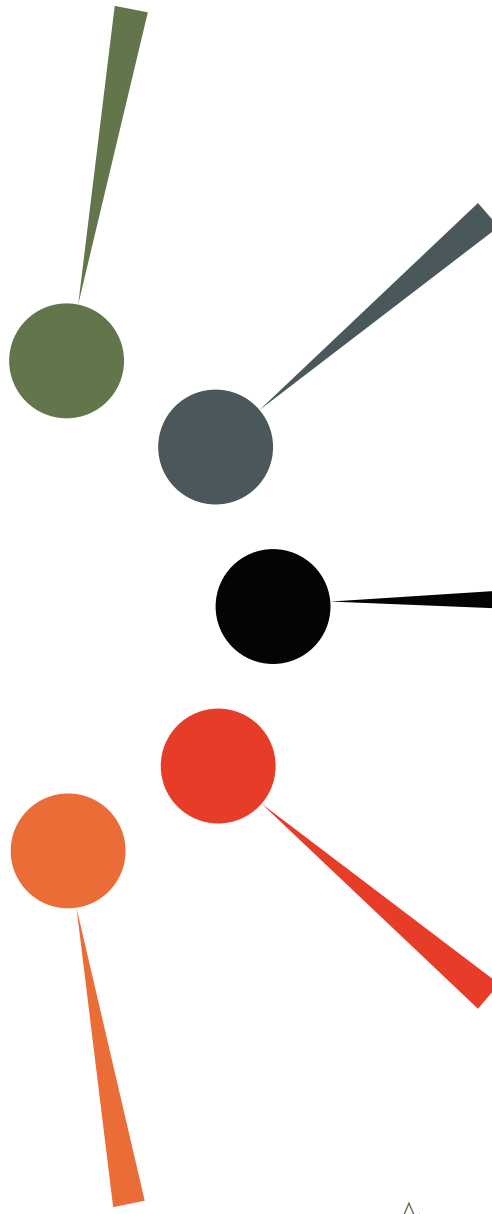
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Most studies on surface forces to date have focused on interactions between rigid objects, yet many systems of interest—particularly in biotribology—require understanding the behavior of compliant materials. Unlike rigid bodies, where deformations are localized near the contact zone, compliant surfaces can deform over much larger distances, making long-range surface forces critically important.

We investigate the mechanics of compliant systems under shear, including supported gels and thin membranes. Our work on microgel films reveals that long-range, distance-dependent repulsive interactions significantly influence contact mechanics, limiting surface approach under pressure due to pressure-induced contact stiffening. Additionally, we observe substantial normal (lift) forces between compliant surfaces in relative motion, with critical implications for lubrication—especially under small applied normal loads. This shear-induced repulsive pressure arises from elastohydrodynamic coupling and the symmetry breaking of the contact geometry under shear.

Membranes, with their slender and highly compliant nature, serve as prototypical examples of deformable boundaries. To accurately characterize their rheological properties and the resulting mechanical consequences, we have developed a modified Surface Forces Apparatus (SFA). This device directly measures the forces acting on a compliant membrane by evaluating its deformation field, enabling the study of membrane rheology and novel elastohydrodynamic effects—without requiring an external measurement spring. Our approach opens new avenues for probing the interplay between elasticity, hydrodynamics, and surface forces in soft matter systems.

A decorative graphic on the left side of the slide featuring five colored circles (green, grey, black, red, orange) of varying sizes. Each circle has a corresponding colored line extending from it at an angle, creating a dynamic, abstract composition.

Topic 5

Wetting Phenomena,
Superhydrophobicity, Capillary,
and Surface Interactions

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Humidity-sensitive mechanical properties of paper

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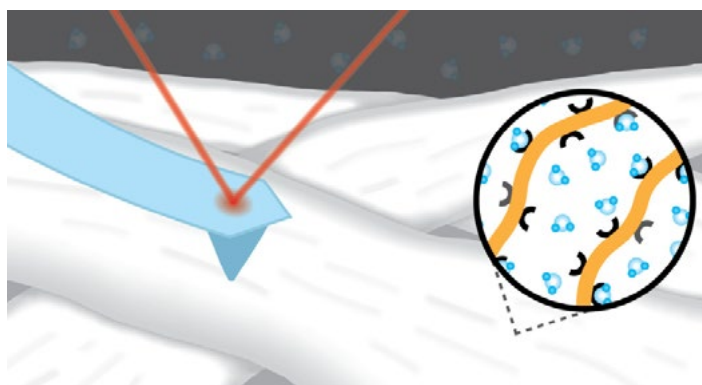
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The effect of moisture on paper is of great relevance for numerous applications ranging from printing to packaging. The uptake of water in the polymer network of the paper fibers via the liquid or vapor phase of water results in hydro- or hygro-expansion of the paper, respectively. In our study, we use an atomic force microscope to measure the out-of-plane hygro-expansion of paper by probing the surface whilst varying the relative humidity. The high spatial resolution of the atomic force microscope enables measuring the out-of-plane hygro-expansion of paper fibers with subnanometer resolution. By locking the atomic force microscopy tip at a predefined location on a paper fiber, we monitor the expansion and shrinkage of paper with a temporal resolution in the millisecond range. We find a linear relation between the relative humidity and the out-of-plane expansion of the paper fibers. We also find a good fit between a sorption isotherm measurement and the Guggenheim-Anderson-de Boer model. The combination of these two measurements suggests that the vast increase in weight seen in the isotherm is due to water filling the pores between the fibers, where it does not result in additional out-of-plane expansion. The high temporal resolution enables studying the kinetics of the out-of-plane hygro-expansion. We find that the process is best described using a double exponential function comprised of two exponents with different time scales, which we attribute to two separate adsorption sites.[1] Additionally, the atomic force microscope is used to record force-distance curves whilst varying the relative humidity. The nanomechanical properties extracted from these curves are used to further study the impact of moisture on the fiber network.

Keywords:

Hygro-expansion, Adsorption, Paper, Cellulose fibers, Atomic Force Microscopy



The illustration shows a network of paper fibers in a humid environment. The surface of this paper substrate is probed using an atomic force microscope. It measures the out-of-plane hygro-expansion, which is due to water molecules adsorbing onto the polymer chains within the paper fibers.

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Contact line friction of bubbles

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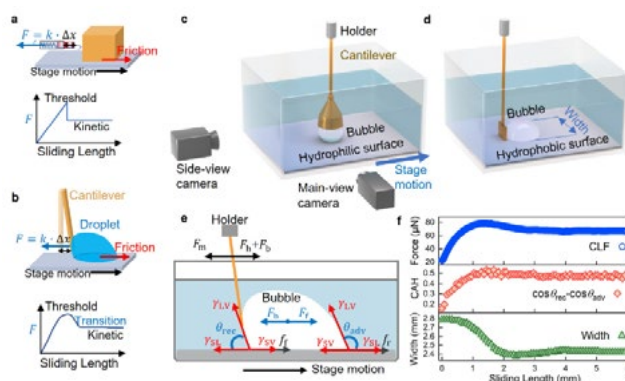
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Contact line friction (CLF) of bubbles is ubiquitous, from bubbles on a beer glass to H₂ bubbles sliding over electrodes in electrolysis. However, a fundamental understanding of CLF of bubbles is still missing, mainly due to the challenge of precisely controlling bubble sliding. For example, it is not clear how bubbles start sliding and how CLF of bubbles depends on velocity. We therefore developed a bubble friction force instrument to directly measure bubble CLF. This force develops from a static regime, through a transition, to a kinetic regime. This entire process is quantitatively described by a modified Kawasaki-Furmidge equation. Bubble CLF was measured for velocities from 0.2 μm/s to 2 mm/s, revealing a transition from a constant CLF regime below about 60 μm/s to a velocity-dependent CLF regime on surfaces with various wettability. The velocity dependence stems from interfacial adaptation governed by the liquid ionic environment with a relaxation time of around 10 μs. Moreover, CLF of bubbles can be measured on hydrophilic surfaces and under a challenging H₂ atmosphere, overcoming the limitations of current droplet-based methods. Our results provide a quantitative basis for understanding CLF of bubbles with relevance to many applications, including bubble manipulation and electrochemistry.



Schematics of CLF measurements. a, b, Setup and force curve of solid-solid friction (a) and droplet-solid friction (b). c, d, BuFFI for hydrophilic (c) and hydrophobic surfaces (d). e, Forces acting on the cantilever and bubble. f, Typical measurement results on a fluorinated silicon wafer.

Acknowledgements:

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The role of ions in the first nanometer below the water-air interface detected by nanometric capillary waves as observed by the LIFI interferometer.

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The LIFI (Liquid Interface Force Interferometer) technique¹ detects surface waves at the air–water interface with amplitudes ranging from ångströms to tenths of a nanometer. We investigate the resonant response of millimeter-sized bubbles to elucidate the role of the ionic strength of the surrounding solution. A range of salts with concentrations between 0.1 and 3 mM is examined. Variations in salt concentration mainly affect the amplitude of capillary surface waves, while only weakly influencing the quality factor of the resonance peaks. Salts with different ionic mobilities, including NaCl, KCl, and larger heavy ions, are compared, together with NaOH and HCl to probe their specific effect and the change of interfacial pH. Increasing the pH appears to slightly stiffen the interface and broaden the resonance, differently than other salts. The frequency dependence of the cross-phase between the exciting field and the resonant response² in the vicinity of the resonance peak provides the sign of the effective charge and the feature of the response. Concurrent conductivity measurements ensure accurate control of relevant solution parameters.

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Contact Line Instabilities in Sliding Viscoelastic Drops

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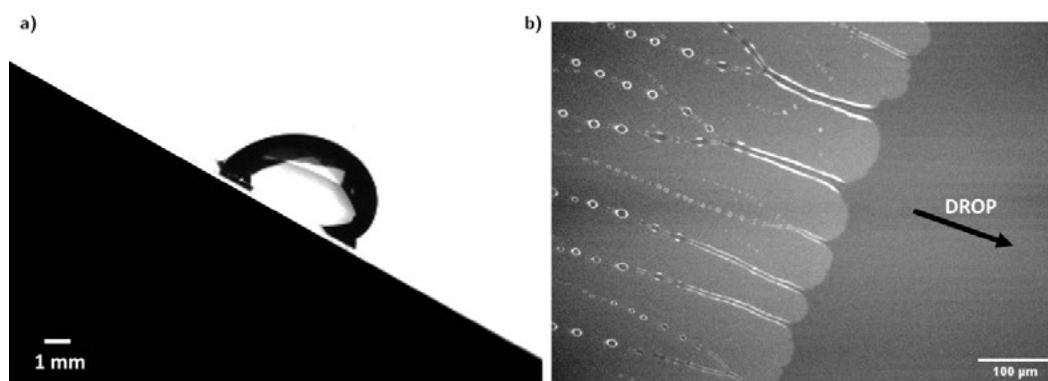
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Controlling the motion of non-Newtonian drops on surfaces is essential for applications ranging from inkjet printing to biomedical devices and food processing. While the macroscopic behavior of viscoelastic drops sliding on tilted hydrophobic surfaces has been characterized—showing reduced velocities [1] and elongation [2] compared to Newtonian fluids—the microscopic mechanisms behind these differences remain poorly understood.

To address this gap, we developed a high-speed, high-resolution reflection microscopy setup that enables direct visualization of the contact line of sliding drops. Using water-soluble polyelectrolyte solutions, we reveal how viscoelasticity influences the dynamics of the receding contact line and, consequently, drop motion. Our experiments demonstrate that viscoelasticity can destabilize the receding contact line, triggering filament formation. This instability previously observed in the coating of thin viscoelastic films [3,4], is reported here for the first time in sliding drops.

We further highlight the critical role of polymer charge in this process: while cationic and non-ionic polymers promote filament formation, anionic polymers do not, a difference that we link to the distinct wetting properties of the solutions. In conclusion, we clarify the interplay between rheology, surface interactions, and drop dynamics.



Viscoelastic drop sliding on a hydrophobic substrate. (a) Side view. (b) Bottom view showing the receding contact line, where instabilities develop and lead to filament formation.

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Antagonistic behaviour in surfactant mixtures spreading over solid substrates

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Synergism between surfactants used in spreading aqueous formulations is well-known. Such an example is a mixture of fluoro- and hydrocarbon surfactants, where low surface tension achieved by preferable adsorption of the fluorocarbon surfactant at the water/air interface is combined with low interfacial tension at water/hydrocarbon interface due to preferable adsorption of the hydrocarbon surfactant. This results in an increase of spreading coefficient and improved wetting of hydrophobic substrates. This synergism is used in aqueous film forming foam (AFFF) enabling extinguishing of fuel fires [1] and in reducing contact angle of aqueous formulations on solid substrates [2].

Remarkably, this possible synergism has not been previously probed for complete wetting scenario on solid substrates. Thus, the aim of this study is to explore whether it is possible to accelerate spreading of aqueous formulations over moderately hydrophobic solid substrates by combining surfactants, which can increase the spreading coefficient in comparison to the single surfactant case. The spreading of aqueous formulations was studied on two commercially available substrates: polyethylene (PE) and polyvinylidene fluoride (PVDF). Studied surfactants included some well-known commercial trisiloxane superspreaders (enabling complete wetting and fast spreading on the studied substrates), a commercial non-superspreader, a cationic surfactant mixture demonstrating superspreading behaviour and a fluorocarbon surfactant sodium bis(1H,1H,2H,2H-perfluorohex-1-yl) sulfoglutarate, 4FG(EO)₂, synthesized at Hirosaki University.

First, mixtures of trisiloxane and hydrocarbon surfactants with fluorocarbon surfactant were explored. Unexpectedly, unlike the spreading on liquids, antagonistic behaviour was observed in spreading on the solid. In particular, both 4FG(EO)₂ and commercial trisiloxane superspreader BREAK-THRU S 278 (BT-278) demonstrated superspreading on PVDF substrate with spread area being proportional to time (spreading exponent ~ 1). The spread area of 5 mm³ drop reached ~ 400 mm² for BT-278 and 600 mm² for 4FG(EO)₂ on the time scale of 12 s, whilst mixtures of these surfactants demonstrated only slow spreading with spread area being proportional to the square root of time (spreading exponent ~ 0.5). The spreading slowed down within 4 s and maximum spread area was below 100 mm².

Study of mixtures of different trisiloxane surfactants and mixtures of trisiloxane surfactant with hydrocarbon cationic surfactant has shown that there is a weak antagonism between various trisiloxane surfactants and moderate antagonism between trisiloxane and hydrocarbon surfactants. In the last case spreading exponent was also reduced to ~ 0.5 , but spreading was considerably faster than for mixtures containing fluorocarbon surfactant.

The change of the spreading exponent indicates a change in spreading mechanism. Therefore, the above results show that the symmetry in adsorption behaviour on liquid/air and solid/liquid interfaces and/or similarity of architecture of surfactants in mixtures are significant for fast spreading on solid substrate. This provides a new insight into superspreading mechanisms.

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Acknowledgements:

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Electrotunable Charge Separation and Its Effect on Dynamic Wetting

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Recent studies have shown that the dynamic wetting of a moving droplet on an inclined surface can be significantly influenced by slide electrification¹. During sliding, disruption of the electrical double layer at the solid–liquid interface leads to charge separation, leaving opposite charges within the droplet and on the solid surface at the rear of the drop². The deposited surface charge can, in turn, affect droplet motion and wetting behavior^{1,3}. Previous work⁴ has further demonstrated that, as charge accumulates, the droplet potential increases and eventually reaches a saturation value on the order of several kilovolts. These findings raise a central question: can charge separation be actively controlled by applying an external potential to the droplet? In this study, we address this question by applying a defined electrical potential to a droplet sliding on an inclined surface and systematically investigating the resulting dynamic wetting behavior. The droplet velocity and acceleration under different applied potentials are measured and correlated with charge separation. The electrostatic interactions arising from deposited surface charges are quantified to evaluate their contribution to droplet motion. In addition, the influence of deposited charge on solid surface energy and dynamic contact angles is analyzed. This work provides a strategy to actively control droplet motion and wetting behavior through modulation of the applied droplet potential.

Keywords:

slide electrification, electrical double layer, dynamic wetting, electrowetting

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Interfacial dripping faucet: generating monodisperse liquid lenses

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The dripping faucet is familiar to many liquid matter scientists, both because of its practical use as a tool to generate monodisperse droplets [1], and its rich behaviour as a dynamical system [2]. In this work, we present a surface analogue to a dripping faucet, where a viscous liquid slides down an immiscible liquid meniscus (Fig. 1). Periodic pinch-off of the dripping filament is observed, generating a succession of monodisperse floating droplets – also called liquid lenses [3]. We show that this interfacial dripping faucet can be described analogously to its single-phase counterpart, replacing surface tension by the spreading coefficient, and even undergoes a transition to a jetting regime [4]. This liquid/liquid/gas configuration opens perspectives for the study of the dynamics of emulsions at interfaces, which are involved for instance in flotation processes, enhanced oil recovery, and food science.

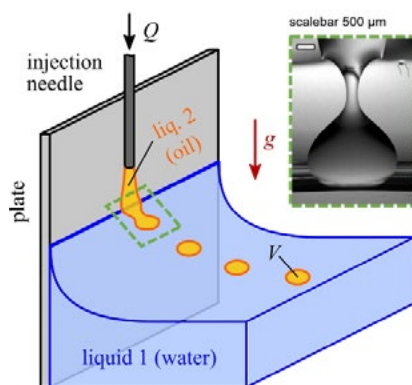


Figure 1. Illustration of the "interfacial dripping faucet" geometry.

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Can Fluorescence Anisotropy Probe Conformational Transitions in Polymer Brushes?

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The ability to undergo conformational transitions in response to external stimuli such as pH, ionic strength, or temperature makes polymer brushes promising surface modifications for sensing¹. The incorporation of fluorescent probes into polymer brushes introduces advanced functionality, enabling non-invasive and highly sensitive real-time spatiotemporal monitoring of structural and dynamic changes. To date, Förster Resonance Energy Transfer (FRET)-based measurements^{2,3} or fluorescence lifetime (LT) analysis⁴ have been applied to probe conformational transitions in polymer brushes. While fluorescence anisotropy (FA) is conceptually simpler and a self-referencing approach, it remains largely unexplored in this context. Excitation with linearly polarized light leads to depolarization of fluorescence emission due to rotational diffusion of the fluorophore. As a result, fluorescence anisotropy directly reports on molecular rotational mobility and polymer chain dynamics⁵.

Here, we demonstrate the application of fluorescence anisotropy to poly(N-isopropylacrylamide) (pNIPAM) polymer brushes in co-nonsolvency conditions. In response to solvent composition, polymer chains with terminal dye alter their conformations as well as the rotational mobility of chains - changes that are directly reflected in the measured anisotropy. FA increased from 0.10 in the swollen state to 0.26 upon collapsed, revealing conformational transitions under co-nonsolvency conditions. Specifically, enhanced segmental mobility in the swollen brush state allows greater rotational freedom of the incorporated dye, leading to lower anisotropy values. In contrast, the collapsed brush increases steric crowding and restricts rotational motion, resulting in higher anisotropy. These results establish fluorescence anisotropy as a broadly applicable tool for studying stimulus-responsive polymer surfaces. Compared to FRET or fluorescence LT measurements, FA offers a simpler and more direct measure of polymer chain mobility without the need for dual labeling or specialized chromophores.

Keywords:

Polymer brush, fluorescence anisotropy, conformational transitions, stimuli-responsive surface coating

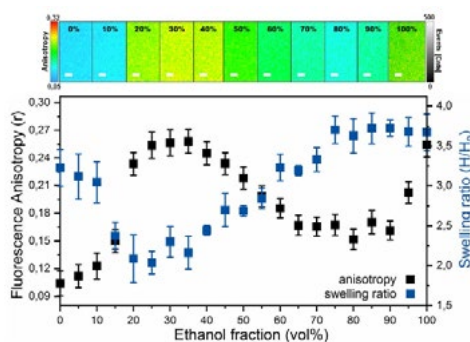


Figure 1. Fluorescence anisotropy images of pNIPAM brushes at varying ethanol fractions; the scale bar represents 10 μm (top). Fluorescence anisotropy and swelling ratio as a function of ethanol fraction (bottom).

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Acknowledgements:

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Charge patterns from water dewetting

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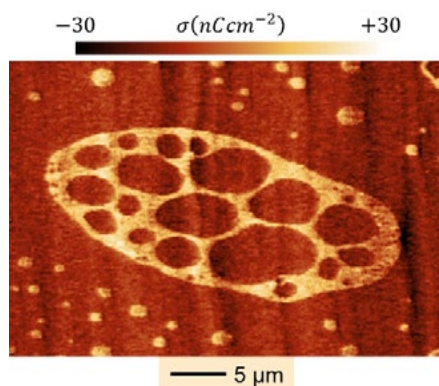
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Dewetting of water from partially wetting surfaces is a ubiquitous phenomenon that leads to charge separation: charges are deposited on the dewetted solid surface, while the receding water acquires an equal net charge of opposite polarity. We employ high-resolution frequency-modulated Kelvin probe force microscopy (FM-KPFM) to investigate surface charge patterns generated by withdrawing polystyrene coated substrates from a pool of water. The 27-70 nm thick polystyrene films were deposited on an indium tin oxide electrode supported by a glass plate. We observe oval charge patches and polygonal charge features up to 100 μm in size, with no corresponding topography. These patterns form predominantly at higher withdrawal speeds (~ 10 mm/s) and under conditions of slow evaporation at high relative humidity near the receding contact line. We attribute these patterns to the dewetting dynamics of nanoscopically thin water films. Based on the observed charge distributions, we propose a three-step charging mechanism: (1) In water, the polymer–water interface typically becomes negatively charged, with positive counterions in the diffuse layer. (2) During bulk water dewetting, a thin water film is formed at the macroscopic receding contact line, in which the positive counterions are slightly depleted. (3) Subsequently, the thin film dewets and thereby concentrates the positive ions, leaving behind regions enriched in negative ions and forming distinct positive charge patterns.

Keywords:

water dewetting, thin film formation, thin film dewetting, dewetting electricity, charge patterns



A positively charged “puddlet” on a negatively charged background observed on a water-dewetted polystyrene thin film. The tessellated hole pattern within the puddlet indicates the transient formation of a thin water film during dewetting, induced by dipping the sample into a pool of pure water..

Polymer Brush Mobility Revealed by Integrated Viscosity-sensitive Fluorescent Molecular Rotors

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As polymer brushes are gaining increasing relevance in numerous fields, including separation, coating and sensing technologies, or as model systems to biological barriers, there is an emerging need for a better comprehension over the material transport within. In the context of material transport, viscosity is a crucial parameter, but the conventional, shear-based and tracer-involving microviscosity measurement approaches are non-applicable for its experimental determination inside the surface-tethered, nanoscopic polymer brushes. To address this issue, brush-bound viscosity-sensitive fluorescent molecular rotors (FMRs) offer a viable route, as their fluorescence lifetime and intensity are indicative of the viscosity of their microenvironment, which - applying fluorescence lifetime-imaging microscopy (FLIM) - allows for visualizing local variations in brush viscosity with diffraction-limited resolution. In this work, we achieved this through the coupling of a rhodamine-derivative molecular probe (RV-1 [1]) to N-isopropyl acrylamide-co-2-hydroxyethyl acrylate (NIPAM-co-HEA) polymer brushes. According to FLIM and in-situ ellipsometry measurements under different water-ethanol mixtures and solvency conditions, the apparent viscosity within the brush increased with decreasing solubility (Fig. 1.), leading to maximum observed fluorescence lifetime and viscosity under cononsolvency conditions (20 V/V% EtOH). As the fluorescence lifetime was proven to be not entirely proportional to the brush expansion, we also ran molecular dynamics simulations to uncover the underlying mechanisms.

Keywords:

polymer brush, microviscosity, fluorescence, cononsolvency, FLIM

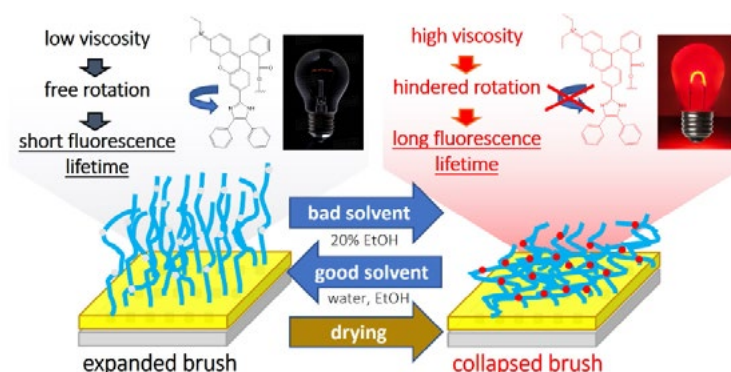


Figure 1. Mechanism of action of polymer brush-integrated fluorescent molecular rotors

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Acknowledgements:

The authors acknowledge the Deutsche Forschungsgemeinschaft (DFG, Project Nr. 496201730) (L.M., Q.A.B.) and the DFG Walter Benjamin Programme (L.M.) for funding.

Adsorption and Wetting Behavior of Epidote in Hematite Flotation: Insights from Experiments and Atomistic Simulations

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Froth flotation is a key beneficiation method in iron ore processing. Particularly, it is used in the flotation of hematite ore for removal of gangue (not valuable) minerals such as quartz (SiO_2), dolomite ($\text{CaMg}(\text{CO}_3)_2$), and epidote ($\text{Ca}_2\text{Al}_{2.16}\text{Fe}_{0.84}\text{Si}_3\text{O}_{12}(\text{OH})$). Among these, dolomite and epidote present significant challenges for the application of starch – the most common depressant for hematite (Fe_2O_3). The main problem arises from the adsorption of starch on dolomite (primarily at Ca and Mg sites) and epidote (likely at Ca and Fe sites). Each mineral exhibits different adsorption affinity and mechanisms depending on their specific surface chemistry. To address this challenge, it is important to understand the adsorption mechanisms of reagents, such as starch and other depressants, within the flotation cell, specifically focusing on how they interact with or adsorb onto mineral surface during the process.

In this study, we combine experimental and theoretical approaches to investigate the complex interactions on epidote surfaces. The experimental work included hydrophobicity tests, and surface characterization via microscopy and spectroscopy. In the theoretical part, we calculated and compared the adsorption energies of a single water molecule (H_2O), hydroxyl (OH^-), and starch on the (100), (010), and (001) planes of epidote ($\text{Ca}_2\text{Al}_2\text{FeSi}_3\text{O}_{12}(\text{OH})$) using density functional theory (DFT) study. Additionally, we compared computational and experimental water contact angles using Molecular Dynamics (MD) simulations. Furthermore, we performed MD simulations using systems that mimic an actual flotation cell to understand the interfacial interactions occurring within realistic flotation environment.

This research aims to provide new insights into the molecular-scale mechanisms governing epidote behavior in flotation systems. Ultimately, this work elucidates the mechanisms required for the effectively removal of epidote, supporting more efficient removal of epidote in iron ore beneficiation.

Keywords:

flotation, molecular dynamics simulations, hydrophobicity, interface

Electrification of water droplets for sustainable energy harvesting

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Solid–liquid electrification—the spontaneous charge separation that occurs when water contacts a solid surface—offers a promising route for renewable energy generation. Although this effect has been known for decades, its practical use has been limited because charge remains limited to the nanoscale electric double layer. However, recent work shows that when water flows as discrete plugs formed by mixing air into a hydrophobic tube, each plug can accumulate substantial charge, producing measurable electric potentials even in millimetre-scale channels. This indicates that natural water flows could be harnessed for power generation if the charging process is optimised.

Using the plug-flow pattern and contact-electrification, we developed an experimental setup that measures both the electrical potential generated as water plugs move through a hydrophobic tube (charging) and the subsequent exponential voltage decay (discharging) that occurs once the water flow stops. In this study, we focus on the charging dynamics. As each droplet moves along the hydrophobic polymer surface, it becomes positively charged while negative ions remain on the tube wall. The positively charged water is collected in an electrically isolated Faraday cup, and the total charge, Q , is determined by integrating the voltage–time signal. Preliminary measurements indicate charge generation on the order of 6.3 nC/mL under the current experimental conditions is achievable.

To understand which parameters govern charge generation in this system, experiments are conducted in which tube material and flow conditions are varied. We examine how properties, such as tube material, tube inner diameter, flow rate, plug size, and contact time affect charge transfer. We also explore how different surface geometries (e.g., flat versus tubular surfaces) may modify the charging of the droplets. At this stage, our measurements primarily demonstrate that reproducible charging curves can be obtained, providing a foundation for analysing how material properties and flow conditions might influence electron transfer and the resulting Q values. As this work progresses, identifying the most influential factors is expected to support a future development of hydrovoltaic systems for energy harvesting and sensing technologies.

Keywords:

Charge separation, contact-electrification

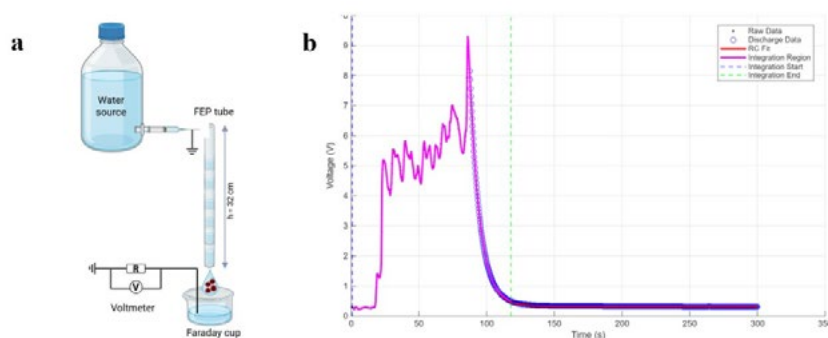


Figure 1.(a) Schematic representation of the experimental setup, (b) a representative voltage–time trace showing the system's charging and discharging dynamics. The total charge generated during the charging phase was 74.4 nC, indicated by the area of the curve in between the dashed lines.

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Direct Measurement of Interactions Forces between Silica Surfaces in Organic Solvents and Mixtures by Atomic Force Microscopy: Agreement with DLVO Theory

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The dispersion of colloidal particles in organic solvents is important in many industrial fields. The dispersion behavior of particles in liquids is governed by the interaction forces between their surfaces; therefore, a detailed understanding of these forces is essential for evaluating dispersion in organic media. While interaction forces in aqueous solutions are generally described by DLVO theory, those in organic solvents remain less understood, and no unified theoretical framework exists due to the diversity of solvent properties. In this study, interaction forces between silica surfaces in polar organic solvents and mixed solvents were directly measured using colloidal probe atomic force microscopy (AFM), and their consistency with DLVO theory was evaluated.

Measurements in various organic solvents revealed long-range repulsion in N,N-dimethylformamide (DMF) and ethanol. In ethanol, an additional attractive force was observed at separations of several nanometers, whereas only attractive forces were observed in 1,4-dioxane. The repulsive forces measured in ethanol and DMF were well fitted by the DLVO theory, suggesting an electrostatic origin.

Furthermore, interaction forces between silica surfaces were measured in binary mixtures of water and DMF, ethanol, and 1,4-dioxane at specified ratios, with NaCl added to a concentration of 1 mM relative to the total volume. The results indicated that electrostatic repulsion acts in solvents with dielectric constants down to approximately 20, but may disappear below this threshold. In solvents with lower dielectric constants, solvation forces were found to dominate the interactions.

Keywords:

Interaction force, Organic solvents, DLVO theory, Atomic force microscopy

A Versatile Method for Controlling the Wettability of Stainless Steel Meshes for High-Efficiency Fog Harvesting

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Addressing global water scarcity requires innovative fog harvesting solutions. While stainless steel meshes are durable and cost-effective, their intrinsic hydrophilicity often leads to pore clogging, reducing collection efficiency. This study presents a systematic experimental framework designed to precisely control the wettability of stainless steel meshes by modulating surface morphology and chemistry.

The framework employs copper electrodeposition to engineer surface roughness [1][2], followed by chemical functionalization with fluoro-silanes to lower surface energy. We demonstrate that the effectiveness of the silanization reaction, and the resulting macroscopic wetting state, is critically dependent on the presence of copper surface oxides. Using XRD analysis, we show that the extent of this oxidation can be systematically tuned through diverse surface treatments, including natural aging, accelerated thermal aging, and plasma treatment. This allows for the reproducible fabrication of superhydrophobic meshes with advancing contact angles above 150° and low hysteresis below 5°.

Single drop impact experiments were conducted on the following mesh configurations: (i) hydrophilic (advancing contact angle (ADV) < 100°, receding contact angle (REC) < 5°), (ii) superhydrophobic (ADV > 150°, REC > 145°), and (iii) double-layer, with one superhydrophobic and one hydrophilic mesh. The drop impact experiments, using millimetric water drops, were conducted across a Weber number range of 5 – 500, spanning two orders of magnitude. Results indicate that a superhydrophobic impact surface minimizes pore clogging, while the combination with hydrophilic mesh promotes droplet penetration and retention.

Among the studied cases, the double-layer configuration exhibited the highest water retention capacity across impact velocities spanning from 0.4 m/s to 3.6 m/s, suggesting that “Janus” configurations exhibit superior performance under varying wind speeds. This surface preparation and testing method provides a precise strategy to better understand wetting behavior and droplet dynamics, offering a significant step forward in the development of high-efficiency fog harvesting technologies based on fundamental surface property control.

Keywords:

fog-harvesting, wettability, functionalized meshes, stainless steel meshes

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How protein droplets phase separate on lipid membranes

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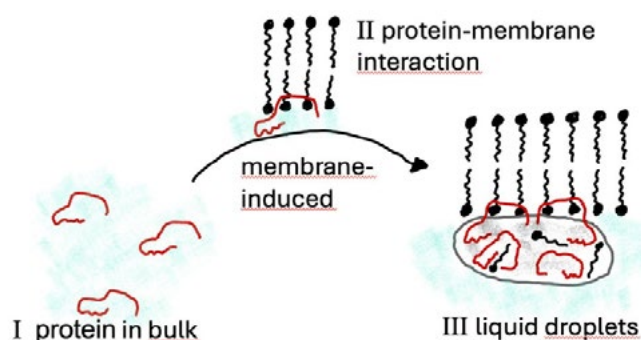
Membrane-induced liquid-liquid phase separation (MI-LLPS) of proteins is a process, where cellularly dissolved proteins interact with lipid membranes to form liquid-like protein microdroplets.

While LLPS is a relevant process to understand the physiological functions of the proteins, by maturation and rigidification these liquid microdroplets can also transition into cytotoxic oligomers and amyloid fibrils, which are directly linked to the pathogenesis of diseases like Parkinson or Alzheimer.

Therefore, phase boundaries of model proteins between the one phase and the two phase region were determined using turbidity measurements. Next these proteins were studied in the presence of lipid model membranes to observe under which experimental conditions membrane-induced LLPS takes place. Using these experimental conditions the model proteins were further investigated using fluorescent labelled protein and confocal microscopy as well as QCM-D.

Keywords:

Liquid-liquid phase separation, protein membrane interactions, prewetting, wetting,



Membrane-Induced Liquid-Liquid Phase Separation

Resonance-Controlled Surface Forces in Confined Aqueous Films

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Surface forces between solids immersed in water are typically measured under static conditions, without vibrations, even though most real interfaces, from engineered devices to biological tissues, function in environments where vibrations are constantly present. In this work, we use a multimodal surface forces apparatus to determine how nanometer-scale vibrations modify both long-range electrostatic interactions and short-range hydration forces between mica surfaces separated by water or dilute electrolyte solutions. By varying vibration frequency and amplitude, we detect a mechanical resonance in the low-kilohertz range at which a pronounced long-range repulsive force emerges. This effect is consistent with a vibroacoustic lift force produced by inertial hydrodynamics within the confined liquid film. The resulting dynamic “levitation” increases the average distance between the surfaces, in quantitative agreement with a continuum description of the squeezed film, showing that even extremely small vibrations can greatly enhance repulsion beyond classical expectations.

At very small separations, the same resonant vibrations also reorganize the hydration structure. Away from resonance, the interaction is dominated by a conventional short-range hydration force associated with a water layer about one molecule thick. At resonance, however, this confined water film expands into a more solid-like layer several molecules thick, whose thickness and effective decay length can be tuned by changing the vibration amplitude. This interfacial structure can also be reversibly formed and removed simply by turning the vibrations on and off. These findings show that surface forces are not fixed material characteristics, but rather interactions that can be dynamically tailored through nanovibrations. This insight has important consequences for colloidal stability, adhesion, lubrication, nanomechanical systems, and biointerfaces, where naturally occurring or intentionally applied vibrations could be used to enhance, suppress, or switch interfacial forces at solid–liquid boundaries.

Keywords:

surface forces, nanovibrations, acoustic levitation, hydration forces, electrostatic forces

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Probing Capillary Torque on Multipolar Particles at Dynamically Deformed Liquid Interfaces

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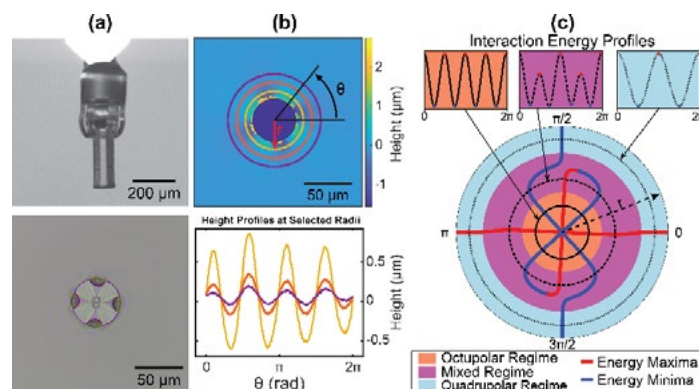
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We present a novel experimental platform for probing dynamic capillary interactions at liquid interfaces through the controlled coupling of externally imposed curvature to particle-induced interfacial multipoles. At the core of our platform is a self-aligning micropillar fabricated by two-photon-lithography (Figure (a), top), which pins the liquid interface to its circumference, creating a global interfacial deformation. The micropillar is mounted on a three-axis automated stage connected to a force sensor, allowing for precise control over both the position and extent of liquid deformation, while simultaneously recording forces. Integrated with a digital holographic microscope, our platform also enables real-time monitoring of the local interface undulations around pinned particles as well as the global interfacial deformation generated by the pillar.

Using this platform, we study two-photon-lithography-printed microparticles with tailored capillary multipoles (Figure (a), bottom) and quantify their response to a dynamically imposed monopolar interface deformation. From measured height fields, we extract the multipolar capillary charges of the particles (Figure (b)) and the monopolar charge of the micropillar. We use these quantities to determine the distance- and angle-dependent capillary energy landscape (Figure (c)) and the capillary torque driving particle reorientation. Because the capillary torque exhibits a slower radial decay than the capillary force, we can isolate particle reorientation in a regime of weak translation and quantify its dependence on particle-micropillar separation. Specifically, we identify a near-field regime governed by the particle's multipolar geometry, a far-field regime dominated by a more slowly decaying quadrupolar mode, and an intermediate regime in which several capillary modes contribute simultaneously (Figure (c)). We show the angular trajectories follow the predicted relaxation toward local energy minima and can be used to extract an effective rotational mobility. The ability to create and visualize controlled liquid deformations broadens our understanding of particle behaviour at liquid interfaces beyond static interfaces and opens new avenues for exploring particle dynamics in complex, dynamically evolving liquid topographies.

Keywords:

Capillary Torque, Rotational Dynamics, Liquid Interfaces



(a) Brightfield images of a mounted micropillar (top) and an octupolar particle at a water-oil interface (bottom), (b) height field measurement (top) of the particle with extracted azimuthal profiles (bottom). (c) Modelled capillary energy landscape based on experimental octu- and quadrupole values.

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From wetting ridge formation to swelling-dependent solvent diffusivity in oil-infused polymer brushes

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Capillary forces induce the spontaneous formation of wetting ridges of oil along the contact line upon depositing aqueous drops onto oil-swollen polymer gels and brushes. Using a combination of confocal fluorescence microscopy and high resolution white light interferometry, we analyze the growth kinetics of such wedges of hexadecane and the concurring depletion of the solvent in partially swollen brushes of poly(ethyl methacrylate) (PEMA). From the dependence of the wedge growth on the degree of pre-swelling with hexadecane, we infer that the polymer-solvent interaction parameter ' χ ' increases from 0.1 (good solvent) to 0.6 (marginal/bad solvent) with decreasing oil saturation. Analyzing the spatio-temporal evolution of the brush thickness next to the drop in terms of Alexander-de Gennes' model (incl. a saturation-dependent ' χ ' function) further reveals that the diffusion coefficient of the solvent in the brush decreases by almost two orders of magnitude from fully to weakly swollen polymer brushes. This finding is confirmed by independent Fluorescence Recovery After Photobleaching (FRAP) measurements. These findings reveal that both equilibrium and transport properties of solvents in brushes depend more strongly on the degree of swelling than frequently assumed.

Keywords:

polymer brushes, wetting, adaptive surface

Acknowledgements:

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Dynamics of Wetting on Submerged Superhydrophobic Surfaces

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Research on superhydrophobic surfaces submerged in water has shown that they remain water-repellent by trapping a layer of air, known as the plastron, within their surface irregularities. Sustainability of plastron is crucial for keeping the superhydrophobic surfaces functional for various underwater applications, such as drag reduction in microfluidic devices and marine vessels [1]. In this work, we induce pressure variations on superhydrophobic surfaces and attempt to understand their behaviour at different time scales ranging from a few days to less than a second.

We trap plastron on superhydrophobic surfaces containing micropillars fabricated in polydimethylsiloxane and coated with fluoropolymer. The micropillars are strategically arranged in a complex lattice arrangement inspired by the non-orderly nature of surface irregularities on natural superhydrophobic surfaces. An experimental setup for studying localized wetting transition on superhydrophobic surfaces underwater by focused ultrasound was earlier developed in [2,3]. In this work, we study the wetting transitions occurring at various time scales ranging from hours to less than 1 second. We classify our observations in three categories: long time scale wetting studies (under constant hydrostatic pressure), static wetting studies (under varying hydrostatic pressure) and dynamic wetting study (under ultrasound induced pressure). Our initial results indicate that the geometrical features of the microstructures play a key role on their wetting behaviours in the three scenarios. This study will help to understand how complex superhydrophobic samples respond and are resilient under different pressure variations (static and dynamic) as well as in different time scales as these scenarios simulate the real conditions for surfaces in various immersed applications.

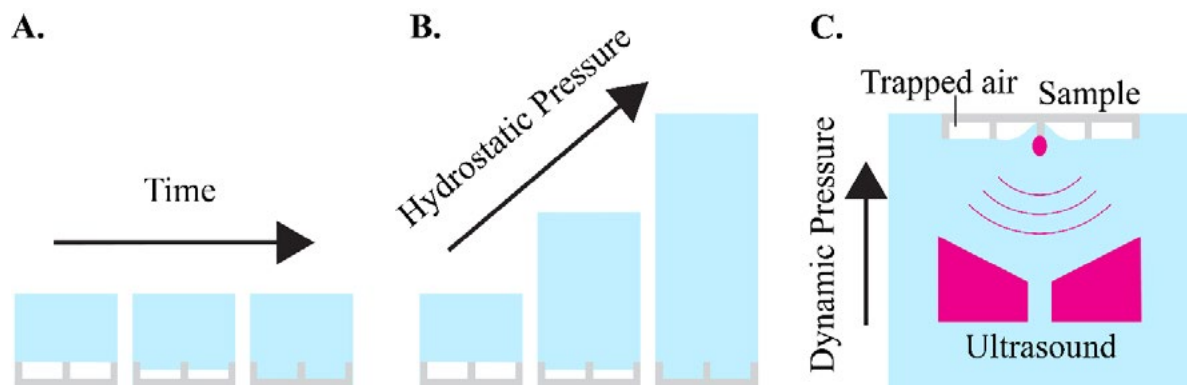


Figure 1: Wetting observations on a submerged superhydrophobic surface under different wetting scenarios. A. Long time scale wetting. B. Static pressure variation by increasing the hydrostatic pressure. C. Dynamic pressure variation induced by ultrasound.

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Acknowledgements:

Academy of Finland for Finland Center of Excellence Program (2022-2029) in Life-Inspired Hybrid Materials (LIBER) project and the grants 342169 and 342170.

Velocity Dependency of Ice Melting at Polymer Interfaces: A Molecular Dynamics Investigation

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The quasi-liquid layer (premelting layer) formed on ice surfaces is a decisive factor governing interfacial properties such as friction and adhesion. However, the influence of the chemical characteristics of contacting polymer materials and dynamic sliding conditions on the molecular structure of this layer remains largely unexplored. In this study, we employed all-atom molecular dynamics simulations to analyze the melting behavior at the interface between ice (TIP4P/Ice model) and three polymers: hydrophobic polystyrene (PS) and hydrophilic polyethylene oxide (PEO) and polyvinyl alcohol (PVA). Static density distribution analysis revealed that hydrophilic polymers (PEO and PVA) significantly promote ice melting, inducing interfacial disorder characterized by the penetration of water molecules into the polymer matrix.

Furthermore, dynamic simulations conducted at shear velocities ranging from 0.04 to 0.9 m/s revealed a unique velocity dependence in frictional characteristics and interfacial heat transport. In the low-velocity regime (below 0.1 m/s), frictional heating enhanced the evolution of the premelting layer, leading to an increase in interfacial temperature. In contrast, at higher velocities, the interfacial temperature unexpectedly decreased. These findings suggest that controlling polymer hydrophilicity and sliding velocity is critical for optimizing tribological performance on ice surfaces, offering fundamental insights for the development of advanced ice-contacting materials.

Keywords:

Molecular Dynamics, Ice Friction, Interfacial Melting, Velocity Dependence, Polymer Hydrophilicity

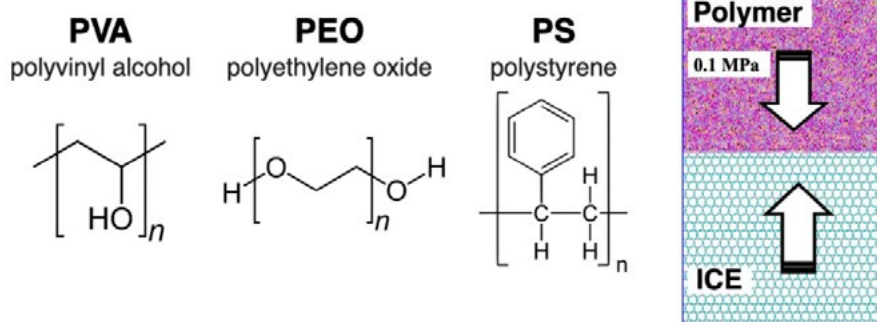


Fig. 1 Initial configuration

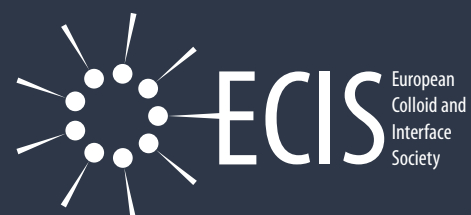
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Topic 6

Active and Bioinspired Soft Materials

! **KEYNOTE**



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Functional Compartmentalized Anisotropic Colloidal Gels

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Soft colloidal structures with programmable chemical functionalities, size and shape are important building blocks for the fabrication of catalyst systems and adaptive biomaterials for tissue engineering. However, the development of the easy up-scalable and template-free synthesis methods to obtain such colloids lack of understanding of molecular interactions that occur during the synthesis step.

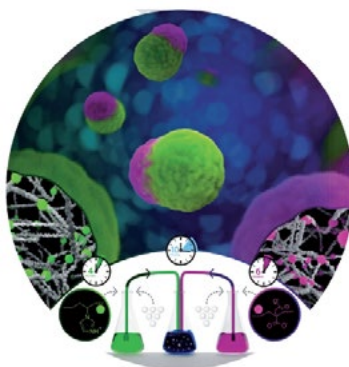
We demonstrate that the use of “programmable” monomers able to undergo specific non-covalent interactions (electrostatic, hydrophobic or π - π -stacking) in aqueous solutions is a key to bottom-up synthesis of anisotropic nanogels with controlled size, shape and chemical structure. A new synthesis method based on the controlled self-assembly of growing polyelectrolyte microgel precursors during the precipitation polymerization process leading to the formation of polyampholyte Janus-like microgels was developed. ¹ In another approach, we used pyrazole-modified monomers able to undergo π - π -stacking and guide the formation of supramolecular bonds between polymer segments and used them in precipitation polymerization to synthesize anisotropic microgels. ² Anisotropic nanogels were synthesized through semi-batch precipitation polymerization using 4-methoxybenzoic acid 4-(6-acryloyloxy-hexyloxy)phenyl ester (LCM) as a functional co-monomer with a liquid crystalline moiety. The resulting morphology of nanogels is tuned to multilobe-, dumbbell-, and raspberry-like shapes by varying the addition time of LCM, temperature, solvent ratio, and monomer ratio.

Using controlled liquid-liquid phase separation in microfluidic droplets, we developed a new methodology to fabricate compartmentalized anisotropic microgels. ⁴ Phase separation of nanogels in aqueous microfluidic droplets triggered by addition of salt, allows fabrication of stimuli-responsive anisotropic compartmentalized microgels with tunable sizes and internal morphologies. ⁵

The application of anisotropic compartmentalized nanogels and microgels in catalysis ⁶, drug delivery ⁷ and soft robotics will be discussed.

Keywords:

nanogels, microgels, compartmentalisation, anisotropic colloids



Anisotropic nanogels synthesized by polymerisation and coacervation-driven assembly of functional monomers.

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Colloidal Robots with Physical Intelligence

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Colloidal scale robotic systems offer exciting opportunities for intelligent behavior without relying on conventional computational hardware. Unlike macroscale robots, micro- and nanorobots at the colloidal level achieve sensing, control, and adaptation through their material composition and physical design. In this talk, I will present two recent colloidal assembly strategies for engineering colloids with programmable structures and responsive functionalities, aimed at applications in biomedicine and environmental sustainability. First, we harness evaporation-driven self-assembly to construct colloidal assemblies with tunable geometries and multi-compartment architectures, enabling controlled motion and cargo release [1,2]. Second, we employ capillarity-assisted particle assembly to achieve modular integration of colloidal building blocks with high spatial precision. This technique supports the incorporation of distinct liquid compartments and functional components, allowing for autonomous motion and localized sensing [3,4]. Together, these approaches establish a versatile colloidal platform for embedding multiple functional components and various responsive mechanisms within a single microsystem. By exploiting colloidal assembly approaches, we aim to develop intelligent colloidal materials capable of performing complex tasks in dynamic environments.

Keywords:

colloidal robots, self-assembly, physical intelligence, microrobotics

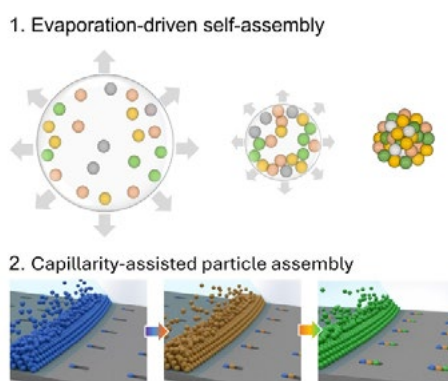


Figure 1. Schematic picture of two colloid assembly strategies.

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Structural colour in disordered media: from photon diffusion to colour

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Structural colours arise from the interaction of light with materials structured on the nanoscale. Natural examples abound in many forms of life, from bacterial colonies [1] to mammals [2]. Among these, amorphous materials are of particular interest because of their non-iridescent colours that inspire long-lasting sustainable pigments. In these systems light propagation is governed by short-ranged order, interference, and long-ranged disorder.

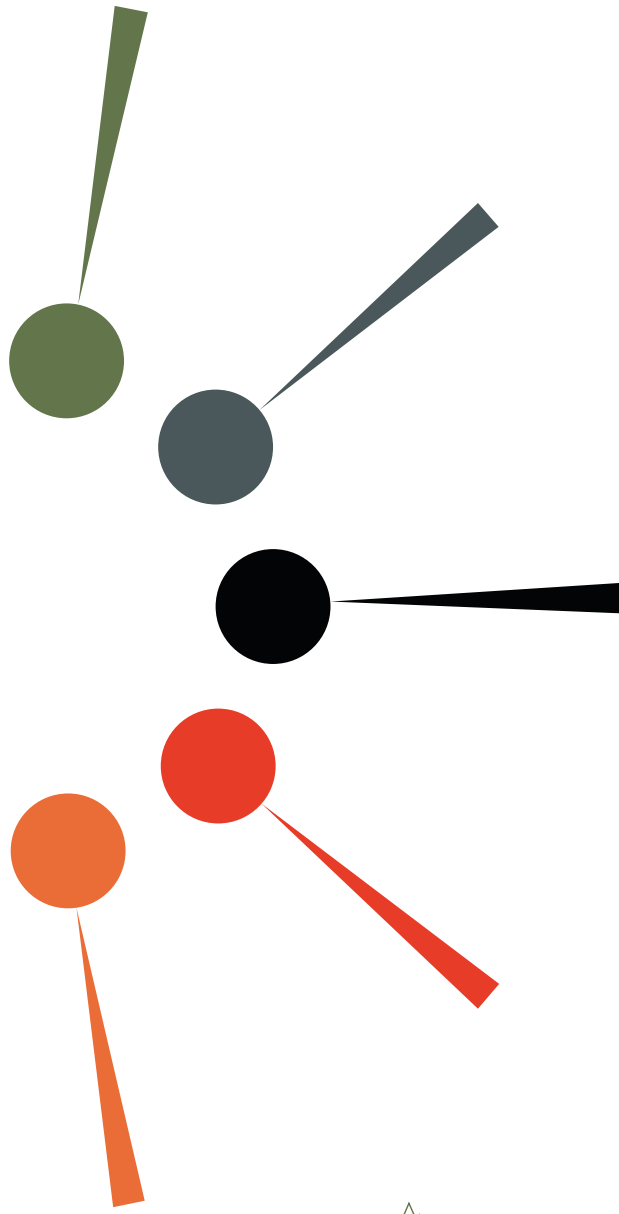
Models to describe the structural colours of disordered materials have so far mostly relied on frameworks developed from single scattering, highlighting the role of short-ranged order and interference [3-7]. Here we develop a complementary model starting from photon diffusion theory, pertinent in the case of disorder. We test our model experimentally on dense and disordered packings of silica particles mixed with controlled amounts of carbon black, a broadband absorber. Our measured colours agree well with model predictions using only one fit parameter. Contrary to prior frameworks, this one is agnostic to the architectural details of the nanostructures. This makes it applicable not only to the packings of spherical particles typically made in the lab, but to any morphology as might be found in nature.

Keywords:

structural colour, scattering, photon diffusion, interference, bio-inspired

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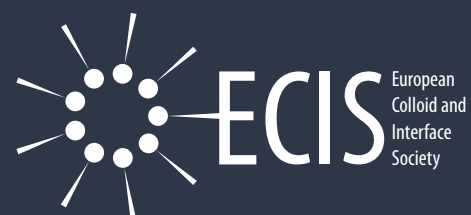
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Topic 6

Active and Bioinspired Soft Materials

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The Sweetest Polymer Nanoparticles: Opportunities Ahead for Glycogen in Nanomedicine

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There is a compelling need for non-toxic and biodegradable nanomaterials in healthcare and medicine, where innovations in the bioengineering of first-generation nanoparticles have primarily focused on synthetic non-degradable polymers, which can have undesirable interactions with our immune system in human blood [1]. In our work, we look to leverage biology against itself in nanomedicine, done so through the use of biomaterial glycogen nanoparticles. Glycogen is a unique biological polysaccharide nanoparticle fabricated by nature through a bottom-up approach [2], which is markedly different from other natural biomaterials. Glycogen is inherently biodegradable, nontoxic, and can be functionalised with diverse surface and internal motifs for enhanced biofunctional properties. [3] In our work, we show how to functionalise glycogen nanoparticles for a therapeutic purpose, before re-integrating them back into biological contexts. These particles have been devised for targeting cancer cells [4], delivering siRNA in tumour spheroids [5], and as highly adhesive biomaterial films [6]. We have proved these nanoparticles to be essentially invisible to our immune system in human blood [7], which leads for them to be used as in-blood active nanoparticles for treating thrombosis and as fibrinolytic (blood clot-busting) agents [8]. Together, our work shows how sugary glycogen nanoparticles can be nano-engineered for functional therapeutic purposes, taken from nature, and reintegrated into biology with a new purpose.

Keywords:

Glycogen, Nanomedicine, Hemocompatibility, Blood Interactions, Colloidal Nanoparticles

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Programmable Fabrication of Biohybrid Microswimmers: Templated Spore Outgrowth using Polar-Localized Membrane-Nanobody Fusion Proteins

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Biohybrid microswimmers integrate the innate motility and sensing strategies of microorganisms with the versatile properties of artificial cargo, offering a sophisticated platform for targeted microscale transport. To overcome the challenges of stochastic assembly [1] and low attachment yields [2], we utilize sequential capillarity-assisted particle assembly (sCAPA)[3]. This technique allows for the precise, highly reproducible control of construct geometry by using *B. subtilis* endospores as a resilient biological starting material. By incorporating these spores into the colloidal fabrication process, we harness their inherent resistance to unfavorable conditions, such as heat and desiccation, without compromising the eventual physiological performance of the living actuator.

In this novel approach, the spores are outgrown directly on a functionalized PDMS template, facilitating a transition into vegetative cells that integrate seamlessly with the pre-assembled cargo (Fig. 1a). To ensure a robust and oriented mechanical link, we have genetically engineered the *B. subtilis* cells to display a nanobody fusion-protein with a polar localized expression. This biological affinity is matched by modifying the artificial particles with a green-fluorescent protein, creating a high-specificity polar bond (Fig. 1b). This programmable interface ensures that the cellular actuator is positioned optimally for propulsion, effectively bridging the gap between synthetic architecture and biological machinery.

The success of this nanobody-mediated attachment demonstrates the profound versatility of the spore-templated sCAPA platform. Beyond mere motility studies, this approach provides a universal framework for the fabrication of complex biohybrid microswimmers, where both the cargo and the cellular interface can be genetically and chemically tailored. By enabling the precise marriage of engineered biology and colloidal science, this platform opens new avenues for creating autonomous, multi-functional microsystems capable of navigating and interacting with complex biological environments.

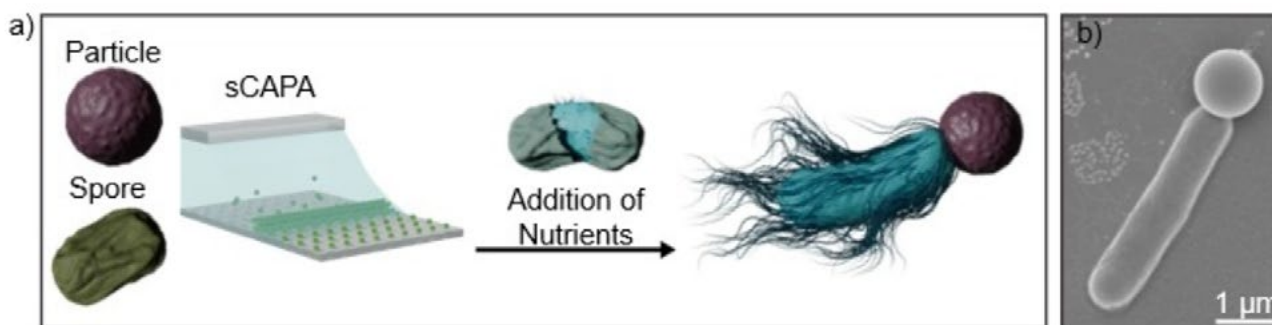


Figure 1: Biohybrid microswimmer fabrication using capillary assisted particle assembly. a) Sequential deposition of colloids and spores on PDMS. Upon addition of nutrients the spores germinate, attach to the particles and form biohybrid microswimmers. b) SEM image of a biohybrid microswimmer.

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Anomalous Transport Phenomena of Active Particles in Porous Media

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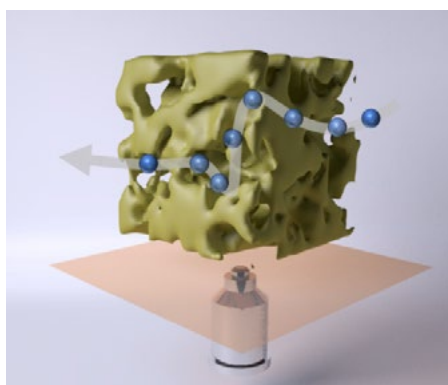
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Active particles capable of harvesting ambient energy to generate autonomous motion are emerging as promising agents for targeted transport in drug delivery and environmental remediation. Although extensive studies have examined their behaviors near interfaces or in quasi-two-dimensional settings, systematic understanding of their motion within complex confined spaces—such as three-dimensional porous media—remains limited. To address this challenge, we developed a three-dimensional single-particle tracking platform to directly visualize the trajectories of active particles in heterogeneous porous structures. The measurements reveal an enhancement in transport efficiency exceeding an order of magnitude compared with passive Brownian particles. Combined experimental, simulation, and theoretical analyses further elucidate confinement-induced mechanisms arising from altered chemical microenvironments, distinctive hydrodynamic effects of active propulsion, and the influence of local energy landscapes. These findings demonstrate the capability of 3D single-particle tracking to resolve transport processes in confined environments and provide a mechanistic foundation for the rational design and efficient deployment of active particles in practical applications.

Keywords:

Active particle, particle tracking, nano/micromotors, transport, porous media, confinement



3D single-particle tracking of active particles in porous media

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Insect dynamics: motion and fluctuations

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Understanding the collective dynamics of living systems composed of many interacting individuals remains a central problem in active matter and biological physics. With this goal, we investigate insect dynamics through a set of controlled experimental systems focusing on ants and moths.

For ants, we study dense collectives confined in quasi-two-dimensional arenas. Under these conditions the system exhibits activity cycles in which it alternates between low-activity states, characterized by the formation of long-lived stationary clusters, and highly active states where most individuals move simultaneously. By analysing spatial number fluctuations within subregions of the system we observe giant number fluctuations characterized by $\langle(\Delta N)^2\rangle \sim \langle N\rangle^\alpha$ with $\alpha \approx 1.6-1.7$, in both regimes. Although the scaling behaviour is similar, we hypothesize that the underlying physical mechanisms are different. In the low-activity regime the large fluctuations appear to originate from the spatial heterogeneities introduced by clustering, whereas in the highly active state they may be related to alignment interactions between individuals and the possible emergence of a collective-motion state. This interpretation, however, remains tentative.

Also with ants, we are beginning to explore how the geometry of the substrate influences insect dynamics. To this end, we perform experiments with ants in curved arenas produced by 3D printing, including spherical and toroidal surfaces. In these systems, which are not yet in the dense regime, we vary the total number of individuals and use image analysis to reconstruct trajectories and characterize insect dynamics on curved spaces.

In parallel, we study moths in a cubic cell where individuals typically walk on the flat walls of the system. In this case our aim is to understand and model the encounter dynamics associated with sexual communication by varying the female-male ratio and analysing the resulting trajectories and interaction patterns.

Keywords:

active matter, insect dynamics, giant number fluctuations

Decoupling Interfacial and Bulk Stabilization in Natural Wax Pickering Emulgels using Cellulose Nanofibers

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In this work, we present the stabilization of natural wax-in-water Pickering emulgel systems using TEMPO-oxidized cellulose nanofibers (TOCNFs). Stable colloidal emulgels were obtained at exceptionally low nanofiber concentrations, with the nanofibers' degree of carboxylation exerting a minor effect on the critical stabilization concentration. We report that the formation of these systems is driven by high-energy emulsification above the wax melting point, where the resulting colloidal stability is maintained during the in situ crystallization of the dispersed phase, with the resulting particle size dependent on the initial energy input.

The stabilization mechanism is attributed by a dual effect: the interfacial assembly of TOCNFs providing surface coverage, which was proven by confocal and electron microscopy, and the development of a hierarchical entangled fibrillar network in the continuous phase. This TOCNF network acts as a supramolecular cage, imparting a macroscopic yield stress and a solid-like viscoelastic behavior. Rheological analysis confirms that these systems behave as structurally arrested soft glassy materials, where the storage modulus is governed by both physical entanglement of the nanofibers and the jamming of the TOCNF-coated wax particles. Thermal characterization reveals a reduction in both the melting temperature and enthalpy compared to bulk wax, indicating a crystallization depression attributed to confinement and fractionated nucleation within the TOCNF shells. Finally, when applied to paper substrates, these emulgels produce high-performance, bio-based highly hydrophobic water barriers.

Keywords:

cellulose nanofibers; natural waxes; Pickering emulgel; confined crystallization; supramolecular network; hydrophobic coating

References:

Lombardo, S. et al. Decoupling interfacial and bulk stabilization in beeswax-in-water Pickering emulgels using carboxylated cellulose nanofibers
submitted to 'Journal of colloid and interface science'

Enzyme-Activated Polymeric Composite Hydrogels for Enhanced Transdermal Delivery of Encapsulated Phycocyanin

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Skin disorders affect nearly 900 million people worldwide and remain a major unmet clinical need due to the limited efficacy of conventional topical therapies. Natural bioactive compounds (NBCs), such as phycocyanin (C-PC), exhibit potent antioxidant and anti-inflammatory activity [1], however, their clinical translation is hindered by poor physicochemical stability and limited transdermal penetration [2].

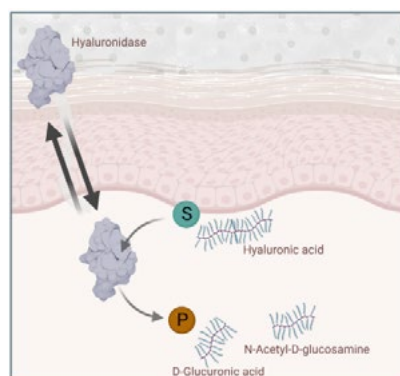
Herein, we report a multifunctional composite hydrogel platform that integrates polymeric microcapsule encapsulation, tunable poly(vinyl alcohol) (PVA)-based hydrogel networks, and enzymatic surface functionalization to enhance dermal delivery. C-PC was encapsulated into polymeric microcapsules with an encapsulation efficiency of 47%, enabling improved stability and controlled release. The microcapsules were incorporated into hydrogels based on PVA and its modified systems, including PVA–sulfobetaine methacrylate (PVA–SBMA) and PVA–propylene glycol (PVA–PG), allowing systematic tuning of hydration, mechanical properties, and handling behavior.

To overcome the barrier function of the skin, hyaluronidase was immobilized within the hydrogel system, providing localized enzymatic activity at the hydrogel and skin interface. This enzymatic functionality selectively modulates extracellular matrix components, facilitating enhanced permeation without compromising material integrity. The resulting hydrogels were characterized in terms of swelling behavior, structural integrity and enzyme activity demonstrating cohesive, transferable matrices suitable for topical application. The performance of the platform was evaluated using Franz diffusion cell studies. The aimed enhancement is based on the synergistic combination of microcapsule-mediated stabilization, a highly hydrated hydrogel environment, and enzyme-assisted modulation of the skin barrier.

Overall, this work introduces a modular and multifunctional dermal delivery platform that combines encapsulation, hydrogel design, and enzymatic activation, offering a promising strategy for the effective transdermal delivery of sensitive NBCs.

Keywords:

composite hydrogels, transdermal delivery, natural bioactive compounds, enzyme functionalization, phycocyanin, Hyaluronidase



Schematic illustration of the reaction of hyaluronidase which catalyses the hydrolysis of hyaluronic acid (S: substrate) through cleave linkages between N-acetylglucosamine and glucuronate (P: products), as well as enzyme association/dissociation equilibrium between the HG and the skin.

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Photoswitchable and valence-free plasmonic superstructures by depletion-induced self-assembly

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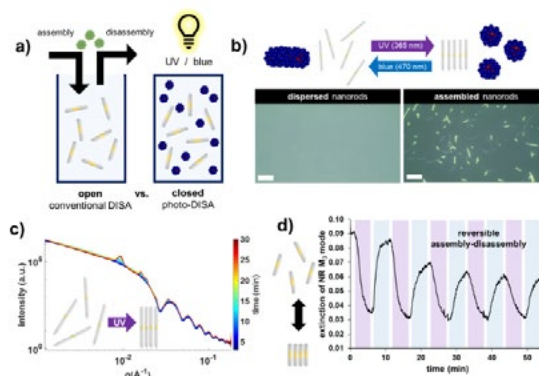
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The depletion interaction is a chemically-universal (valence-free) attractive force observed in many colloidal systems, and is important in water treatment, biomolecular interactions, and the self-assembly of nanoparticles. While using depletants is useful for controlling the stabilization of mixtures and assemblies, this interaction requires external addition of material into an open system. Active metamaterials are stimuli-responsive systems with opto-electronic properties not found in nature. We recently reported a method for preparing such reconfigurable superstructures via depletion-induced self-assembly (DISA) of plasmonic nanorods (NRs) using CTAC micelles as depletants [1-2]. While DISA is promising, switching between the assembled and disassembled states currently requires redilution, making it impractical. To overcome this “open system” limitation, we propose using azobenzene-based photosurfactant micelles as light-sensitive depletants (photo-DISA) to have in situ switchable superstructures in a “closed system”.

Our system consists of passive silver nanorods dispersed in water together with active AzoTAB photosurfactant. Although photosurfactants are well known [3], their use as photoswitchable depletants is proposed here for the first time. AzoTAB micelles change their size and shape depending on their isomerization state, thus modulating the attractive depletion force acting on the NRs [Fig. 1a-b]. By irradiating a nanorod/AzoTAB suspension with UV or blue light, we can reversibly switch between assembled and disassembled NR states with a full cycle time of 2-3 min. Switching between UV and blue irradiation also tunes the inter-NR gap in the assemblies. This ‘re-contractable’ system yields tunable plasmonic enhancement which modulates the detected Raman (SERS) signal of analytes like methylene blue [Fig. 1c-d].

This work offers a new strategy of creating active, light-sensitive, plasmonic metamaterials via photo-DISA, which can be extended to a wide range of nanostructures with different composition or surface chemistry due to the universal nature of depletion. Finally, our photo-DISA system serves as a potential platform for tunable and switchable plasmonic detection via SERS.



a) Open DISA versus closed photo-DISA. b) Reversible photoswitchable assembly of silver nanorods into plasmonic superstructures with AzoTAB. c) SAXS kinetics of photo-DISA. d) Cyclic NR assembly-disassembly by alternate UV/blue irradiation. Scale bars are 10 μm .

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Interfacial hydrogel formation and entropic effects in adsorption of mixed-linkage glucans on cellulose surfaces

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Cereal hemicelluloses, i.e., mixed-linkage glucans (MLGs) are interesting components for polysaccharide-based materials due to their unique gel formation tendency even at low concentrations[1]. While attractive interactions of annual plant hemicelluloses with cellulose surfaces have been shown priorly[2,3], several knowledge gaps on the plant cell wall component interactions in nature and technical materials exist. To reveal the mechanisms underlying the interconnections, we methodically probe MLG solution properties, adsorption at cellulose interfaces, and the thermodynamics of interaction using dynamic light scattering (DLS), quartz crystal microbalance with dissipation monitoring (QCM-D), and isothermal titration calorimetry (ITC), respectively. We show the intriguing solubility aspects and the pronounced interfacial hydrogel formation behaviour of MLGs adsorbed on cellulose nanocrystal surfaces (Figure 1). This is different from many other hemicellulose systems, which display polyelectrolyte-like adsorption. While entropy is accepted fairly universally as a driving force for polysaccharide adsorption, it is far from trivial to verify and has been demonstrated for few cellulose-hemicellulose systems[4,5]. Despite the experimental challenges resulting from the limited solubility and gelling tendency of MLGs, the entropic contribution in MLG-cellulose interactions is systematically evidenced. Additionally, we attempt to discuss the synergistic effect of entropy and MLG solubility on the adsorption, which is often only vaguely mentioned in similar studies. Overall, these findings point toward the wet-strength mediating and life-sustaining features of MLGs in nanocellulosic networks[2] being attributed to the interfacial hydrogel formation, as well as the hemicelluloses providing a hydrating layer in the plant cell wall.

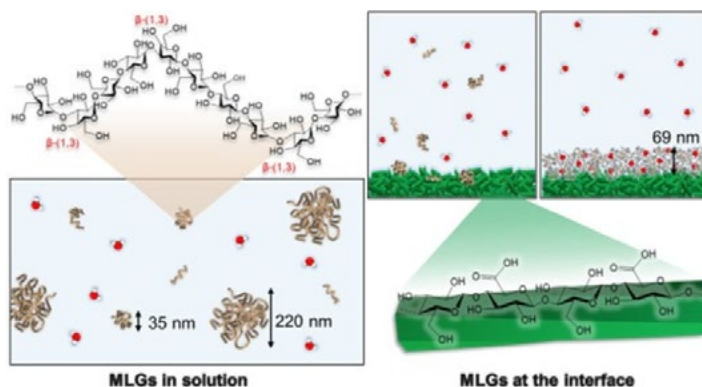


Figure 1. Schematic view and dimensions of mixed-linkage glucans (MLGs) in solution and adsorbing on a cellulose surface, forming a hydrogel layer at the interface. The chemical structures of MLG and cellulose are shown.

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Towards bio-inspired underwater adhesives: barnacle cement protein 19 structural ensembles via molecular modelling

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Barnacles are marine organisms with a remarkable ability to stick to almost any surface underwater. This, however, causes serious fouling problems in the marine industry, increasing fuel and maintenance costs. However, this extremely strong adhesion is also a source of inspiration. Producing synthetically in the lab a biobased, biocompatible underwater adhesive with equal, or superior, but also tunable characteristics, is highly fascinating but also holds high technological potential.

In nature, barnacle adhesion is through a protein-mediated process in which barnacle cement protein 19 (Cp19k) plays a key role. Central to the adhesion response are the structure and its changes of this intrinsically disordered protein, yet limited knowledge exists on the structural characteristics.

We have used molecular modelling, especially metadynamics enhanced sampling together with AlphaFold 3 (AF3) predictions combined with comparison to experimental Raman and CD spectroscopy characterization, as well as optical microscopy to examine Cp19k structural ensemble. We report that Cp19k adopts a coil structure that contains some β -sheets and helices but also that salt drives local structural ordering. Secondary structure and radius of gyration analysis on the ensemble are consistent with experiments and give insights on the phase separation behavior of the protein which is a critical step for material development. We pinpoint the changes to the amino acid sequence level, directly linking molecular detail to macroscopic material behavior. From a methodological perspective, the study offers a critical evaluation of AF3 vs advanced molecular modelling approach demonstrating that AF3 significantly overestimates the structural order in Cp19k. We discuss the origins of this based on the architecture and training data of the AF3 and similar algorithms. From a material design perspective, our results establish a mechanistic basis for the rational design of protein inspired adhesives with tunable desired material properties.

Keywords:

barnacles, adhesion, protein-based materials, metadynamics, structural ensemble, β -sheets, AlphaFold3

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Light-Driven Self-Propulsion of Rod-like fd-Virus Functionalized Janus Particles

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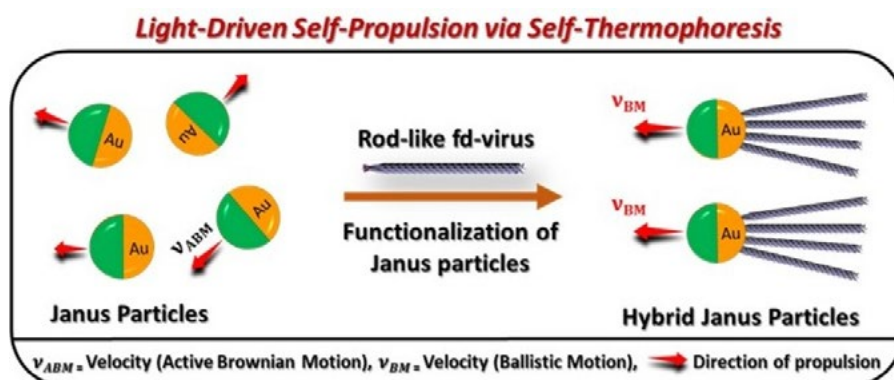
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Abstract: Active matter systems, which convert energy into autonomous motion, offer various strategies for designing synthetic devices capable of self-propulsion [1]. Among the different propulsion mechanisms, light-driven self-thermophoresis is more appealing and stands out as it is fuel-free and provides on-demand switchable motion [2]. However, achieving controlled directional motion at the nanoscale remains challenging as Brownian motion rapidly randomizes particle trajectories. To overcome this limitation, an effective strategy is required to suppress rotational diffusion and enable directional ballistic motion.

Herein we show the engineering of hybrid Janus particles by selectively functionalizing the gold hemisphere of the Janus particles with rod-like filamentous viruses. This approach was previously successfully used for fabricating star-like colloids from gold nanoparticles [3]. In this work, we investigate whether grafting of filamentous viruses, acting as long macromolecular tails, onto Janus particles can significantly inhibit rotational diffusion thereby promoting ballistic motion driven by light induced self-thermophoresis. This approach establishes a novel strategy for enhancing directional persistence in the motion of active hybrid colloids and paves the way toward more efficient advanced active matter systems.

Keywords:

Active matter, Janus particles, self-propulsion, self-thermophoresis, fd virus



Schematic illustration showing the functionalization of Janus particles with fd-virus and their self-propulsion via light-induced self-thermophoresis. fd-virus functionalization suppresses rotational diffusion and enable directional ballistic motion.

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Precision delivery of siRNA using Human Transferrin Receptor-targeted lipid nanocarriers: linking nanoscale structure to in vivo performance

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RNA interference (RNAi)-based gene therapy is increasingly recognized as a promising personalized strategy for cancer treatment. At the core of this approach are small interfering RNAs (siRNAs), which enable selective gene silencing and precise inhibition of disease-associated proteins. Despite its potential, the clinical translation of siRNA therapeutics remains limited by the need for efficient delivery systems capable of crossing biological barriers—particularly the cell membrane—while protecting siRNA molecules from enzymatic degradation.

To overcome these challenges, we developed lipid nanocarriers (LNCs) engineered for enhanced delivery efficiency and biocompatibility. The formulation incorporates POPC, a naturally occurring phospholipid that improves membrane compatibility; DODMA, an ionizable lipid that promotes efficient siRNA encapsulation; cholesterol, which enhances bilayer stability; DOPE-PEG2000-maleimide, which reduces immune recognition and allows covalent conjugation of the CGSG-T7 peptide (CGSG-HAIYPRH), targeting the human Transferrin Receptor (hTfR). This strategy is expected to enhance LNCs accumulation at the disease site, thereby increasing therapeutic efficacy.

The physicochemical properties of the LNCs were comprehensively characterized. Dynamic Light Scattering (DLS) and Small-Angle Neutron Scattering (SANS) measurements indicated a hydrodynamic diameter of 91 ± 1 nm and a bilayer thickness of 0.46 ± 0.01 nm. ζ -potential revealed a positive surface charge under acidic conditions (10.6 ± 0.2 mV), reflecting the pH-responsive behavior of the LNCs, driven by protonation of the ionizable lipid DODMA at lower pH, consistent with the tumor microenvironment. In addition, Electron Paramagnetic Resonance (EPR) spectroscopy provided detailed insights into the structural organization of the lipid bilayer.

Successful incorporation of siRNA into the functionalized LNCs was confirmed by agarose gel electrophoresis and fluorescence spectroscopy (E.E. = $79\% \pm 4$), complemented by fluorescence anisotropy to probe changes in the local microenvironment and mobility of the fluorescent probe associated with encapsulation.

In parallel, biological assays demonstrated a significant reduction in GFP fluorescence, confirming successful siRNA delivery and biological activity. Furthermore, in vivo experiments were conducted on animal models to evaluate biodistribution and uptake, with particular focus on ocular administration as a route to investigate LNCs penetration and transport across biological barriers.

These findings provide a strong foundation for the development of advanced siRNA delivery platforms and support their future translation into targeted cancer therapies.

Keywords:

siRNA Delivery, Lipid Nanocarriers (LNCs), Targeted Therapy (hTfR), Endosomal Escape, Ocular Biodistribution

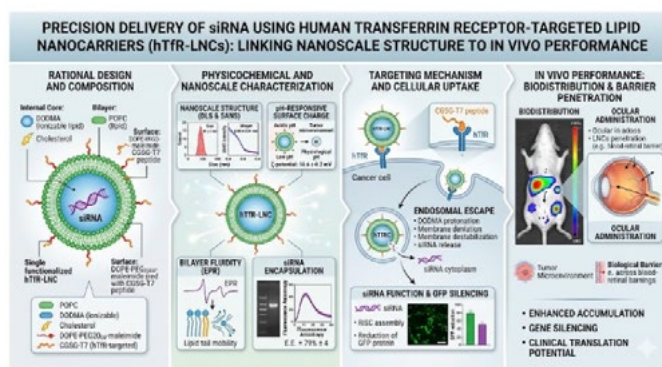


Figure 1. Structure-property relationships in hTfR-LNCs. Schematic linking nanoscale architecture to in vivo siRNA delivery. Highlights include pH-responsive targeting, endosomal escape, and ocular gene silencing. (AI-generated).

Conductive Active Colloids Propelled by Releasing Ions

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By converting chemical energy into autonomous motion through tunable surface chemistries, synthetic active colloids provide a versatile platform for various applications, including targeted cancer therapies, cargo transport, and environmental remediation.

[1]

These particles achieve propulsion driven by chemical potential gradients that induce fluid-mediated body forces through engineered asymmetric surface activities. **[2]**

Although the self-phoretic framework—originally developed for externally imposed electrolyte gradients—is commonly adapted to model these systems, its validity remains an open question for active particles that generate their own ionic gradients through surface reactions. **[3]**

We investigate the motion of an active colloidal particle with a fixed surface electrostatic potential that releases ionic species in an electrolyte solution. Our approach is based on the theoretical and numerical solutions of the full Nernst-Planck-Poisson equations, and we compare our findings to the predictions of a self-diffusiophoretic model. Our results exhibit several features that cannot be explained within the classic self-diffusiophoretic framework.

Our findings demonstrate that particles with zero surface potential can still achieve propulsion through the release of ionic species. Overall our results have implications for the design of the next generation of active nano and micro robots for biomedical applications.

Keywords:

Nano robots - Active colloids - Self propulsion

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Functional Multiphase Systems Stabilized by Protein–Cellulose Nanocomposites

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Cellulose nanocrystals (CNCs), as charged rod-like nanoparticles, have attracted significant attention as eco-friendly stabilizers for Pickering emulsions. However, their inherent hydrophilicity often requires surface modification to achieve optimal interfacial performance. In this study, we propose a biomimetic strategy to fabricate programmable cellulose nanocomposites through the integration of CNCs with phase-transitioned bovine serum albumin (PTB). Specifically, reduction of disulfide bonds in bovine serum albumin induces amyloid-like aggregation, enabling rapid self-assembly of PTB oligomers onto CNC surfaces. The resulting PTB/CNC nanocomposites synergistically combine the enhanced interfacial activity of the hybrid particles with bioadhesive properties arising from protein structural reorganization. The hybrid nanocomposites exhibit excellent interfacial stabilization capabilities and spontaneously adsorb at fluid interfaces, enabling effective stabilization of both oil-in-water and water-in-water emulsions. Moreover, the interfacial behavior and stabilization performance can be precisely tuned by adjusting the PTB-to-CNC ratio, allowing programmable control of the nanocomposite architecture and emulsion properties. These nanocomposite-stabilized emulsions demonstrate strong potential for sustainable agricultural applications, such as precision pesticide delivery. More broadly, the programmable interfacial assembly strategy provides a versatile platform for developing functional soft materials with controlled droplet deposition and surface adhesion, with potential applications in functional coatings, cosmetic formulations, and targeted drug delivery systems.

Keywords:

CNC, Interfacial Assembly, Multiphase Systems

Acknowledgements:

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Phosphatidylserine lipids affect the location of chondroitin sulfate at the membrane surface

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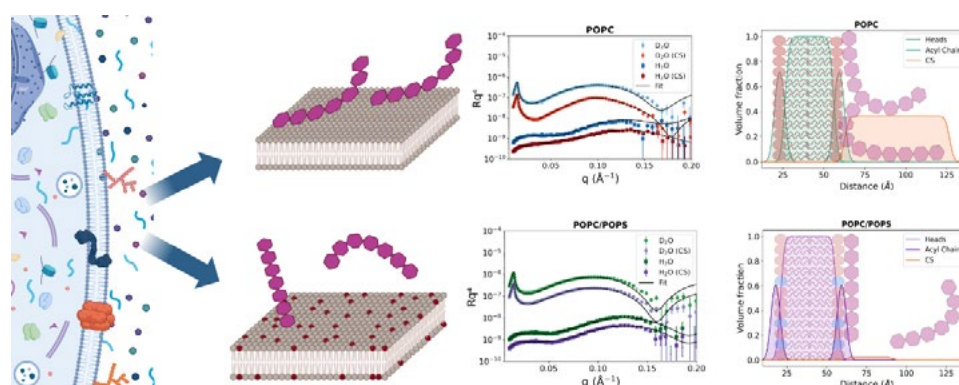
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Chondroitin Sulfate (CS) is a negatively charged polysaccharide constituting one of the key components of the extracellular matrix [1]. CS can be found anchored directly to the plasma membrane, in close proximity to membrane phospholipids. Despite its potential role in pathological conditions such as cancer, i.e. CS is overexpressed at the surface of cancer cells[2], and its potential application as a biomarker [3], only a limited number of studies have investigated CS–lipid interactions [4,5]. Most of these studies used lipid monolayers at the air–water interface, with a prevailing focus on phosphatidylcholine (PC) systems. In this work, quartz crystal microbalance with dissipation monitoring (QCM-D), neutron reflectometry (NR), fourier-transform infrared spectroscopy (FTIR), and molecular dynamics (MD) simulations were combined to investigate CS interaction with PC bilayers, as well as bilayers containing a negatively charged phospholipid, phosphatidylserine (PS) in mixture with PC.: While healthy cells predominantly expose PC at the outer leaflet, PS exposure occurs during inflammation and is also observed within cancer cells [6]. QCM-D and NR confirmed stable CS adsorption on POPC bilayers, consistent with prior studies on DPPC monolayers [5]. MD simulations identified electrostatic interactions between CS sulfate groups and the choline moiety of POPC as the primary stabilising contacts, a finding further supported by FTIR spectroscopy. In contrast, CS adsorption on PC/PS bilayers was undetectable by both QCM-D and NR; MD simulations attributed this to a reduction in sulfate–lipid contacts, likely due to electrostatic repulsion from the anionic serine headgroups of POPS.

To the best of our knowledge, this is the first study probing CS–bilayer interactions in a physiologically relevant PC/PS mixture. Comparison with previous data on DPPG monolayers [5] suggests that negatively charged PS and PG lipids affect CS association differently, indicating that the specific headgroup composition, rather than net charge alone, governs CS–membrane interactions. These findings provide mechanistic insight into how plasma membrane lipid composition modulates the structural organisation of extracellular matrix components at the cell surface.

Keywords:

Chondroitin sulfate, supported lipid bilayers, neutron reflectometry, molecular dynamics simulations, infrared spectroscopy



Neutron reflectometry reveals how chondroitin sulfate interacts differently with POPC and POPC/POPS lipid bilayers.

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How Interfacial Chemistry Controls Macromolecular Binding and Responses to Stimuli

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Stimuli-responsive supramolecular assemblies are central to the development of smart coatings and bioinspired materials, yet the interfacial parameters that govern their formation, reversibility, and adaptive behavior remain insufficiently understood. Here, we investigate redox- and thermoresponsive supramolecular interactions, as well as click-based membrane functionalization, on well-defined model interfaces using complementary surface-sensitive techniques, including quartz crystal microbalance with dissipation monitoring, surface plasmon resonance, spectroscopic ellipsometry, electrochemistry, and fluorescence microscopy [1,2].

Using self-assembled monolayers as tunable model surfaces for redox-responsive host-guest assembly [1], we show that the grafting strategy, the nature of the molecular linkers, and the interfacial ligand density strongly influence the efficiency, specificity, and reversibility of supramolecular assembly, as well as the selectivity of multivalent interactions [3]. Using supported lipid bilayers as model membrane interfaces for thermoresponsive polymer coatings [4], we further demonstrate the strong impact of lateral mobility on the contraction and lateral reorganization of polymer coatings, providing new insight into the behavior of these systems on fluid membranes. In the same model system, we also investigate the efficiency of SPAAC click functionalization of lipid membranes with polymers and show that the interfacial chemistry, including lateral mobility and the nature of the click group, strongly affect the reaction efficiency.

These results provide useful insight for the rational design of functional liposomes for biomedical applications, for example as building blocks of self-healing hydrogels that we are currently developing, and more broadly identify surface density, mobility, and the nature of molecular linkers and diluents as key interfacial parameters controlling stimuli-responsive supramolecular assemblies on surfaces. Overall, these findings establish design rules for the development of functional and adaptive interfaces, biomimetic membranes, and soft materials with high specificity and precisely tuned responses to external stimuli.

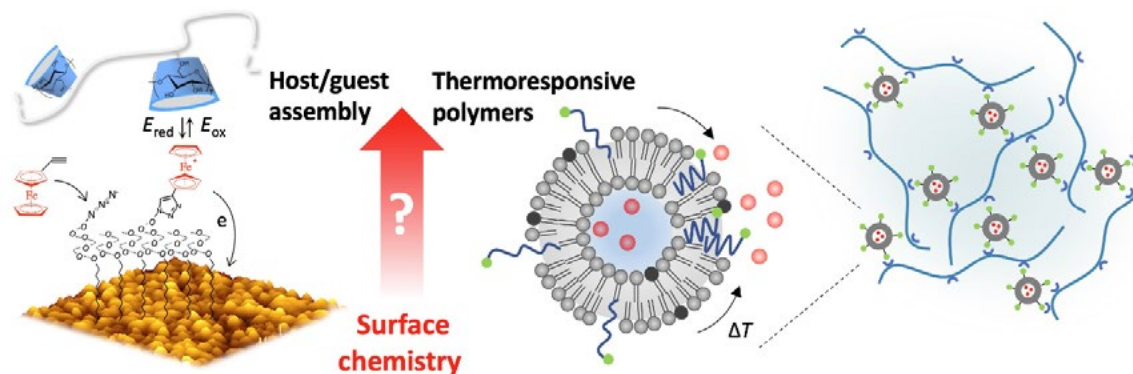


Figure 1. Schematic of studied systems: redox-responsive host/guest assembly on surfaces (left) and thermoresponsive polymers at laterally mobile lipid interfaces (right).

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Hydrogen bonding versus electrostatic screening in saponin-stabilised interfaces: molecular origins of foam stability

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Understanding how intermolecular interactions govern the structure and mechanics of biosurfactant interfaces is essential for the rational design of sustainable foams and emulsions. Here, we investigate how hydrogen bonding and electrostatic interactions modulate the interfacial organisation and foaming behaviour of Quillaja saponin systems in the presence of small, water-soluble additives.

Using a multi-scale experimental and computational approach combining surface tensiometry, interfacial dilational rheology, foam stability measurements, vibrational sum-frequency generation (SFG) spectroscopy, electrokinetic analysis, and atomistic molecular dynamics (MD) simulations, we identify distinct, additive-specific mechanisms that control interfacial structure and performance.

Despite negligible intrinsic surface activity of the additives, profound changes in interfacial mechanics and foam stability are observed. Glycerol, acting as a hydrogen-bond promoter, enhances interfacial cohesion and increases dilational elasticity up to $\sim 200 \text{ mN m}^{-1}$, leading to significantly improved foam stability. In contrast, urea disrupts cooperative hydrogen-bond networks, weakens interfacial elasticity, and accelerates foam decay. Choline chloride induces strong electrostatic screening, reduces interfacial charge, and lowers surface elasticity, while simultaneously promoting large aggregate formation that contributes to intermediate foam stability via Pickering-like effects.

SFG spectroscopy reveals that these macroscopic trends originate from additive-induced reorganisation of interfacial water and saponin headgroups. Glycerol reduces the fraction of strongly hydrogen-bonded interfacial water while reinforcing lateral cohesion, whereas urea redistributes hydrogen-bond populations and disrupts headgroup interactions. Choline chloride strongly suppresses interfacial OH response, consistent with charge neutralisation and reduced interfacial electric fields. MD simulations confirm the formation of dynamic, short-lived additive–saponin associations and highlight the dominant role of collective intermolecular interactions rather than specific complexation.

Our results demonstrate that foam stability in saponin systems is not governed by surface activity alone but is controlled by the interplay between hydrogen-bond networks and electrostatic interactions within the interfacial layer. These findings provide a mechanistic framework for designing bio-based formulations with tunable interfacial properties and enhanced performance in pharmaceutical, cosmetic, and industrial applications.

Keywords:

Saponin; Hydrogen bonding; Electrostatic interactions; Surface activity; Interfacial dilational rheology; Foam stability; Biosurfactants;

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The Mechanism of Self-Phoresis

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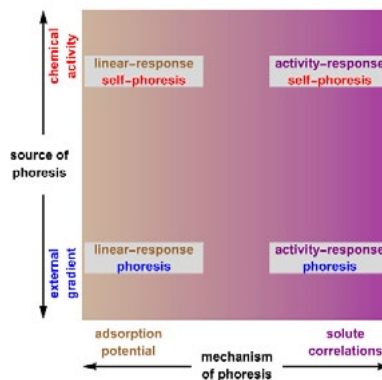
A frequent experimental realization of a microswimmer relies on self-chemophoresis. Chemophoresis (also called diffusiophoresis) denotes the motion of a particle in a fluid solution driven by a composition gradient. And self-chemophoresis pertains to the case that the gradient is generated by the particle itself through catalytic activity on its surface.

Conceptually one can write "phoretic velocity = *phoretic coefficient* x chemical gradient". In the "classic picture" of chemophoresis, the *phoretic coefficient* follows from linear response theory and is controlled by the interaction potential between the phoretic particle and the solute ("adsorption potential"). This picture lies at the basis of the usually invoked paradigm that "self-phoresis is just normal phoresis, but in a self-generated gradient". It has been argued [1-3], however, that this paradigm may break down because the activity of the particle can also affect the response significantly, leading to a contribution to the *phoretic coefficient* dominated by the solute-solute correlations [3-7].

We will discuss these two mechanisms of chemophoretic self-propulsion and their relative importance. We will also touch briefly on the recently found [8] unexpected connection with the self-propulsion of an intruder immersed in a shaken granular bath.

Keywords:

Chemophoresis, diffusiophoresis, active particle, theory



The phoretic diagram [4,7] for addressing the relative importance of different sources of chemophoresis (externally imposed vs. self-generated composition gradient) and of different mechanisms (linear vs. activity-induced response).

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Acknowledgements:

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Bio-inspired Ice-Control Materials for Cryopreservation of Cells and Tissues

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Cryopreservation is the process of preserving biological samples, such as cells, tissues, and organs, at ultra-low temperatures to halt metabolic activity, enabling long-term storage and recovery upon thawing. It plays a critical role in cell therapy, regenerative medicine, and organ transplantation. However, the high-water content (70%-90%) in biological samples makes them susceptible to damage during cooling and thawing due to ice crystal formation, osmotic imbalance, and excessive solute accumulation. Traditional methods rely on organic cryoprotectants like dimethyl sulfoxide (DMSO) to prevent ice formation, but these are cytotoxic and unsuitable for preserving tissues and organs. Ice-binding proteins (IBPs) from cold-adapted organisms offer a promising alternative by preventing freezing damage through precise control of ice nucleation and growth. Understanding the mechanisms of IBPs has inspired the development of biomimetic ice-control materials as safer and more effective cryopreservatives. My lecture will present our recent findings on IBPs, the design of biomimetic ice-control materials, and their application in cryopreservation, along with future strategies for improving preservation outcomes.

Design and Production of Lipid Vesicles and Nanoparticles with Exosome-Mimetic Composition Using a Crossflow Membrane Mixing Device

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Background

Although lipid-based drug nanocarriers are indispensable for modern drug delivery, their production method still requires significant improvement. The crossflow membrane mixing device is one of the promising methods for producing lipid vesicles and lipid nanoparticles (LNPs) in a large scale. In this study, impacts of various process parameters on the size and the internal structure of the resulting particles were studied.

Methods

Dipalmitoylphosphatidylcholine (DPPC), cholesterol (CH), and sphingomyelin (SM), were used for the preparation of the vesicles and LNPs. Its physicochemical characterization was conducted using nanoparticle tracking analysis, zeta potential measurements, differential scanning calorimetry, circular dichroism spectra, fluorescent lifetime analysis, and so on. In the preparation process using the crossflow membrane mixing device, lipids were dissolved in ethanol to be injected into flow of aqueous buffer solution. Effects of the operation parameters on resultant particles were investigated using dynamic light scattering, nanoparticle tracking analysis, and transmission electron microscopy.

Results

An optimum molar ratio of lipids to accommodate helical peptide was determined to be DPPC/CH/SM = 45/15/40, for which CH and SM played important roles to increase softness of the membrane and to provide highly-mobile phase, respectively¹). These properties were essential for the transmembrane-domain peptide of integrin family to form and maintain α -helical structure; and thus, this composition was identified as exosome-mimetic. In the production of such exosome-mimetic vesicles (EMVs) using the crossflow membrane mixing device, we examined the effects of various process parameters on the morphology of resulting particles. While the product was generally in the form of vesicles, LNP-like dense particles were formed when a highly concentrated lipid solution was injected at relatively low flow rate at room temperature, which is likely the result of lipid aggregation caused by rapid dilution. Also, when vesicles were formed, their lamellarity varied depending on the process parameters including the lipid concentration, the flow rates, and temperature. The lipid density of the vesicles was strongly affected by the temperature, the lipid concentration in ethanol, and its flow rate, that is, both vesicles and LNPs were manufactured by changing the operation conditions using the crossflow membrane mixing device.

Conclusion

Factors influencing the morphology of exosome-mimetic vesicles/LNPs manufactured by the crossflow membrane mixing device were clarified.

Keywords:

Crossflow membrane mixing, exosome-mimetic vesicles, lipid nanoparticle

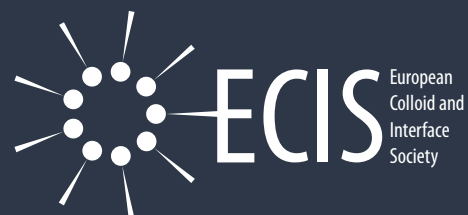
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Topic 7

Polymers, Polyelectrolytes,
Gels, Micro/Hydrogels, Glasses,
and Liquid Crystals

KEYNOTE



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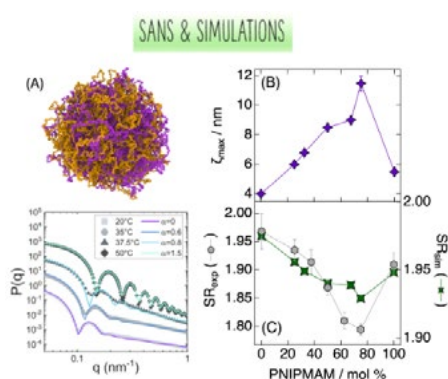
Block-like monomer distribution and heterogeneous collapse of thermoresponsive copolymer microgels

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The internal structure of microgels is fundamental in determining their responsiveness and thus potential applications. It remains however difficult to resolve with molecular resolution. In this work we combine small-angle neutron scattering (SANS), dynamic light scattering (DLS), and nuclear magnetic resonance (NMR) measurements with multi-scale simulations to investigate the internal structure of Poly(N-isopropylacrylamide-co-N isopropylmethacrylamide), P(NIPAM-co-NIPMAM), copolymer microgels, in which a random monomer distribution is conventionally assumed. By synthesizing samples containing selectively deuterated PNIPAM or PNIPMAM we probe the individual distributions of these components that we compare with simulation results obtained for different copolymer models (Fig.1 A). In particular, direct comparison between experimental and numerical form factors provides evidence of preferential organization into block structures, challenging the prevailing view of random distribution. Additional ¹³C-NMR experiments confirm NIPAM-rich blocks and atomistic simulations provide a link between this unexpected block-like architecture and distinct local hydrogen-bonding patterns. SANS analysis also reveals for all investigated copolymer compositions a maximum in the polymer mesh correlation length near the volume phase transition, evidencing coexistence of collapsed NIPAM-rich and swollen domains (Fig.1 B). The correlation length increases with increasing NIPMAM content, reaching a maximum at 75 mol % NIPMAM, implying a large degree of heterogeneity due to the presence of a large fraction of intercalated, non-collapsing PNIPMAM monomers. The maximum heterogeneity corresponds to a minimum in the equilibrium swelling ratio (Fig.1 C), suggesting that collapsed microgels retain a structural memory of the transition and present a less-compliant structure in response to temperature variations. Overall, these insights highlight a complex effect of the block-like monomer distribution on the responsive properties of copolymer microgels with different compositions, thus providing a design rule for tailoring responsive colloids for functional soft materials.



(A) Simulation snapshot of a 50:50 PNIPAM-PNIPMAM microgel and simulation-SANS comparison at different temperatures. (B) Maximal correlation length and (C) swelling ratio (experimental and simulated) as a function of composition.

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LipoGels: Robust self-lubricating physically cross-linked alginate hydrogels embedded with liposomes

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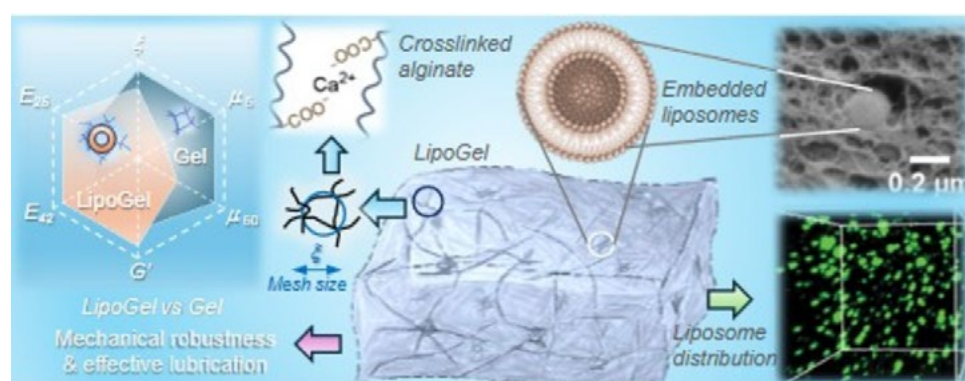
The exceptional lubrication devised by living systems (e.g. knee joints and eyelids) has stimulated intensive research into designing lubricating hydrogels and investigating the underlying mechanisms [1,2]. Current hydrogels for this purpose are typically *chemically* cross-linked, needing sophisticated synthesis and preparation procedures with a multitude of chemicals, which pose challenges in biocompatibility and sustainability.

Inspired by Klein's pioneering research [3], where lipid multilamellar vesicles were incorporated in synthetic hydrogels to facilitate cartilage-like lubrication, we have devised a facile method to incorporate ~ 100 nm 1,2-dipalmitoyl-sn-glycero-3-phosphocholine (DPPC) liposomes into a Ca^{2+} physically cross-linking sodium alginate hydrogel, which we term 'LipoGel' [4]. Cryo-SEM and confocal fluorescence microscopy confirmed the uniform distribution of liposomes within a compact porous hydrogel network. Small-angle neutron scattering (SANS) revealed a classic de Gennes' mesh size $\xi \sim 3.8$ nm, consistent with rheology-derived estimates, which yielded a shear elastic modulus G' 4 times that of chemically cross-linked hydrogels incorporating liposomes. The *LipoGels* exhibited robust mechanical strength with a Young's modulus $E \sim 1$ MPa from micro-indentation, comparable to some of the recent chemically cross-linked hydrogels. Underwater tribological tests demonstrated an ultra-low friction coefficient $\mu \sim 0.02$, highlighting their self-lubricating capabilities of the *LipoGels* in the presence of trace amounts of lipids (~ 0.05 -1 ppm). We further explore the effects of incorporating different types of liposomes, also comparing small unilamellar vesicles (USVs) with multilamellar vesicles (MLVs).

The facile yet effective gelation strategy for fabricating lubricating *LipoGels* with robust mechanical strength also emphasizes environmentally friendly processing and inherent biocompatibility. The versatility of this hydrogel system offers a platform for further exploration of the relationship between nano-structural features and lubrication effectiveness, opening up avenues for further biomedical applications.

Keywords:

Alginate hydrogels, biolubrication, liposomes, LipoGels, friction



Physically cross-linked alginate hydrogels embedded with DPPC liposomes (LipoGels) demonstrate robust mechanical strength, excellent lubrication, and stability under load, with inherent biocompatibility, transparency, and simple formulation.

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Study of polymer pseudo-brushes by Rheo-NR

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Polymeric fluids constitute a class of materials with remarkable physical properties, especially when subject to shear. They have several industrial applications, from e.g., production of plastics to functional coatings and lubrication. Understanding their rheology is both fascinating from the perspective of fundamental science and useful for technological development. When considering melts and semi-dilute solutions of high molecular weight polymers, the rheological properties are mostly independent of chemistry. Rather, they are defined by the chain length and the topological interactions between chains, and can thus be generalized. For example, in flowing through capillaries, entanglements of the chains and adsorption at the walls cause the stick-slip defect, a phenomenon whose molecular origin has been described theoretically [1] but not directly observed experimentally. Neutron reflectometry (NR) is a technique capable of characterizing buried interfaces in terms of layer thickness, roughness and composition, the latter thanks to the scattering contrast between deuterated and hydrogenous species. Combining *in situ* rheology and NR, it is possible to define the density profile of a polymer adsorbed on a solid substrate and study how it changes under shear. In previous work [2], we applied rheo-NR to study a polymer brush grafted to a substrate and in contact with a solution of the same polymer. We observed a collapse of the brush under shear, which is in line with molecular dynamics simulations and theory. In this presentation we investigate a Guiselin, or pseudo-, brush [3,4], in which the polymer chains are physisorbed on a substrate as this is a more realistic model for polymer flow at solid walls. The pseudo-brush is composed of deuterated polystyrene, and is immersed in a solution of hydrogenous polystyrene, to differentiate the contributions to the scattering signal via the isotopic contrast of the chains. Results suggest that, interestingly, chains from the pseudo-brush under shear exchange with those in solution rather than simply desorbing from the surface.

Keywords:

Polymer brush, Rheology, Neutron Reflectometry

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Associative and Segregative Liquid-Liquid Phase Separation in Macromolecular Solutions

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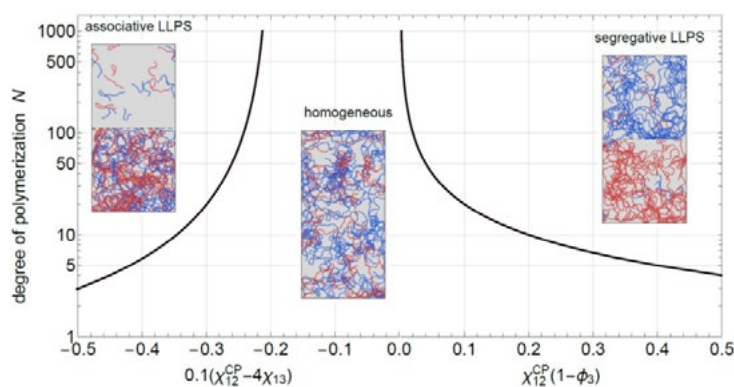
We investigated liquid-liquid phase separation (LLPS) and interfacial properties of two LLPS modes: associative (ALLPS) and segregative (SLLPS). Analytical expressions for the critical point (CP) and binodal boundaries are derived and show excellent agreement with self-consistent field (SCF) lattice computations.

Distinct thermodynamic features differentiate ALLPS from SLLPS: (1) in ALLPS, polymers co-concentrate within a single dense phase coexisting with a solvent-rich phase, whereas in SLLPS each polymer forms a separate phase; (2) the attractive interaction per monomer in ALLPS is strongly dependent on solvent quality, but solvent independent in SLLPS; and (3) ALLPS binodals exhibit near-universal behavior, largely independent of solvent content.

SCF results further show that interfacial tension increases and interfacial width decreases with distance from the CP. We provide scaling relations for both quantities. Compared with SLLPS, ALLPS displays higher interfacial tension and a thinner interface, reflecting distinct molecular organization at the liquid-liquid boundary.

Keywords:

Liquid-liquid phase separation; Associative phase separation; Segregative phase separation; Polymer mixtures; Interfacial tension; Interfacial width



LLPS phase diagram: associative, homogeneous, and segregative regimes for symmetric polymers.

Solvent controlled plasticization and thermal response of polyelectrolyte assemblies

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Polyelectrolyte (PE) complexes form spontaneously in solution with counterion release and ion-pair formation. PE complexes and multilayers are sensitive to pH, temperature, and ionic strength of the solution which makes PE assemblies highly responsive to external stimulus. Specifically interesting is their well-defined thermal transition that bears resemblance to a glass transition and is used widely in, e.g., thermo-responsive drug delivery and thermally adaptive polymer coatings. We have studied this transition, and its control via variation of the PE components, added salt, and most recently also the solvent environment by molecular modelling and theory approaches combined with experimental characterization of the corresponding materials.

Here, I discuss using solvent as a controlling means of the plasticization of polyelectrolyte assemblies, and in particular for the thermal transition at molecular level. We have combined molecular modelling and experimental characterization of PE assemblies to resolve the molecular level mechanisms and control means for various synthetic PE and solvent systems. Besides water as solvent, we have examined several different alcohol solvents and urea as solvent additives, extracting relation of the solvent quality and hydrogen bonding ability to the T_g and PE association response [1,2] but also connecting that the transition temperature T_g has a relation to the number of solvent molecules at the intrinsic ion pairs [3]. Our molecular simulations and experimental results together enable mapping the ionic strength and hydration, but also solvent composition dependencies of the intrinsic and extrinsic charge compensation of the PE assemblies and associating the transition specifically with the hydration of intrinsic PE-PE ion pairs and the solvent structure there [2-5]. In total, the findings rise attention to solvent and solvent partitioning as a control means to PE systems mechanical and structural characteristics.

Keywords:

polyelectrolyte complex, molecular modelling, layer-by-layer, LbL, multilayer, glass transition, thermal transition, thermal characterization, PE

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Star-like thermoresponsive microgels: a new class of soft colloids with Gaussian effective interactions

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Microgels are soft colloidal particles with micro- to nanoscale dimensions, consisting of a crosslinked polymer network with the ability to respond to various external stimuli. Among the most widely investigated microgels are those based on poly(N-isopropylacrylamide) (PNIPAM), a thermoresponsive polymer that exhibits a volume phase transition (VPT) in response to temperature changes. PNIPAM microgels are typically synthesized via free radical polymerization in the presence of a crosslinking agent, most commonly N,N'-methylenebis(acrylamide) (BIS).

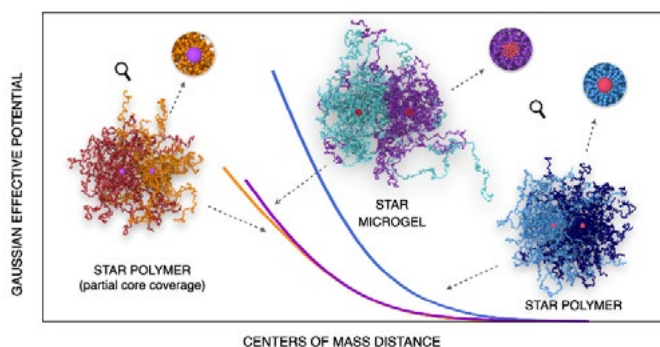
Star polymers, consisting of multiple arms radiating from a central small core, are instead the prototypes of ultrasoft colloids. However, the chemical synthesis of multi-arm stars is quite involved, requiring deep expertise. Furthermore, the polymers used to produce stars are usually not thermoresponsive.

In this contribution I will present recent experimental and simulation results on PNIPAM microgels where the cross linker is ethylenglykol dimethacrylate (EGDMA), building on the pioneering work of Hellweg group back in 2002 [1]. Thanks to the much faster reactivity of EGDMA with respect to BIS, these microgels adopt a peculiar star-like structure, with a crosslinker-rich core and crosslinker-free arms, at low crosslinker concentration. This is confirmed by the comparison between Small Angle X-ray Scattering and monomer-resolved computer simulations of star polymers and of star-like microgels [2]. For all studied EGDMA concentrations, these microgels undergo a very sharp Volume Phase Transition and manifest a high deswelling ability, in contrast with standard PNIPAM-BIS microgels. We also assess the role of crosslinker concentration and added surfactant stabilizers to ensure the formation of star-like topologies across different microgel sizes.

Next, we investigate the effective interactions of star-like microgels by computer simulations finding that they are Gaussian, in contrast to the Hertzian-like potential of regular microgels [3], and that they closely resemble stars with a core partially covered by arms, in contrast to ideal star polymers whose core is fully covered. We conclude by discussing the possible role of these unusual interactions on the phase diagram and dynamical arrest of these microgels under dense conditions.

Keywords:

microgels, star polymers, monomer-resolved simulations, soft colloids, effective interactions



Calculated Gaussian effective potentials between star-like microgels, star polymers and star polymers with a partially covered core as a function of the centers of mass distance.

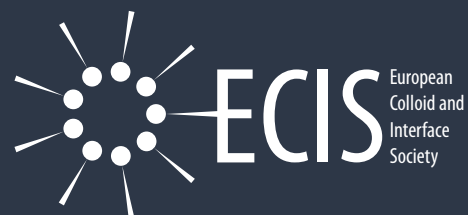
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Topic 7

Polymers, Polyelectrolytes,
Gels, Micro/Hydrogels, Glasses,
and Liquid Crystals

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Water-Soluble Interpolyelectrolyte Complexes (IPECs) - Effect of Hydrophobic Modification on Structure and Solubilisation

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Oppositely charged polyelectrolytes have a strong tendency to co-assemble in aqueous solution, thereby forming interpolyelectrolyte complexes (IPECs). Their structure depends strongly on the type of polyelectrolytes, where chemistry of the monomeric unit, degree of polymerisation, and the architecture play major roles. The typical problem of insolubility encountered upon approaching charge neutralisation may be addressed by employing polyelectrolytes with a second, neutral hydrophilic block, i.e. using a double-hydrophilic block copolymer (DHBC).

In our work, we studied a larger range of such IPECs, including DHBCs, to control the phase behaviour. Most interestingly we introduced hydrophobic modifications into the polyanion, based on poly(acrylic acid) (PAA) and poly(methacrylic acid) (PMAA). By introducing different percentages of C4 to C16 alkyl chains we not only modify the assembly behaviour of their IPECs but the presence of the hydrocarbon chains also changes the solubilisation properties of the IPEC core, which normally is rather polar due to the high concentration of oppositely charged units.

The structure of the complexes formed in aqueous solution was characterised by means of static and dynamic light scattering, small-angle x-ray and neutron scattering (SAXS, SANS), and complementary cryo-TEM measurements. The focus was on how the aggregate structure depends on the mixing ratio of the two polyelectrolytes and the extend of hydrophobic modification. In parallel to this mesoscopic characterisation, we studied in detail how the solubilisation capacity of the IPECs for different drug molecules like curcumin, fenofibrate, carbamazepine, etc. depends on the choice of the IPEC components and in particular on the presence of hydrophobic modifications. These studies showed that a very marked (by factors of 50-100) enhancement of drug solubilisation can be achieved by appropriate choice of the IPEC components and in particular by the presence of the hydrophobic modification.

In summary, we find that hydrophobic modification is an interesting way to tune the structure and properties of IPECs and the solubilisation properties can be directly related to the mesoscopic IPEC structure. By combining the concepts of HM-PEs and DHBC one can control phase behaviour and structures over a large range, thereby offering the option to tune soluble IPECs for desired properties and potential applications.

Keywords:

interpolyelectrolyte complexes, solubilisation, small angle scattering

Reconfigurable Liquid Crystals of Plasmonic Nanorods

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Elongated (high aspect ratio) rod-like particles in suspension can spontaneously organize into liquid crystal phases, due to excluded volume interactions.¹ While this phenomenon has been observed with various colloidal systems, including organic (e.g., viruses)² and inorganic (e.g., oxides) nanorods, plasmonic colloidal liquid crystals (CLCs) based on gold or silver nanorods remain largely unexplored. Here, we report on LC phases (nematic and smectic B, depending on concentration) found in aqueous suspensions of Au@Ag (core-shell) nanorods. We combine small-angle x-ray scattering (SAXS) and optical experiments to study the phase behavior of these charged plasmonic nanorods. LC suspensions align in both electric and magnetic fields, at field intensities comparable to those required by molecular LCs. Furthermore, the suspensions show a reversible transition from nematic to smectic B phases in response to thermal and photoinduced stimuli. Such original reconfigurability of these CLCs, imparting them with novel collective optical properties, makes them good candidates for designing photonic devices and responsive sensors.

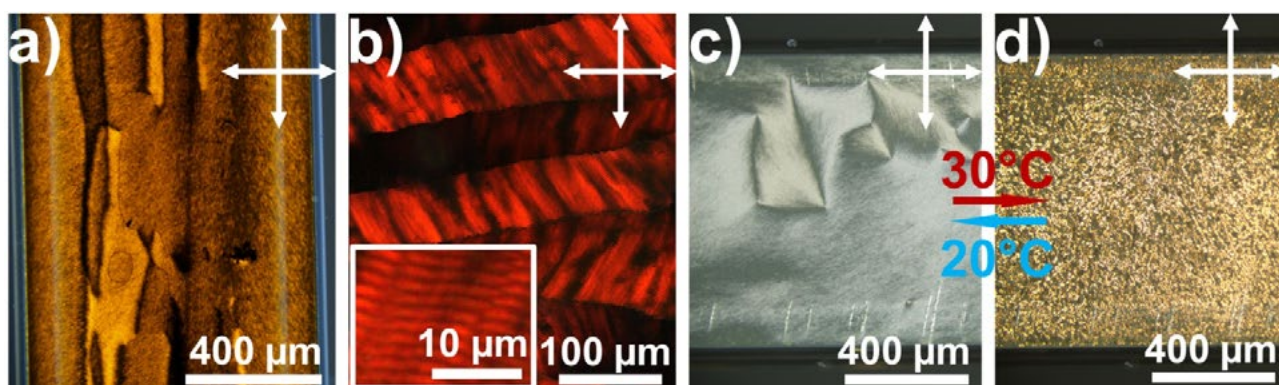


Fig. 1: a) and b) Polarized-light microscopy images of Nematic and Smectic B phases, respectively (the inset in b) is a magnified image showing the smectic layers); thermally-induced phase transition from c) Nematic to d) Smectic B phase.

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This work was supported by the Grant ANR CODENAME (ANR_PRC-CE09). Thomas Bizien is acknowledged for the help during Soleil Synchrotron run.

Super-Resolution Imaging of Nanoscale Monomer Distribution in Copolymer Microgels

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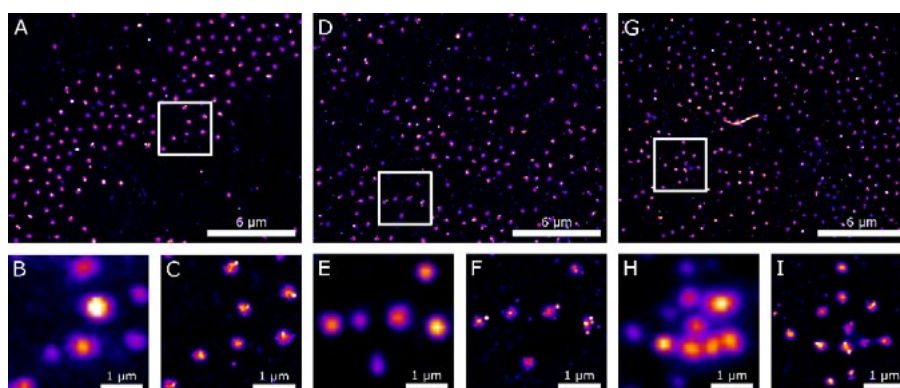
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Microgels, three-dimensional polymer networks with colloidal dimensions, are promising candidates for catalysis, sensing, and drug delivery applications due to their responsive properties. Cationic copolymer microgels are particularly interesting, as they can be conjugated with biomolecules such as peptides, antibodies, or nucleic acids.[1] Poly(*N* -*n*-propylacrylamide-co- *N* -3-(dimethylamino)propylmethacrylamide) (Poly(NNPAM- *co* -DAPMA)) is one such microgel, exhibiting thermoresponsiveness through *N* - *n* -propylacrylamide (NNPAM) and pH responsiveness through *N* -3-(dimethylamino)propylmethacrylamide (DAPMA).[2]

In this study, the network structure of Poly(NNPAM- *co* -DAPMA) microgels was investigated using direct stochastic optical reconstruction microscopy (dSTORM), a high-resolution fluorescence technique that allows visualization of comonomer distribution at the nanoscale.[3] Microgels with varying DAPMA concentrations were synthesized and characterized for their swelling behavior using photon correlation spectroscopy (PCS), providing insight into size distribution and polydispersity. Morphological properties, including particle shape and surface topology, were examined using atomic force microscopy (AFM). Post-synthetic fluorescence labeling was performed using the anionic dye DY-654-carboxylic acid [4], which targets the cationic DAPMA units through electrostatic interactions. This specific dye-target coupling, combined with the photoswitching properties of DY-654-carboxylic acid, enabled the visualization of the internal microgel structure via dSTORM. The labeling revealed high fluorophore localization within the microgel core alongside distinct high-density domains, indicating a heterogeneous network with non-uniform comonomer distribution. These results demonstrate that the internal architecture of cationic microgels is more complex than previously assumed, and that dSTORM can provide quantitative and spatially resolved information on functional polymer networks. Such insights are crucial for the rational design of microgels in catalysis, drug delivery, or biosensing applications, where network structure strongly affects performance and interaction with biomolecules.

Keywords:

Smart Microgels, Labeling, Monomer Distribution, Fluorescence Microscopy, Super-Resolution Imaging, dSTORM, 3D Density



dSTORM of NNPAM microgels with varying DAPMA content. All microgels labeled with DY-654-carboxylic acid. (A-C) 5 mol%, (D-F) 7.5 mol%, (G-I) 10 mol% DAPMA. (A, D, G) Large dSTORM FOVs; (B, E, H) Wide-field ROIs; (C, F, I) Corresponding dSTORM ROIs showing structural heterogeneity.

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Gelatin-Based Hydrogel Materials for Controlled Sorption and Release of Metoprolol

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Gelatin-based materials, particularly hydrogels, are widely used in various biomedical science fields such as drug delivery and tissue engineering [1-2]. In this study, we utilized microfluidic techniques to generate two different gelatin methacryloyl (GelMA) hydrogels with inverse macroscopic structures but similar microscopic network structures, specifically porous hydrogels and hydrogel particles. Inverse macroscopic structures mean that the node size of the porous hydrogels equals the diameter of the hydrogel particles, as shown in Figure 1. The similarity of the hydrogel network structures of both materials, in terms of the hydrogel volume ratio upon swelling, was confirmed by using X-ray microtomography (μ CT). Furthermore, the ion transport property of both hydrogel materials, in terms of sorption and release, were investigated using metoprolol as a model drug. We investigated the effect of the material shape, porous hydrogels and hydrogel particles, the material size, pores 550 and 850 μ m in diameter, and particles 230 and 150 μ m in diameter, on the sorption and release of metoprolol. The study was conducted under two conditions, equilibrium and time-dependent kinetics. We found that at equilibrium, the hydrogel morphology and size do not influence the sorption and release. On the other hand, they significantly affect the sorption and release kinetics. Metoprolol kinetics can be accelerated by increasing the pore size in the case of the porous hydrogel, and by decreasing the particle diameter in the case of the hydrogel particles, achieving the goal of controlling the sorption and release kinetics of metoprolol with the hydrogel matrix.

Keywords:

GelMA, microfluidics, porous hydrogels, hydrogel particles, X-ray microtomography, sorption, release

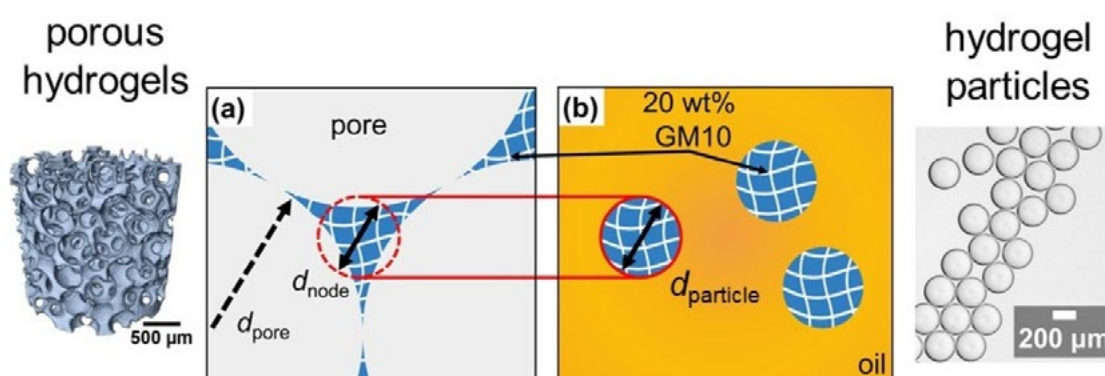


Figure 1: Schematic 2D drawing of GM10 (a) porous hydrogel and (b) hydrogel particles. The dashed circle in (a) represents a circle with a diameter (d_{node}) that has the same area as the blue area enclosed by three pores, i.e. the node. Fulfilling the condition $d_{\text{particle}} = d_{\text{node}}$ one obtains hydrogels

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Resolving the liquid-to-glass transition(s) of water under soft nanoconfinement

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Water has challenged scientists with numerous anomalies and confounding problems since the very early times. The kinetic glass transition of bulk water is a pristine example, as its location remains mostly inaccessible to experimentalists in an area below about -41 °C, where bulk water spontaneously crystallises. Confining water within nanometre-sized domains is an intriguing approach inspired by the cellular environment in nature to completely prevent crystallisation. In this talk I will present our recent efforts directed to probing the liquid-to-glass transition(s) of water nanoconfined between non-freezing lipidic bilayers and will showcase a peculiar and counterintuitive regime over an extended temperature range, for which a sub-nanometre layer of water remains glassy in between fluid (mobile) walls of lipidic molecules. I will provide comprehensive evidence for a slowing down of water dynamics under soft nanoconfinement occurring in the -63 to -20 °C range across six orders of magnitude in time scales from 10^{-6} to 10^{-12} s, and a static glass transition ranging between -74 and -64 °C. These findings offer previously uncharted insights into the elusive glass transition of water under nanoconfinement, with broader implications for all those areas where water is confined at the nanometre scale below its freezing point.

Keywords:

No-man land, supercooling, glass transition, dynamic arrest

Polymer Microgels as Synthetic Mimics of Cellular Compartments and Nucleoprotein Condensates

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Polymer microgels are emerging as modular soft matter platforms that bridge materials science and synthetic biology by recreating essential structural and functional features of living systems. Their defined network architecture, tunable mechanics, and chemical responsiveness/adaptiveness enable the construction of synthetic microenvironments that mimic cellular confinement and dynamics as well as macromolecular crowding. Along these lines, hyaluronan-based microgels were engineered to immobilize functional proteins while preserving their activity, creating spatially confined reaction volumes capable of supporting cell-free gene expression.[1] These systems mimic intracellular organization by coupling matrix mechanics with localized biochemical functionality. In a complementary approach, polymer microgels equipped with DNA-binding motifs were developed as simplified model to study protein-DNA interactions of a bacterial cell division machinery.[2] By reproducing key aspects of nucleoid-associated protein-DNA interactions within a defined hydrogel network, these materials enable controlled investigation of biomolecular condensation and spatial protein synthesis in a bottom-up approach.

Stimuli-responsive microgels further expand this biomimetic concept. PNIPAAm-based networks with tailored crosslinking architectures translate molecular interactions into temperature-dependent swelling, providing adaptive and quantifiable readouts relevant for biosensing and cell heating during optical trapping.[3] Complementary micromechanical analyses of hydrogel viscoelasticity[4] contribute to understanding how local elasticity and relaxation behavior in microgels may influence a biological machinery therein.

Together, these studies showcase microgels as synthetic mimics of cellular compartments and nucleoprotein assemblies that integrate mechanical programmability with biochemical function. With these systems, we have a versatile tool at hand for constructing bottom-up cell models, studying confined biomolecular interactions, and designing programmable biomaterials for synthetic biology and bioinspired soft matter applications.

Keywords:

Synthetic biology, hydrogels, microgels, additive manufacturing, droplet microfluidics

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Counterion-mediated growth of ruthenium nanoparticles stabilised by polymerized ionic liquids for future catalysis applications

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Ruthenium nanoparticles (RuNPs) have garnered significant interest as catalysts for many industrially important reactions, but in order to attain commercial viability, their catalytic activity and selectivity, stability, and recyclability must be improved. These RuNPs can be stabilised through the addition of polymerised ionic liquids (PILs) during synthesis, which sterically and electrostatically stabilise the RuNPs while maintaining chemical accessibility to the catalyst surface. Preliminary investigations with in-house SAXS have shown that the size dispersion of RuNPs stabilised by imidazolium-based cationic PILs, *i.e.* Ru@PIL(+), vary dependent on the PIL counterion, with previously published X-ray photo-correlation spectroscopy (XPS) data from our consortium suggesting that this may be due to whether the counterion or the PIL chain interacts with the RuNP surface. ^{1,2} Using small-angle X-ray and neutron scattering (SAXS/SANS), transmission electron microscopy (TEM) we have revealed that the PIL counterion was the key parameter towards tuning the morphologies of Ru@PIL(+) during synthesis in ethylene glycol, while the pendant alkyl chain group length had only a minor influence. We propose a mechanism whereby the PIL mesh size dictates the size of the RuNP formed, then the size of the counterion and its affinity with the RuNP surface controls the aggregation of these particles through “electrosteric” stabilisation (**Figure 1**). In the case of each counterion: with **Cl⁻**, spherical RuNPs were obtained, whose radius was directly related to the PIL concentration (and thus mesh size), ranging between 0.7 and 1.5 nm; with **Br⁻**, 1 nm spherical RuNPs coexist with 3 nm cluster forms and further aggregated mass fractals, irrespective of the PIL concentration; while for **I⁻**, solely larger objects were obtained. These structures were preserved when redispersed in water, and their behaviour in complexed polyelectrolyte coacervate gels containing high concentrations of RuNPs was also studied as a promising reaction medium. These insights, combined with data on catalytic performance, will produce essential links between RuNP nanomorphologies and catalytic activity.

Keywords:

Metallic nanoparticles, nanocatalysis, polymers, stabilizers, aggregation behaviour, coacervates

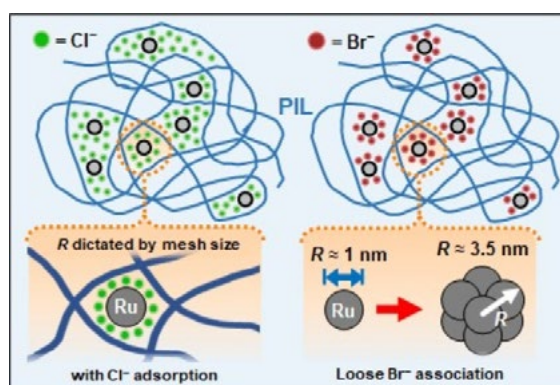


Figure 1. Schematic illustrating the proposed mechanism by which RuNPs grow in synthesis when stabilised by imidazolium-based polymerised ionic liquids and their associated counterions. These RuNP structures are then replicated when the products are purified and redispersed in water.

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A polymer-supported microcontact printing (μ CP) routine for submicroscale patterning of capillary-active interfaces and hydrogels

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We present an innovative μ CP technique that enables highly precise patterning of capillary-active surfaces and hydrogels. This method uniquely combines exceptional spatial resolution with the ability to generate chemically functionalized regions directly at the printed sites. A polymer brush-supported printing strategy is central to this method.[1]

In this approach, polymer brushes are grafted onto an elastomeric polydimethylsiloxane (PDMS) stamp, which facilitates controlled and reactive ink transfer. The ink molecules are first immobilized within the polymer brush matrix through chemical attachment. Upon contact with the substrate, these molecules are transferred and form irreversible bonds with the surface. This mechanism effectively suppresses undesired ink spreading or smearing, a common limitation in conventional microcontact printing techniques, resulting in sharply defined and highly reproducible patterns.

Using this method, chemically well-defined patterns can be transferred with excellent local precision. Its versatility further broadens its applicability: a wide range of substrates—including (i) oxidic surfaces,[2, 3] (ii) cellulose,[4] and (iii) glycan-containing hydrogels[5] – can be functionalized (Figure 1). Moreover, the technique is not limited to planar systems; it can be extended to complex and curved geometries, enabling the modification of microscale objects such as microparticles[6] and even cellular interfaces.[5]

This adaptability opens up opportunities across multiple scientific and technological domains. By integrating microscale accuracy, chemical specificity, and broad substrate compatibility, the polymer brush-supported μ CP approach represents a significant advancement in surface engineering, biointerface design, and materials science.

Keywords:

Microcontact printing, polymer brushes, patchy particles, surface patterning

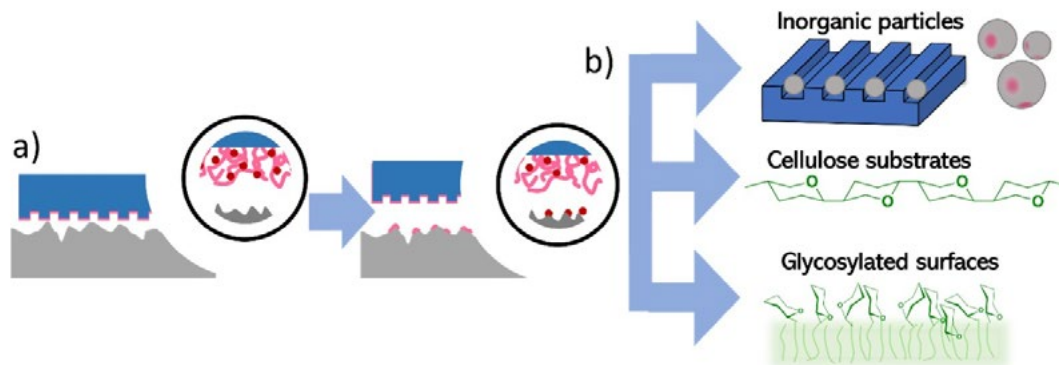


Figure 1: Polymer brush-supported μ CP. a) Principle. b) Possible substrates.

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Ratiometric detection of perfluoroalkyl carboxylic acids using dual fluorescent nanoparticles and a miniaturised microfluidic platform [1]

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Per- and polyfluoroalkyl substances (PFAS) are a group of chemicals with fluorinated carbon chains, including perfluorocarboxylic acids (PFCAs) such as perfluorooctanoic acid (PFOA). Extensive industrial use, particularly in Teflon production, has led to widespread environmental contamination. PFAS are highly persistent, bioaccumulate, and are now found globally in water, soil, and living organisms. Due to their toxicity, PFOA and related compounds were listed as persistent organic pollutants under the Stockholm Convention in 2019, prompting increased monitoring in water sources.[2]

According to the current state of the art, PFAS are predominantly analyzed using chromatography techniques coupled to mass spectrometry, such as GC-MS, HPLC-MS, tandem HPLC-MS/MS, or HRMS.[3] While these methods offer excellent sensitivity down to the ppt range, they are time-consuming, costly, and require laboratory infrastructure and trained personnel, limiting their use for on-site or routine monitoring, for example at industrial sites or wastewater treatment plants. In contrast, fluorescence assays provide a simpler, portable, and cost-effective alternative with rapid response and high sensitivity, particularly when analyte binding enhances probe emission. Integrating such probes with suitable carrier platforms and miniaturized optofluidic devices represents a promising approach for point-of-need PFCA monitoring.

In this study, we present the development of a green-fluorescent guanidine-BODIPY indicator monomer incorporated into a molecularly imprinted polymer (MIP) for the selective detection of perfluorooctanoic acid (PFOA). Analyte binding induces a fluorescence enhancement, enabling sensitive detection. The MIP is deposited as a thin layer on silica nanoparticles doped with tris(bipyridine)ruthenium(II) chloride, which provides an internal orange-emitting reference and improves measurement precision. In combination with a liquid–liquid extraction protocol, the system allows direct detection of PFOA in environmental water samples with a detection limit of 0.11 μM . Integration into an opto-microfluidic platform further enables rapid and user-friendly analysis within 15 minutes (Figure 1).

Keywords:

Molecularly Imprinted Polymers (MIPs), Fluorescence, Microfluidics, Onsite assay, PFAS

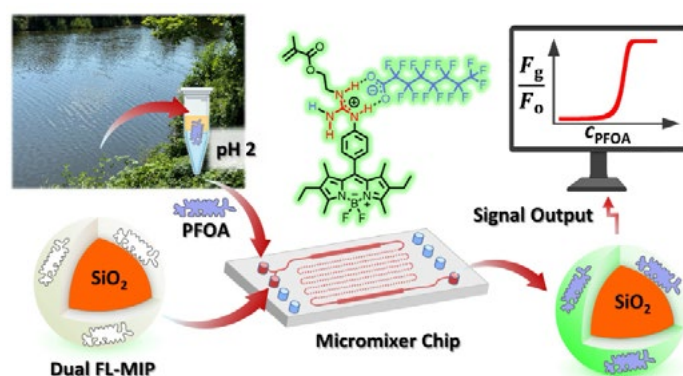


Figure 1: Scheme of miniaturized device for detection of PFOA with MIPs.

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Enrichment of higher charge density subspecies of random polyelectrolyte copolymer in complex coacervate

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Mixing pH-adjusted solutions of oppositely-charged polyelectrolytes results in the formation of polyelectrolyte complexes. We explore the spontaneous liquid-liquid phase separation which results in a polymer-rich phase coexisting with a polymer-poor phase, known as complex coacervation, in the context of the complexation of a strong polyelectrolyte charged at every monomer and a weak one, randomly charged. Herein we focus in the effect of added monovalent salt, and the question of the partitioning of each of the monomers (positively charged, negatively charged and neutral) in the two phases. With the use of quantitative phase microscopy, solution NMR and inductively coupled plasma mass spectrometry, we establish a quantitative phase diagram, tie lines for the monomers, and salt partition in stoichiometric and off-stoichiometric ratios.

Our main result exhibit the enrichment of the dense phase by the weak polyelectrolyte's higher charge density subspecies. This self-organized partitioning may have implications in the phase separation of proteins revealing how post-translational modifications that alter the charge density may controlling the partitioning inside versus outside dense droplets.

Keywords:

complex coacervate, phase separation, quantitative phase microscopy, NMR

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Polyelectrolytes with guanidine structural motifs: From internal chain dynamics to the formation of interpolyelectrolyte complexes

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The guanidinium ion has the ability to form dimers (Fig. 1a) despite like charges of the group due to its Y-conjugated pseudoaromatic character [1]. The unique combination of this short-range attractive interaction of guanidinium groups with the long-range electrostatic repulsion between them is the reason for the distinct behavior of polyelectrolytes bearing guanidinium side groups. In this communication, we present the results of a solution behavior study of two classes of polyelectrolytes containing guanidine structural motifs in their monomeric units.

(1) Polyelectrolytes with guanidinium side chains, synthesized by guanylation of polyallylamine (GPAs, Fig. 1b). By comparing polyallylamine with its partially and fully guanylated derivatives, we follow the influence of the modification on polymer's conformation and dynamics in a broad range of length scales (from single coils to aggregates and from internal chain motion to translational diffusion) using scattering techniques (static and dynamic light scattering, SANS, neutron spin echo spectroscopy) and DOSY NMR.

(2) Polyelectrolytes synthesized by condensation of biguanide derivatives with formaldehyde. The biguanide condensates, bearing guanidine structural motifs in both the side groups and in the backbone, can have a complex structure as the condensation can lead to branching of the polymer chain. We will focus on the solution behavior of the metformin condensate (MFC, Fig. 1c) as well as the formation of core-shell nanoparticles with double-hydrophilic polyanion poly(methacrylate)-*b*-poly(ethylene oxide). The formation occurred at much lower MFC/PMAA-PEO ratios than would correspond to the isoelectric point, yielding strongly negatively charged nanoparticles, suggesting the role of specific interactions in the stabilization of the MFC/PMAA complex [2].

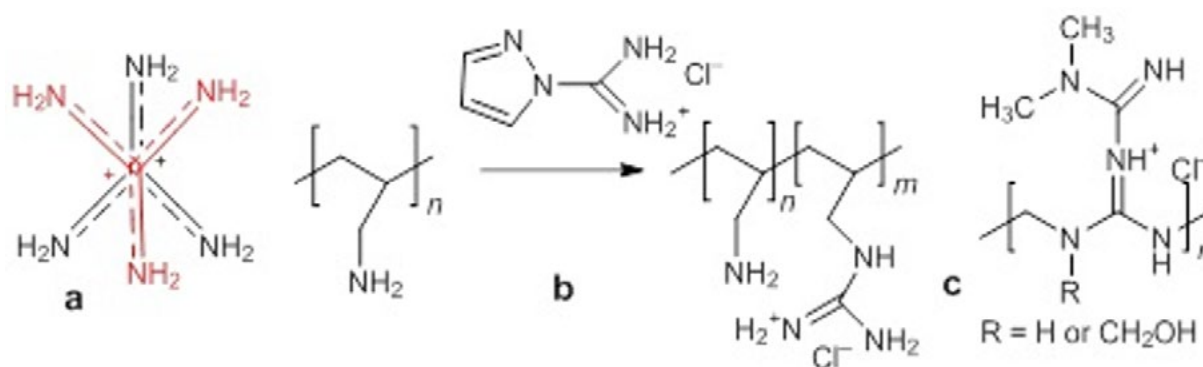


Fig. 1. (a) guanidinium ion pair, (b) scheme of polyallylamine guanylation, (c) metformin condensate

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Cyclable Photomodulation of Supramolecular Gels in Deep Eutectic Solvents

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Deep eutectic solvents (DESs) are a class of designer solvents formed by the complexation of two or more components (e.g., a hydrogen-bond donor and an organic salt), yielding a mixture with a significantly depressed melting point. This cooperative hydrogen-bond network produces liquids with tunable physicochemical properties dictated by the specific combination of precursors [1].

Building on this versatility, DESs have emerged as compelling media for directing soft-matter organization. Specifically, DES-based gels (eutectogels) offer a paradigm shift in the design of functional soft materials [2], enabling macroscopic properties that emerge fundamentally from solvent–solute interplay rather than isolated molecular design [3].

In this contribution, we present a flexible methodology for the preparation of photo-responsive eutectogels that display inherent capabilities for mechanical tuning. To accomplish this, we targeted supramolecular co-assembly process pairing an amphiphilic molecule with a custom-synthesized azobenzene derivative, which was specifically optimized to dissolve readily in anhydrous DES environments. Analysis at both the molecular and mesoscale levels sheds light on the molecular interactions responsible for generating elongated, one-dimensional networks. Importantly, our findings reveal how molecular-level photoisomerization propagate into mesoscopic morphological changes, ultimately switching macroscopic behavior. When exposed to ultraviolet light, the assemblies contract, which triggers a distinct transition from a gel to a fluid state and effectively erases its solid-like properties. Conversely, exposure to visible light regenerates strong, stable gel networks that display remarkable stability to prolonged storage. These light-driven phase shifts demonstrate excellent reversibility, allowing for numerous cycles with virtually no degradation in mechanical strength or structural integrity. Overall, our findings provide a broad, adaptable framework for creating advanced, dynamic smart materials using DES platforms.

Keywords:

Deep Eutectic Solvents, Eutectogels, Photo-responsive Materials, Self-Assembly

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A neutron enters a bar and meets a microgel, a cubosome, and a spaghetti strand...three tales on small-angle neutron scattering with contrast variation

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Small-angle neutron scattering (SANS) with contrast variation is a fundamental tool to study soft materials, from model systems for soft spheres to understand the role of softness on the phase behaviour and flow properties of materials and complex fluids (e.g. microgels), to nanoparticles for applications such as drug delivery (e.g. cubosomes) and also to unravel the perfect cooking conditions of spaghetti. In this talk, I will present different applications of SANS with contrast variation, combined with complementary small-angle X-ray scattering. I will show how one can access the information on soft and compressible colloids (microgels) in crowded and overcrowded conditions using the so-called tracing methods [1]. Then I will show how SANS and contrast variation can be used to quantify the response of cubosomes to external osmotic stress [2]. Finally, I will use SANS with contrast variation to disentangle the structure of the gluten matrix and the structures of starches in regular and gluten-free spaghetti to show how different cooking times and salt concentrations affect the structural evolution of the pasta [3].

Keywords:

neutron scattering, contrast variation, microgels, cubosomes, spaghetti

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Controlling the structure of star-like copolymer microgels through the monomer chain length to modulate softness and deswelling

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Softness and stimulus responsivity of deformable polymeric particles are at the core of their properties and behaviors in suspension or when interacting with interfaces, being thus fundamental parameters for the design of functional materials and complex fluids. Synthetic microgels, crosslinked polymeric networks partially soluble in the solvent in which they are dispersed, particular those made of poly(N-isopropylacrylamide) (PNIPAM), are one of the most prominent example of soft colloids, and are extensively studied for fundamental understanding of soft matter systems and for their application potential.

We recently discovered,[1] combining experiments and monomer-resolved simulations, that replacing commonly used crosslinkers with ethylene glycol dimethacrylate (EGDMA) allows obtaining microgels with an unprecedented internal structure combining microgel features with that of star polymers. Such a star-like morphology presents a small and dense core containing most of EGDMA and a sparse shell with polymer arms, particularly at low crosslinker concentration. These star-like microgels fully retain PNIPAM thermoresponsivity and undergo a sharp volume phase transition at ~32 °C.

Taking a step further, in this presentation I will show that copolymerization with oligo(ethylene-glycol) methyl-ether-methacrylates (OEGMA) of varying chain lengths represents a powerful handle to control particle softness and thermal response.[2] Light and neutron scattering allowed us to quantify the single-particle bulk modulus and link it to temperature-induced deswelling, elucidating the complex interplay between network conformation and mechanical properties in response to different stimuli. The results reveal a non-trivial dependence on comonomer chain length: short OEGMA chains smooth the core-shell contrast yielding more homogeneous particles, while longer chains produce extremely compliant star-like morphologies that maintain star features even at high temperature. Overall, these findings provide new tools to finely tune softness and stimulus responsivity of soft colloids.

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Recent progress in studying the phase behavior of deformable colloids at fluid interfaces: Why in situ techniques are needed.

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The stabilization of fluid interfaces by colloidal particles is crucial for applications (e.g. stabilization of foams and emulsions, nanolithography) and fundamental science (e.g. crystallization, role of defects, collective behavior). While monodisperse rigid spheres tend to arrange in hexagonal lattices when adsorbed at fluid interfaces at sufficiently high packing fraction, their spacing is typically limited to close-packing. In contrast, deformable colloids like microgels[1] can assemble into dense monolayers with a spectrum of interparticle distance that is controlled by the available area. Many studies in the last two decades attempted to understand the phase behavior of soft, deformable microgels at such liquid interfaces. Typically, the microstructures in dependence of the applied surface pressure are studied *ex situ* using transfer of microgel monolayers from the liquid to a solid interface followed by investigation with different types of microscopies. Recent works have shown that microstructures obtained from *ex situ* analysis can differ significantly from the phase behavior observed *in situ* at the fluid interface [2-4]. In this contribution we will reflect on different methods that can be applied for *in situ* investigations of colloidal monolayers at fluid interfaces. We will discuss limitations of these techniques and with respect to the requirements for the colloids under investigation. In particular, we will focus on two approaches that are compatible with Langmuir trough experiments: 1) Small-angle light scattering (SALS) as a tool to study structure factors under equilibrium as well as non-equilibrium conditions [2, 5]. 2) Extinction spectroscopy that can be applied to labelled microgels as for example core-shell microgels with plasmonic cores [6]. Finally, we will shine light on the complex interplay of different forces that act on a soft colloidal monolayer during transfer to a solid substrate and the subsequent drying of the thin film (figure 1) [3].

Keywords:

deformable colloids, microgels, self-assembly, Langmuir trough, uniaxial compression, small-angle light scattering



Figure 1: Microgel monolayer during different states of drying (from right to left) on a hydrophobic substrate. Scale bar = 10 μm .

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Molecular level insight into behavior of ternary polyelectrolyte complexes

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Polyelectrolyte complexes (PECs) are highly tunable soft materials formed by the association of oppositely charged polymers. Owing to their broad range of physicochemical properties and potential applications, PECs have attracted increasing attention in recent years. However, most studies have focused on binary systems, whereas ternary polyelectrolyte compositions remain comparatively underexplored. In this field, the lack of a molecular-level framework limits the reliable interpretation of experimental observations and hinders a comprehensive understanding of multicomponent polymer blends.

In this work, all atom molecular dynamics simulations and experimental characterization were used to investigate the ternary PECs composed of poly(styrenesulfonate) (PSS), poly(acrylic acid) (PAA), and poly(diallyldimethylammonium chloride) (PDADMAC). The results reveal a clear asymmetry between the two polyanions in ternary complexes. PSS forms preferential and comparatively salt-resistant ion pairs with PDADMAC, suggesting a more persistent contribution to the complex formation. In contrast, fully charged PAA interacts more strongly with PDADMAC at low ionic strength, whereas at higher salt concentration it becomes increasingly compensated by Na^+ . As a result, PAA-rich complexes favor more hydrated, gel-like assemblies, whereas PSS-rich complexes form more compact, solid-like structures. These findings provide molecular level insight into the role of salt and composition in ternary PECs and suggest that ternary composition can be used as additional mean to tune the macroscopic properties of polyelectrolyte systems.

Keywords:

Ternary polyelectrolyte complexes, Polymer blends, Molecular dynamics simulation, PDADMAC, PSS, PAA

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Influence of structure and processing on plant-based wax on physical properties of micro-oleogels

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Wax-based oleogels are used as natural structuring agents to convert liquid oils into semi-solid forms, enabling applications in food, pharmaceutical, cosmetic, and allied industrial applications. However, the influence of structure and processing conditions of oleogels on their bulk properties is not yet fully understood, particularly for room-temperature oleogelation process. In this study, two different waxes, rice bran wax (RBX) and rapeseed wax (RSX) were selected to prepare oleogels in sunflower oil. A two-step process was applied, employing oleogel formation followed by formation of oleogel-based particles *i.e.* micro-oleogel *via* controlled shearing at 25 °C. A combination of polarized light microscopy (PLM), differential scanning calorimetry (DSC), X-ray diffraction (XRD), small angle X-ray scattering (SAXS) were employed to characterize the multiscale structure of the wax crystals and their influence on the bulk physical properties of the micro-oleogels. XRD alongside SAXS analyses revealed that RBX had an orthorhombic crystal structure compared to RSX, which had triclinic packing. Microscale structural assessment revealed that RBX-oleogels exhibited needle-shaped crystals, whereas RSX-oleogels formed spherulitic structures. Both structures underwent a significant reduction in size after conversion to micro-oleogels, where the shear-induced micro-oleogelation process allowed forming a stable self-supporting gel at 25 °C with orders of magnitude higher viscosities at lower shear rates (10 s⁻¹), unlike the parent oleogels at the same concentration of wax (10 wt%). Remarkably, the micro-oleogelation processing step did not influence the nanoscale crystal structure of the waxes, suggesting that bulk physical properties of the micro-oleogels were primarily governed by the microscale structure of the wax particles. Overall, our multiscale analysis demonstrates that processing plays a crucial role in determining the microscale structure, which in turn govern the rheological behaviour and stability of oleogels without altering their nanoscale crystal structures. Future studies will focus on how these micro-oleogels behave at liquid-liquid interfaces.

Keywords:

Rapeseed wax, Rice bran wax, Oleogel, micro-oleogels, X-ray diffraction, Polarised light microscopy

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Re-entrant plasmon coupling driven by phase behavior of microgel–nanoparticle systems

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The development of flexible photonic devices with adaptive optical properties has attracted increasing attention in recent years. A well-established strategy to integrate soft and photonic components relies on embedding plasmonic nanoparticles (NPs) within thermoresponsive microgels [1]. In these hybrid particles, the volume phase transition (VPT) of the polymeric microgel couples microscale structural changes to nanoscale plasmonic interactions, enabling external control over interparticle distances and, consequently, over plasmon coupling and optical response [2]. However, the role of colloidal stability in determining the optical response of such hybrid systems has been largely overlooked, despite its potential to give rise to a much broader range of optical behaviors.

We reveal a counter-intuitive re-entrant behavior in the optical response of electrostatically assembled microgel–NP complexes as a function of the NP-to-microgel number ratio: increasing NP loading initially enhances coupling, but beyond a critical threshold it leads to a weakening of the optical response [3]. To rationalize this behavior, we combine optical spectroscopy with X-ray and dynamic light scattering techniques to establish a quantitative relationship between plasmonic coupling and interparticle distance, identifying two distinct coupling regimes. We then demonstrate that, beyond the VPT-driven gathering of NPs within individual complexes, plasmonic coupling is also governed by inter-complex interactions that emerge at intermediate NP loading, where loss of colloidal stability leads to the formation of large aggregates and to pronounced enhancement of the plasmonic response.

We rationalize the overall phenomenology within the framework of charge-patch interactions by constructing a NP-loading-temperature phase diagram that directly links colloidal stability to optical response. Our findings demonstrate that plasmonic coupling in soft colloidal systems is controlled not only by nanoscale structure but also by mesoscale phase behavior, thus establishing a general framework for harnessing colloidal interactions to program optical responses in soft photonic materials.

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Tailoring the Physico-Chemical and Biological Interface of Gelatin-Based Hydrogels: The Role of Lactic Acid in Network Stability and Cell Viability

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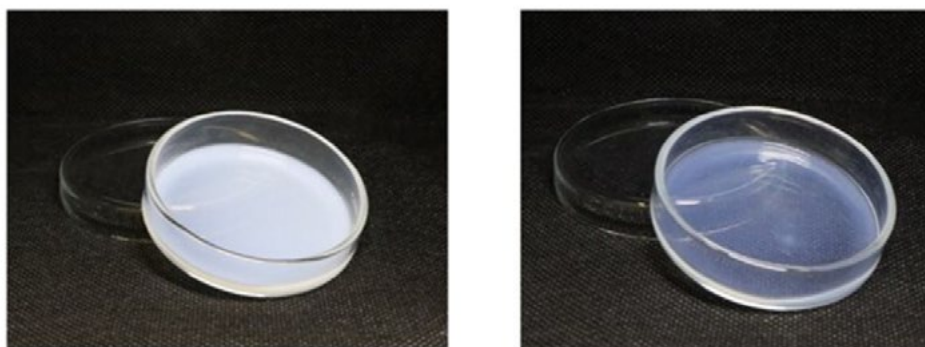
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Hybrid hydrogels based on natural and synthetic polymers are key materials in modern bioengineering, yet achieving a balance between pre-polymerization stability, mechanical integrity, and biological activity remains a challenge [1-2]. This study investigates the influence of lactic acid (LA) and photoinitiator concentration on the structural and interfacial properties of gelatin-poly(ethylene glycol) diacrylate (PEGDA) networks synthesized via UV-induced photopolymerization. A critical aspect of our research was the analysis of the stability of pre-polymerization mixtures using the Multiscan MS20 system. We demonstrate that the incorporation of LA significantly enhances the homogeneity of the system, preventing phase separation and ensuring a high light transmission (over 90%), which is crucial for uniform network formation. Rheological studies revealed thixotropic behavior and a pseudoplastic flow character, where LA concentration acts as a precise modulator of dynamic viscosity and final gel hardness. Furthermore, we show that LA content systematically reduces the swelling capacity in physiological fluids, providing better structural stability. Surface characterization (SEM and contact angle measurements) confirmed that LA increases surface free energy and hydrophilicity, directly impacting the bio-interface. Most importantly, cytotoxicity assays (HaCaT and P388D1 lines) revealed a dramatic shift in biocompatibility: while LA-free gels showed significant cytotoxicity (<15% viability), the optimized LA-modified networks achieved cell viability up to 88%. These findings position these tunable hydrogel platforms as promising candidates for bioactive implant coatings and advanced wound dressings with controlled mechanical and biological interfaces.

Keywords:

hydrogels; lactic acid, photopolymerization, colloid stability, bio-interface, cell viability, soft matter rheology



Photograph of the hydrogel material immediately after synthesis in the UV radiation field without and with the addition of lactic acid.

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Charge regulation in microgels across the volume phase transition under varying salt conditions

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Charged microgel dispersions constitute an excellent benchmark for studying colloidal interactions among charged spheres permeable to microions. Here, we explore the electrostatic properties of poly-N-isopropylacrylamide microgels in the liquid phase as a function of microgel size, which can be controlled by temperature, and ionic strength. The experimental static structure factor measured by light scattering can be successfully described by primitive model calculations, where the bare charge of the microgel is a fixed parameter independent of the microgel size, microgel concentration, and ionic strength. The calculations indicate that at low salt concentrations, there is an uptake of counterions upon collapse of the microgel but this scenario reverses at high salt concentrations, where a release of counterions is observed upon shrinking.

Keywords:

Microgel dispersions, Electrostatic interactions, Static Light Scattering, Poly(N-isopropylacrylamide)

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Multifunctional p(NIPAM-co-NIPMAM)-Fe₃O₄ nanocubes hydrogel patches integrating antimicrobial activity and magnetic hyperthermia-controlled drug release

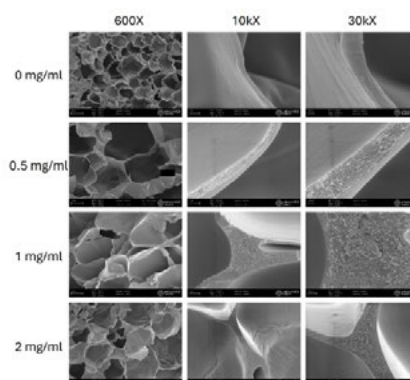
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Hydrogels are three-dimensional soft materials formed from natural or synthetic polymers that can absorb large amounts of water while retaining their structure [1]. Due to their tunable properties and biocompatibility [2], hydrogels have attracted significant interest for biomedical applications, including antimicrobial purposes [3,4]. Antimicrobial activity can be achieved through two main strategies: (i) “inherently active” hydrogels, in which the three-dimensional polymer network itself has antimicrobial properties [5], and (ii) “carrier” hydrogels that encapsulate and release active agents. In carrier hydrogels, several cargos have been investigated, including antibiotics [6] and antimicrobial nanoparticles such as zinc oxide, copper oxide, titanium oxide, and iron oxide [7]. Most cargos are released passively from hydrogels; however, uncontrolled release can reduce therapeutic efficacy and promote antimicrobial resistance. Therefore, controlled delivery of agents and drugs is highly desired to improve their efficiency and safety. To overcome the limitations of passive release, several advances have been made in recent years, primarily using pH- or temperature-responsive hydrogels. Temperature-responsive hydrogels can be triggered by laser irradiation in the presence of a photothermal agent [8] or by an alternating magnetic field in magnetically active materials [9]. Thus, iron oxide nanoparticles offer a unique opportunity to design dual-function systems that combine on-demand drug release with direct antimicrobial activity.

In this work, we developed p(NIPAM-co-NIPMAM) based hydrogel patches containing iron oxide nanocubes and antimicrobial drugs (gentamicin and vancomycin). Due to the known magnetic properties [10], superior to those of standard iron oxide nanoparticles, the nanocubes allow a fast and controlled release of drugs under an alternating magnetic field, while simultaneously exhibiting antimicrobial activity against Gram-positive *Staphylococcus aureus* and Gram-negative *Escherichia coli*. Overall, this system provides a versatile approach to combine local antimicrobial treatment with controlled drug delivery, as demonstrated by its dual ability to eradicate bacterial populations and modulate the spatiotemporal release of antibiotics.



SEM micrographs at various magnification of the hydrogels with different nanoparticle concentrations

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Fluorescent chromic properties of polycyclic aromatic polymer colloidal particles

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Nanosized fluorescent particles are widely used in various fields, such as fluorescence imaging, analytical probes, and biological cell labeling. Many of these materials are classified as quantum dots containing rare metals or as nanoparticles (e.g., polymers and silica) doped with fluorescent dyes. We have been developing fully organic fluorescent polymer nanoparticles composed of a polycyclic aromatic backbone. In this presentation, we describe the facile preparation of polycyclic aromatic polymer colloidal particles with fluorescent chromic properties, as well as their solvatochromism and stimuli responsiveness.

Fluorescent polycyclic aromatic polymer colloidal particles were prepared by precipitation polymerization using 1,3-dihydroxynaphthalene as a monomer and 1,3,5-trimethyl-1,3,5-triazinane as a crosslinking agent. TEM observations revealed spherical particles with diameters of 100–150 nm, and their luminescence color under UV light changed from blue to red and then to white, depending on the reaction time. The obtained particles were thoroughly washed to remove unreacted monomer and crosslinking agent, and then dispersed in various solvents.

Interestingly, the luminescence color was strongly affected by the solvent; for instance, it was yellow-green in chloroform and red in DMSO. Fluorescence spectra ($\lambda_{\text{ex}} = 365 \text{ nm}$) showed emission peaks at 490 nm and 640 nm in chloroform, and at 441 nm and 650 nm in DMSO (Figure 1). The emission intensity at shorter wavelengths was relatively higher than that at longer wavelengths in chloroform, whereas the intensity at longer wavelengths was higher in DMSO. This luminescence color was maintained over a long period when the particles were stored in a dry state.

Presumably, interactions between polymer chains within the particles are altered by the penetration of solvent or metal ions into the network structure, resulting in changes in the luminescence color.

Keywords:

Polynaphthoxazine, Precipitation polymerization, Mono-dispersed spherical particles, Stimuli-responsive

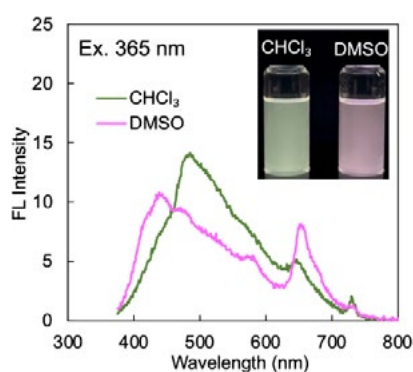


Figure 1 Fluorescence spectra of polycyclic aromatic polymer colloidal particles in CHCl_3 and DMSO ($\lambda_{\text{ex}} = 365 \text{ nm}$), with corresponding photos under UV irradiation.

Probing Free Volume and Gas Solubility in Silicon-Functionalized Ionic Liquids

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The design of ionic liquids (ILs) with tailored free volumes and selective gas absorption properties is critical to advancing sustainable industrial processes, including gas separation and transformation. In a joint experimental and computational study, we investigate the role of silicon-functionalized sidechains in imidazolium-based ILs, demonstrating their capacity to yield fluids of exceptionally low density and viscosity, properties that are promising for gas capture due to their enhanced free volume. [1] By employing argon as a noninteracting probe, we quantify the relative free volumes in these systems, revealing that silicon-based branching with alkylsilane and siloxane groups enhances argon solubility compared to carbon-based analogues, though anion size remains the dominant factor. Using classical MD simulations with the CL&Pol polarizable force field, [2] we demonstrate similarities between cavity and argon local environments in ILs, confirming argon as a good probe for free volume analysis. Our approach enables the identification of the IL with the highest gas solubility without the need for computationally expensive free energy calculations or costly experiments. Building on these insights, we extend our analysis to the absorption of small hydrocarbon gases, such as ethylene and acetylene, and elucidate the molecular mechanisms by decomposing the residual chemical potential into van der Waals, electrostatic, and polarization contributions. We also demonstrate that, unlike ethylene, acetylene solubilities are influenced by specific interactions with IL ions, such as the formation of H-bonds with anions and enhanced π -stacking with the imidazolium cation. Our findings identify IL structural features that determine absorption thermodynamics and propose design rules for next-generation sorbents for a range of applications.

Keywords:

Ionic liquids, free volume, gaseous solutes, solubility, molecular dynamics, polarizable force field

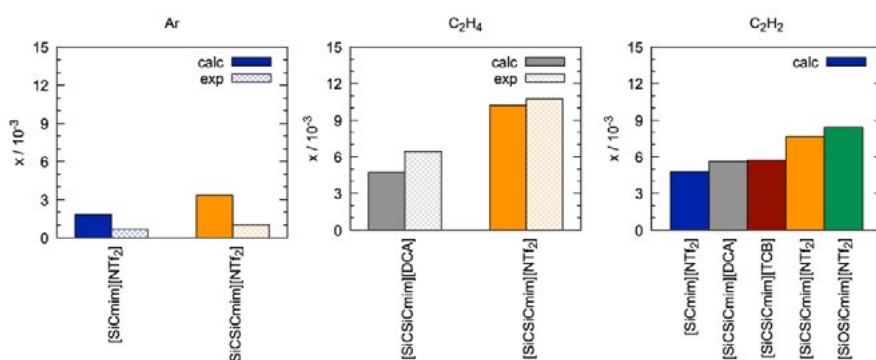


Figure 1. Experimental and calculated solubilities of argon, ethylene and acetylene in Si-functionalized ILs

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Liquid-like dynamics in ordered soft-particle systems

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Structure most frequently constrains material behavior through the presence of a characteristic length scale that determines the properties of the system. This coupling is, in fact, a well-established paradigm in materials science [1], extending from atomic to colloidal systems. It is, in particular, reflected in the approach to the glass whereby strong spatial correlations between nearest-neighbor particles dominate the structural relaxation time of the material [2,3]. The relevance of colloids versus atoms lies in the fact that their interactions and single-particle softness can be tailored. This provides additional degrees of freedom that activate alternative relaxation pathways and even lead to a structural relaxation time that is independent of the strong short-range positional correlations between particles. As a result, structural and dynamics aspects become decoupled [4,5]. While these previous results indicate that elastic tailoring can manipulate dynamics properties independently of the structural ones, to date, this has been mostly explored in systems where each of the constituent particles has identical or very similar elastic properties.

Here, we explore the effects of elastic heterogeneity through numerical simulations of two-dimensional systems. Starting from a perfect triangular lattice, we introduce a broad range of particle elastic moduli, which enables the system to transition from a liquid to a crystalline state. Throughout this transition, the microscopic dynamics slow down, resembling those observed in glassy materials: structural relaxation becomes a two-step process, involving particles trapped in microscopic cages formed by their neighbors. Surprisingly, although strong elastic heterogeneity promotes long-range positional and orientational order, the presence of soft particles allows the system to remain dynamically active at long times, eventually reaching a diffusive regime. These findings stand in stark contrast to conventional crystals, where dynamics are typically restricted to vibrations, while translational degrees of freedom are suppressed as a result of the long-range order. Remarkably, the liquid-like dynamics we observe emerge while preserving the crystalline state, owing to swapping mechanisms in which particles exchange positions yet maintain the integrity of their local microscopic cages. As a result, elasticity polydispersity not only introduces translational degrees of freedom but also simultaneously stabilizes the crystalline structure. Our findings therefore blur the conventional distinction between solids and liquids, or between crystals and glasses, and highlight that elasticity polydispersity can decouple static and dynamic properties [6].

Keywords:

Elastic polydispersity, colloidal systems, swapping, structure-dynamics decoupling

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From Many-Body Interactions to Collective Behaviour in Core-Shell Microgels

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Core-shell microgels, composed of a solid core covalently bonded to a crosslinked polymer shell, are versatile stimuli-responsive colloids with promising applications in soft matter and materials science.[1] Yet, a microscopic, temperature-resolved understanding of their effective interactions—and of how these govern collective behaviour—remains incomplete. The challenge becomes particularly acute in dense suspensions, where resolving all microscopic degrees of freedom proves computationally prohibitive and coarse-grained effective interaction potentials become essential. For soft, deformable particles such as microgels, however, these interactions are inherently environment-dependent: crowding, compression, shrinking, and interpenetration can all induce significant deviations from a simple pairwise picture. In this talk, we present a numerical framework to generate realistic core-shell microgels with tunable crosslinker concentration and shell-to-core ratio, reproducing the structural features of experimental silica-pNIPAM systems across the volume phase transition (VPT). We then determine their effective interactions as a function of temperature, uncovering a clear many-body signature: three-body contributions, while smaller than pair interactions, are not negligible and change qualitatively across the VPT, being attractive at low temperature, repulsive at high temperature, and nearly absent near the transition.[2] Guided by these microscopic insights, we develop coarse-grained descriptions for dense suspensions in which effective pairwise approximations become inadequate. Using a machine-learning framework trained on fine-grained simulation data, we construct computationally efficient many-body effective potentials that encode the environmental dependence of the underlying interactions and remain predictive at high packing fractions.[3] These models accurately reproduce the structural and thermodynamic properties of dense core-shell microgel assemblies, providing a route toward predictive and architecture-aware modelling of collective behaviour in responsive soft-matter systems.

Keywords:

Microgels, Molecular Simulation, Machine Learning

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Microstructural transformations in magnetic hydrogels under flow-magnetic field coupling

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Magnetic soft matter, such as magnetic gels, elastomers, composites, and hydrogels that combine soft polymer networks with magnetic particles, is a versatile class of materials ¹. These materials are finding applications in an array of fields, ranging from soft robotics and adaptive materials to biomedical technologies, owing to their stimuli-responsiveness and ability to be controlled remotely ^{2–4}. Magnetic hydrogels are a common example of magnetic soft matter used in biomedical applications, for instance, for targeted drug delivery or bioprinted scaffolds. Often in such applications, magnetic hydrogels experience both shear flow and an external magnetic field. In this scenario, a rearrangement of both the polymeric network and the embedded magnetic particles is inevitable. However, there remains a limited understanding of the microscopic structural changes that occur within magnetic hydrogels during these scenarios. In this work, we developed glycyrrhizic acid (GA) hydrogels incorporated with superparamagnetic iron oxide nanoparticles, through a co-precipitation route, to investigate these transformations. GA is a bioderived, self-assembling polymer often used for drug delivery applications ^{5,6}. A rearrangement of the pure GA hydrogel and the magnetic GA hydrogel is observed under shear and an external magnetic field, through birefringence measurements (**Figure 1**). Furthermore, to understand the shear–magnetic force interactions, the nanoscale structure of the hydrogel is probed *in situ* under flow using small-angle neutron scattering (SANS). An in-house built setup, equipped with syringe pumps, flow control valves and flow channels, has been used with the SANS equipment, in combination with a magnetic field of 300 mT. An influence of the flow direction with respect to the magnetic field is observed on the particle alignment and anisotropy in the hydrogel. With this work, we strive to understand the effect of shear and magnetic field on magnetic GA hydrogels. Understanding the alterations in the microstructure of such hydrogels during their application phase, will help us design next-generation magnetic materials for biomedical applications.

Keywords:

magnetic hydrogel, neutron scattering, magnetic field, flow, nanoscale

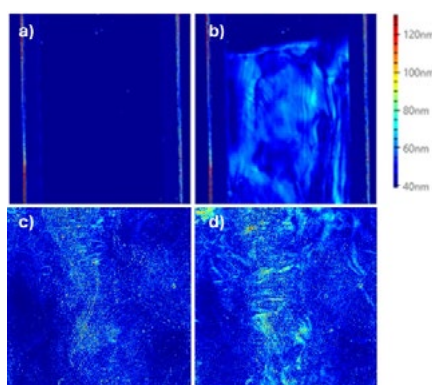


Figure 1: Retardation image of GA and magnetic-GA gels before and after application of shear. a) 23 mM GA after heated b) 23 mM GA after sheared using needle. c) 23 mM GA + 0.5 wt % Fe₂O₃ after heated d) under external magnetic field

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Interactions of Soft crystalline materials with solid-liquid interfaces studied by neutron scattering

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Soft crystalline materials are used in many applications that improve human life, like tissue engineering [1] or in photonic crystals in optical devices [2]. The ability to tune the optical or mechanical properties of such materials easily through changes in temperature, pressure, composition as well as the exact type of interface they are in contact with, paired with the usually low toxicity, makes them frequently used in the industry today. Understanding the structural mechanisms and surface effects on the molecular scale of these materials has, however, remained challenging to study, especially in the near surface region. The sample in this study is a triblock co-polymer from polyethylene-glycol(PEG)-polypropylene-glycol(PPG)-PEG, which self-assembles into micelles. At higher polymer concentrations or temperatures, the spherical micelles form close-packed superstructures whose viscoelastic and optical properties are highly tunable. The hydrated crystals can experience beam-damage in X-rays and cryo-methods exclude the study of dynamic shear and pressure-effects on the sample. The buried interface of interest only allows for highly-penetrating probes. As such, neutron scattering methods, mainly neutron reflectometry and Grazing incidence small angle neutron scattering (GISANS) [3], with their high-penetration power and the ability to harness the high hydrogen-deuterium contrast in nuclear scattering, have been used to study the solid-liquid interface in some detail.

We employ *in situ* -Rheo-Near-surface-SANS (NSSANS) to study the effects of mechanical deformation on the ordering of polymer micelles close to interfaces of varying surface energies. An increasing shear rate is observed to reduce the order of cubic stacking in the near surface region, which is in contrast to previous bulk studies, where shear has generally improved ordering of dense layers in out-of-plane direction. At the same time, the near surface crystallite size decreases. We propose that close to the interface, the shear-induced transitioning to hexagonal states may be explained by stress-induced deformation faults in the stacking sequence. Fault probabilities of a few percent are sufficient to derive the observed intensity distributions in the NSSANS patterns. Further surface scattering experiments showed that even pressure can be used as an excitation to obtain rich structural behavior in the interfacial region for this sample. A pressure of 500 bar was observed to destroy any close-packed order at room temperature, while a higher temperature could overcome this high hydrostatic pressure to reform the crystal.

Keywords:

polymers, micelles, self assembly, soft crystals, rheology, neutron scattering

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Formulation and In Vitro Assessment of a Hybrid Gel-Microparticle Composite for Ocular Delivery of Dual-Antiglaucoma Drugs

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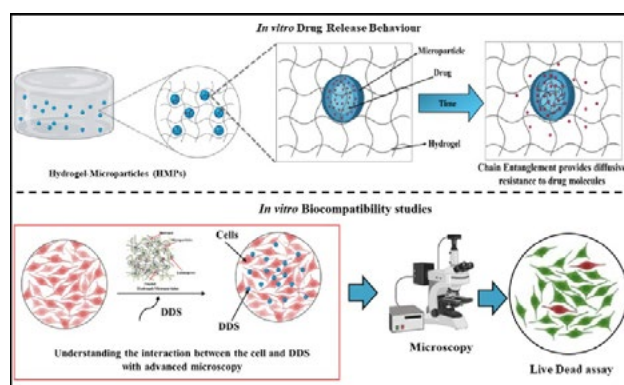
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Glaucoma, a major global health issue, is the second leading cause of blindness. Topical eye drops are commonly used due to their simplicity, but the eye's protective barriers hinder optimal drug concentration at the target site. This study addresses these challenges by developing a novel dual-drug delivery system, integrating polycaprolactone microparticles loaded with latanoprost (hydrophobic) and timolol maleate (hydrophilic) antiglaucoma drugs into a gelatin-alginate hydrogel matrix. There is a fundamental challenge to combine both drugs in the same delivery system with a controlled release profile. Hydrogel-microparticles (HMPs) were assessed via in vitro drug release and cell culture for biocompatibility, with Raman analysis for chemical compatibility and drug diffusivity. Results showed that the HMPs system has prolonged drug release for up to 32 days. Raman analysis confirmed the chemical compatibility of the formulation components, and in vitro biocompatibility studies demonstrate that the HMPs system is biocompatible and exhibits minimal cytotoxicity. This novel HMPs system can serve as a flexible, controlled-release platform that modulates the release profile. Our study highlights that the polymer and drug properties, along with the external matrix, were key factors influencing the drug release behavior of the formulations, and the proposed HMPs system can potentially be considered for glaucoma therapy.

Keywords:

Hydrogel-microparticles (HMPs), Drug release, Latanoprost, Timolol maleate, Raman analysis, Biocompatibility studies



Graphical Abstract

References:

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The structure of core-shell microgels: A light, X-ray and neutron scattering study

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Hybrid colloids that combine polymers and plasmonic nanoparticles, e.g. gold or silver, gained increasing interest over the last years. [1] Gold-poly- *N*-isopropylacrylamide (Au-PNIPAM) core-shell microgels were used for periodic coatings due to the localized surface plasmon resonance (LSPR) of the cores leading to surface lattice resonance (SLR), which position strongly depends on the core size. [2],[3] Compared to other core-shell microgels, Au cores can be precisely overgrown in the shell *in situ*. [2] Although cores grow in size, the overall hydrodynamic diameter of the microgels does not change. It is unknown how the internal structure of the shell changes during the overgrowth.

Here, we are analyzing Au-PNIPAM microgels with two different crosslinker densities (8 mol% and 16.5 mol%). The cores are overgrown from 14 nm in diameter to nearly 100 nm (see Figure 1a and 1b). We perform different scattering methods, namely light scattering (LS) and small-angle X-ray and neutron scattering (SAXS/SANS) to study the respective form factors. SAXS provides information about the gold cores (Figure 1c), LS about the shell and the cores in dependence of core size and SANS about the shell (Figure 1d). We also investigate the microgels at different temperatures, below, at and above the volume phase transition temperature (VPTT) of the thermoresponsive PNIPAM shell. Thus, we can compare swollen and collapsed state of each microgel batch. Additionally, temperature dependent extinction spectra are recorded to study the optical properties. We also perform reverse Monte Carlo and coarse-grained molecular dynamics simulations of the different microgels. The simulations provide further insights into the internal structure of the shell and the radial polymer density distribution before and after the overgrowth of the core.

Keywords:

core-shell microgels, Au-PNIPAM, thermoresponsive system, internal structure, small-angle scattering, form factors

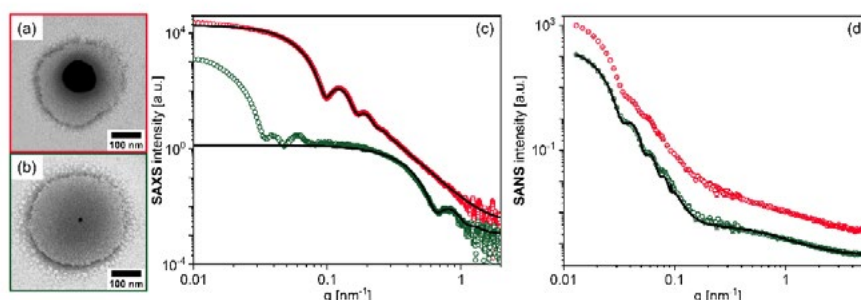


Figure 1. TEM images of Au-PNIPAM microgels with core sizes of 100 nm (a) and 14 nm (b) in diameter. Corresponding SAXS (c) and SANS (d) curves of the Au-PNIPAM microgels. Fits are shown in black.

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Controlling the volume phase transition and structure of microgels by copolymerization

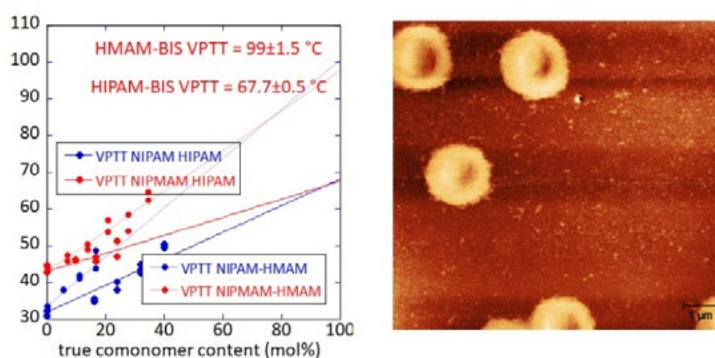
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The thermosensitivity of microgel particles, i.e. their temperature-dependent swelling properties, has triggered ongoing interest over the past forty years. The most-studied family of polymers is represented by poly(N-isopropylacrylamide), PNIPAM. Here, we aim at controlling the microgel VPTT by copolymerization with comonomers of different hydrophilicity, for energy applications. We precisely determine the incorporation of N-(hydroxymethyl)acrylamide (HMAM) and purpose-synthesized N-(2-hydroxyisopropyl)acrylamide (HIPAM) and N-(1-hydroxy-2-propyl)methacrylamide (NIPMAMol) into microgels. The swelling properties and microstructure of the resulting copolymer microgels are then characterized via turbidimetry, DLS, SANS, and AFM. At low comonomer contents, all microgel particles exhibit moderate growth in size. Beyond a threshold, we observe a significant jump in size, and smoother swelling behavior. For NIPAM-HIPAM, the size increase is linked to a strong rise in swelling capacity, and the formation of a thick corona. The effect of the hydrophilic comonomers on the VPTT correlates linearly with their true composition, allowing us to extrapolate the VPTT of hypothetical pure comonomer microgels. This leads to ca. 99°C for HMAM, 85°C for NIPMAMol, and 68°C for HIPAM for the respective VPTT, indicating their effect on the VPTT in the copolymerized microgels. The observed changes in VPTT, swelling, size, and morphology suggest that high-VPTT microgels possess unique internal molecular composition gradients, likely due to hydrophobic interactions during synthesis.



Left) VPTTs of copolymer microgels with extrapolation to pure comonomer microgels. Right) Observation of nominal 50 mol% NIPAM-HIPAM microgels in the dry state by AFM.

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Protein-Mimetic Heterograft Polymers as Model Systems for Controlled Complexation with Oppositely Charged Biomacromolecules

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Amphiphilic random heterograft polymers mimic key protein features such as folding, transport, and catalysis [1]. Their synthesis is straightforward, based on copolymerizing hydrophilic, hydrophobic, and charged monomers, enabling a wide design space. When interactions are balanced, these polymers remain folded and resist aggregation, allowing folding and association to be decoupled [2]. This opens the way to investigate how protein-like polymers behave in complex environments, particularly during polyelectrolyte complexation and coacervation.

Here, we investigate the complexation behavior of positively charged heterograft polymers based on poly(DMAEMA-ran-LMA-ran-OEGMA)* with two model polyanions of increasing biological relevance: poly(glutamic acid) and RNA. These polymers in their isolated state adopt a compact, intramolecularly structured conformations in water and display only a weak expansion upon increasing charge, as revealed by SAXS, consistent with protein-like folding behavior. By varying the relative content of charged (DMAEMA) and neutral hydrophilic (OEGMA) units, together with pH, we tune the effective charge of the polymer and its electrostatic interactions with the polyanion. To capture the resulting phase behavior, we construct phase diagrams of the binary polycation–polyanion systems as a function of pH and composition (polycation/polyanion ratio), revealing marked differences in the phase separation regions depending on polymer composition and the nature of the polyanion. Close to the phase boundaries, we identify slightly turbid yet stable regimes where well-defined complexes are formed. These structures are further characterized by SAXS and DLS, providing insight into the role of polymer composition and charge in governing polymer–polyanion complexation across multiple length scales.

*DMAEMA: dimethylaminoethylmethacrylate; LMA: laurylmethacrylate; OEGMA: oligoethyleneglycolmethacrylate

Keywords:

Amphiphilic random heteropolymers, Polyelectrolyte complexation, Biomimetic polymers

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Silicon nanowire aqueous liquid crystal formation and processing into macromaterials

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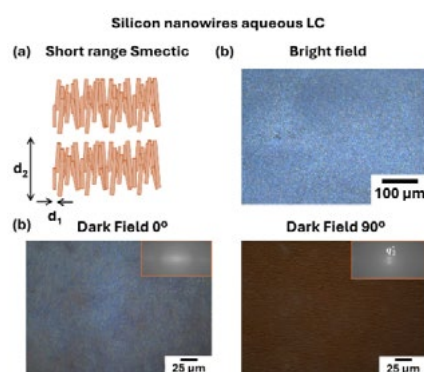
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Nanowires are elongated inorganic crystalline objects whose shape and nanoscale size in one dimension give them a wealth of properties distinct from their bulk analogues[1,2]. For silicon nanowires (SiNWs), these include size-dependent optical absorption and Mie scattering, tolerance to electrochemical alloying for energy storage. In many instances, the challenge is in translating single-nanowire properties to the macroscopic scale. In particular, it is of interest to study the formation of ordered fluid phases with nanowires and their use for controlled assembly into networks. This strategy could enable formation of new macromaterials with extreme anisotropy and bulk properties beyond the envelope of their monolithic analogues.

We report for the first time the formation of liquid-crystal (LC) dispersions of SiNWs and their assembly into macroscopic fibres[3]. SiNWs are synthesized by Floating catalyst chemical vapour deposition (FCCVD), enabling gram per day synthesis of these one-dimensional nanomaterials. These nanowires exhibit high crystallinity, log-normal length ($\sim 2.5 \mu\text{m}$) and diameter ($\sim 40 \text{ nm}$) distributions, and aspect ratios of 50–100[1,2]. In concentrated aqueous media, the nanowires behave as charged rigid rods, spontaneously forming LC domains. The concentration phase diagram shows isotropic–biphasic and biphasic–nematic transitions at 1.2 and 2.1 vol.%, respectively. Followed by the emergence of short-range-ordered smectic phase at 4.5 vol.%. Remarkably, smectic ordering persists despite the broad aspect-ratio polydispersity, contrary to predictions based on hard-rod steric interactions[4]. This behavior is attributed to electrostatic interactions, with the effective nanowire diameter governed by the Debye length, leading to a narrowing of the effective size distribution. Aligned domains exhibit anisotropic resonant Mie scattering and strong polarised Raman feature. Harnessing this spontaneous order, we assemble continuous macroscopic fibres that are flexible and remarkably tough, with a specific fracture of energy of 2.1 J g^{-1} , approximately $150\times$ that of monolithic silicon.

Keywords:

Silicon nanowires, lyotropic liquid crystal, smectic phase, fibre



Silicon nanowires 4.5 vol.% aqueous dispersion characterization: (a) Schematic of the smectic phase, (b) Bright light optical micrograph in reflection of the dispersion, revealing smectic structure, (c) Optical dark field micrographs show strong light scattering for different polarization directions

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Tuning polypeptide multilayer growth and mechanics via solvent-mediated interactions

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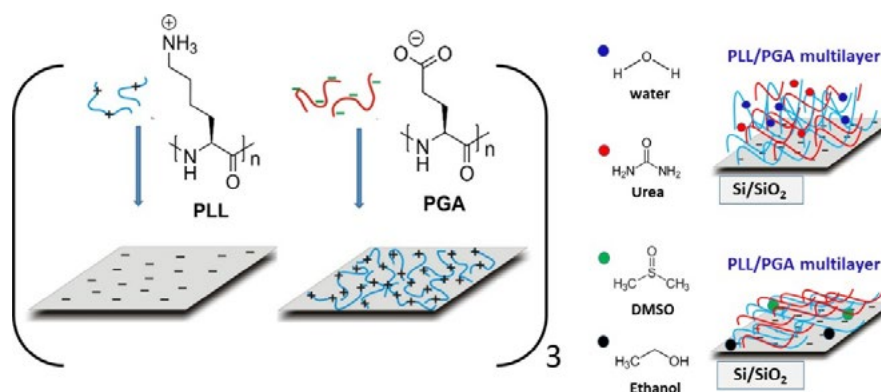
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The use of co-solvents is a common strategy to modulate polypeptide conformation; however, their specific role in coupling charge regulation with interfacial assembly and film mechanics remains insufficiently understood. In this work, we investigate how three widely used co-solvents—ethanol, urea, and dimethyl sulfoxide (DMSO)—affect the solution behavior of poly(L-lysine) (PLL) and poly(L-glutamic acid) (PGA) across a broad pH range (3–11) at controlled ionic strength, and how these effects translate into layer-by-layer multilayer formation on silica substrates.

By combining electrokinetic measurements, spectroscopic analysis, molecular dynamics simulations, and in situ mechanical characterization, we identify distinct solvent-dependent mechanisms governing polypeptide behavior. Ethanol and DMSO primarily promote counterion condensation and partial dehydration of the polymer chains, whereas urea induces charge compensation via direct hydrogen bonding with the peptide backbone, leading to significant disruption of secondary structure. These molecular-level effects directly impact multilayer growth and viscoelastic properties. At pH 6, where both polyelectrolytes are highly ionized, the presence of co-solvents significantly enhances multilayer buildup compared to purely aqueous conditions. Ethanol produces thin, compact, and mechanically stiff films, while urea and DMSO yield thicker, softer, and more dissipative multilayers.

Overall, this study establishes a direct link between solvent-mediated charge regulation in solution and interfacial assembly, demonstrating that solvent selection alone provides a powerful route to tailor the architecture and mechanical response of polypeptide multilayers.



Schematic of PLL/PGA layer-by-layer assembly on Si/SiO₂ in water, urea, DMSO, and ethanol.

Acknowledgements:

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Effects of Internal Emulsifier Structure and Concentration on Dispersion Properties and Film Performance of Anionic Waterborne Polyurethanes

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Anionic waterborne polyurethanes (WPU) are amphiphilic polyelectrolyte dispersions in which charged ionic moieties, introduced via internal emulsifiers, drive the formation of colloidal particles with core-shell architectures. The hydrophobic polyurethane segments form the particle core, while ionized carboxylate groups at the particle surface generate electrical double layers that stabilize the dispersion electrostatically. This study investigates the effects of two widely used anionic internal emulsifiers, dimethylolpropionic acid (DMPA) and dimethylolbutanoic acid (DMBA), on the dispersibility and physicochemical properties of WPUs designed for breathable membrane applications, through a combination of experimental characterization and computational simulation. DMPA and DMBA differ in alkyl chain length and hydrophilicity, with log P values of -0.5 and -0.09 , respectively. Their concentrations were varied from 0.065 to 0.105 mol. Dynamic light scattering and zeta potential measurements show that increasing emulsifier concentration reduces particle size from 1547 to 174 nm for DMBA and from 3949 to 242 nm for DMPA, accompanied by enhanced electrostatic stabilization. DMBA yields smaller, more narrowly distributed particles at lower ionic content, attributed to its greater miscibility with the isocyanate component and more efficient ion distribution at the particle interface. Dissipative particle dynamics (DPD) simulations were performed using Flory–Huggins χ -parameters derived from DFT-based molecular dynamics calculations. Pair correlation function analysis shows that DMPA, with a lower χ -parameter with water (0.34 vs. 0.40 for DMBA), promotes more uniform polymer–water interfacial mixing, whereas DMBA induces larger water cluster formation consistent with its hydrophobic character. The experimental and simulation results are in good agreement, providing a consistent picture of how emulsifier molecular structure influences polyelectrolyte interfacial organization and colloidal stability in WPU dispersions.

Keywords:

waterborne polyurethanes, internal emulsifiers, breathable membranes, dissipative particle dynamics simulation

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Acknowledgements:

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Training soft colloidal gels by shear flows

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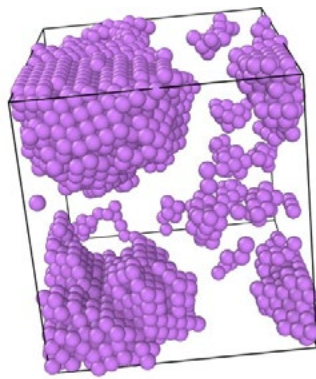
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We investigate the structural and dynamical properties of soft colloidal gels formed a Lennard-Jones-Yukawa potential using Langevin dynamics simulations. After quantifying equilibrium properties at different densities and temperatures we train their mechanical properties by applying steady shear flow of varying shear rate. We identify different distinct mechanical deformation modes under shear including non-isotropic deformation and re-structuring, breakup and non-isotropic crystalline droplet formation. Interestingly, while shearing the system, we identified dynamical restructuring of the entire gel at intermediate length scales associated to the break-up and formation of arms of the colloidal gels. After further cessation we identified the emergence of distinct structural phases deviating from the untrained structures, which depend on the applied shear rate during training, temperature and the packing fraction of the gels.

Keywords:

colloidal gels, shear flow, mechanical training, cessation, Langevin dynamics simulations



Gel structure after cessation

Influence of Dispersants on Graphite-Polydimethylsiloxane Composites and Interfacial Structures

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Inorganic-organic hybrid composites consisting of ceramic particles and polymer matrix have both properties delivered from each component such as thermal or electric conductivity, mechanical strength, flexibility, adhesive, and so on, however there is the tradeoff relationship between them. Viscous composites consisting of liquid polymer commercially require low viscosity for the dispensing process performance. To address the requirement, dispersants could be potentially used for the composite. Dispersants effectively interact with filler surfaces and improve their compatibility with polymer matrix and filling-up characteristics in filler/polymer composites. At the present work, the capability of polydimethylsiloxane-based dispersants (PDMS-dispersants) having different functional groups to decrease the viscosity in Graphite/PDMS composites was evaluated. To explore the relationship with the composite macroscopic properties, the adsorption characteristics of PDMS-dispersants were investigated. Graphene substrates were used as a surface model for graphite particles. Deuterated PDMS (D-PDMS) containing PDMS-dispersants were spin-coated on the graphene substrates, and the formed interfacial layers were observed by neutron reflectometry (NR) [1-2]. It revealed that PDMS-dispersant segregated with a single nanometer in the graphene interface and varied structures in different functional groups and molecular weights. Pyrene-terminated PDMSs (Py-PDMSs) showed strong adsorption characteristic for the graphene, and pyrene moieties played a role to form the segregation layer whereas the dimethylsiloxane chain gave the compatibility with PDMS matrix and form the diffusion layer in the graphene interface. The interfacial structures explained that Py-PDMSs effectively decreased the viscosity in graphite/PDMS composites. This work is the first report to observe the interfacial structure in liquid PDMS/graphene by NR, and this imitative interfacial observation could be referred to a design of new polymer-based dispersants in composite uses.

Keywords:

Neutron reflectometry; interfacial structure; graphene substrate

References:

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Tuning Semicrystalline Polymer Brush Morphology and Surface Properties via Solvent-Mediated Crystallization

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Functional polymer brush coatings have significant potential for a wide range of industrial applications due to their responsiveness to environmental stimuli, enabling precise tuning of surface properties. Here, we demonstrate that in semicrystalline poly(octadecyl methacrylate) (P18MA) brushes, surface roughness and interfacial properties can be controlled by tuning crystallization conditions. Using solvent-mediated crystallization, the brush morphology can be reversibly tuned from smooth ($R_q \approx 3\text{nm}$), spherulitic structures to highly porous architectures with feature sizes of several hundred nanometers (**Fig. 1**). This morphological control enables tunable wetting behavior, with direct implications for adhesion and fluid transport. [1] Control over morphology can be achieved both macroscopically, via solvent infusion followed by cooling and solvent evaporation, and locally, using a focused laser beam to generate patterned regions with distinct roughness. Previous work on the same system showed that melting induces a coupled swelling and wetting transition upon exposure to liquid alkanes, with the top surface exhibiting a higher melting temperature than the bulk. This allows independent control of bulk-driven swelling and surface-driven wetting transitions. [2] In contrast, the morphological changes reported here originate from bulk side-chain crystallization in the presence of solvent. By varying solvent quality, concentration, and crystallization rate, a wide range of morphologies can be accessed, from dense to highly porous structures. This behavior can be understood in analogy with thermally induced phase separation (TIPS), where the interplay between phase separation and crystallization governs structure formation, e.g. for polymeric membranes. [3] Such control over surface topography enables precise tuning of wetting properties, opening new opportunities for the design of functional and adaptive interfaces.

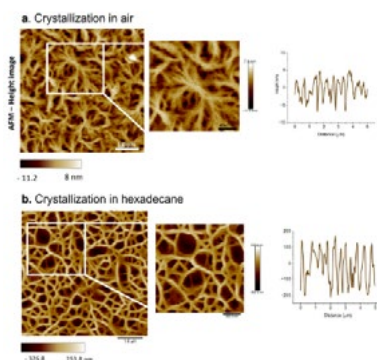


Fig. 1. AFM tapping-mode height images of semicrystalline P18MA brushes, together with corresponding cross-sectional height profiles (right) showing surface height variation along the x-direction.

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Clustering of Gold Nanoparticles in Soft Confined Environments Using pH responsive Double Hydrophilic Block Copolymers

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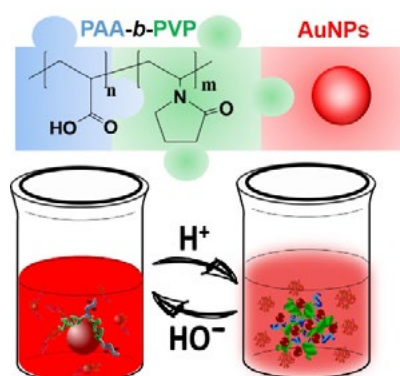
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The controlled organization of inorganic species in soft, confined environments is fundamental to processes such as crystallization, catalysis, and bioimaging [1,2]. Double hydrophilic block copolymers (DHBCs) provide a powerful and modular platform for directing such assemblies in water, thanks to their selective interactions with nanoparticles. Here, we unravel the assembly pathways of the poly(acrylic acid)- block -poly(N-vinyl-2-pyrrolidone) (PAA-b-PVP) DHBC in the presence of gold nanoparticles (AuNPs), and we identify the molecular mechanisms governing the formation of the resulting architectures [3]. AuNPs interact selectively with the non-ionizable PVP block, and their assembly is activated by pH-controlled modulation of PAA solubility. This stimulus-responsive strategy enables the rapid and reversible formation of three-dimensional hybrid supracolloids (hSCs) in water. The resulting structures consist of a highly swollen, disordered hydrogel-like polymer matrix in which AuNPs are uniformly distributed.

A multimodal characterization approach (SAXS, QCM-D, STEM-EDX, FEG-SEM) reveals that hSC formation emerges from the synergistic interplay between reduced PAA solubility and the establishment of inter- and intra- chain hydrogen bonding. Altogether, these findings provide fundamental insight into DHBC– nanoparticle interactions and establish PAA-b-PVP assemblies as versatile, tunable platforms for engineering hybrid nanomaterials in solution, with promising implications for multicomponent functional architectures.

Keywords:

hybrid supracolloids, pH responsiveness, double hydrophilic block copolymers, gold nanoparticles clustering



Schematic representation of the formulation of the hybrid supracolloids between preformed gold nanoparticles and PAA-b-PVP block copolymer, in acidic and basic conditions.

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Tunable Structural Color in Copolymer Microgels through Controlled Synthesis and Thermally Induced Assembly

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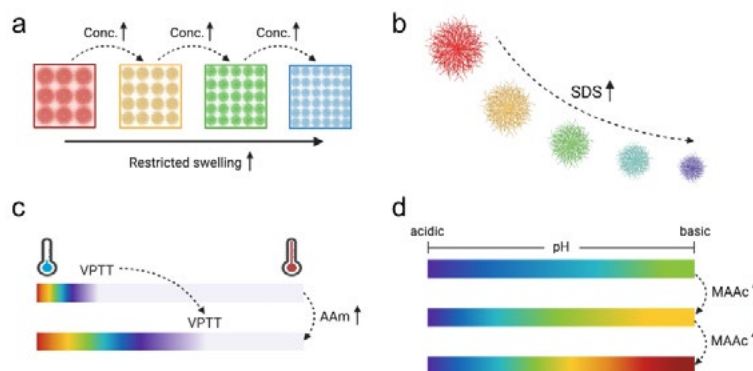
Structural color formation in soft colloidal systems represents a promising and straightforward approach toward stimuli-responsive photonic materials. In this study, we investigated the assembly of poly(N-isopropylacrylamide) (PNIPAm)-based microgels incorporating varying percentages of anionic (methacrylic acid), neutral (acrylamide), and cationic (2-(dimethylamino)ethyl methacrylate) comonomers to create multifunctional colloidal building blocks capable of forming dynamic structural colors. Through systematic synthesis optimization and surfactant-mediated size control, we obtained libraries of copolymer microgels with precisely tailored particle diameter, surface charge, and stimuli-responsive swelling behavior.

We generated structural colors across the visible spectrum by colloidal crystal assembly through thermal annealing and modulated the interparticle spacing and consequently the reflected wavelengths by changing the microgel concentration. Additionally, by fine-tuning the microgel responsiveness, we engineered materials with precise wavelength shifts in the reflected color upon environmental stimuli (temperature or pH).

Our findings provide key insights into the interplay between microgel composition, particle properties, concentration-dependent ordering, response behavior, and resulting optical properties. This offers a foundation for designing dynamic, structurally colored colloidal photonic materials for a broad application range, including multifunctional sensors, optical tags, and responsive coatings.

Keywords:

(PNIPAm)-based copolymer microgels, functional comonomers, temperature- and pH-responsiveness, colloidal assembly, dynamic structural color



Schematic representations of investigated microgel properties and their effect on structural color. a) Microgel concentration affects swelling capabilities. b) Surfactant modulation affects microgel size. c/d) Change of response behavior (temperature/pH) through incorporation of suitable comonomers.

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Nanocolloids at Block Copolymer Interfaces: Mesoscale Modelling of Self-Assembly and Morphology Control

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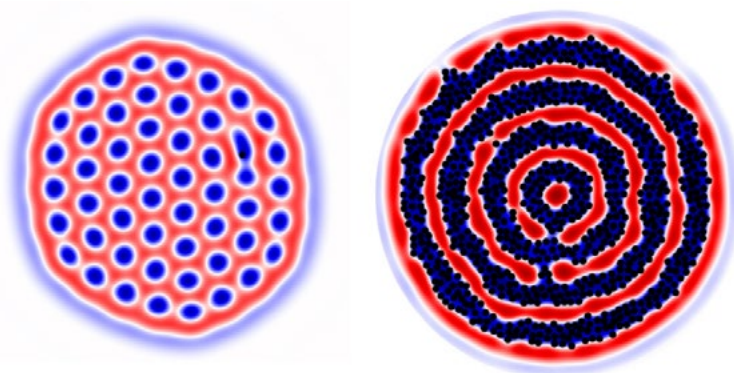
Block copolymer (BCP) systems provide a versatile platform for directing the spatial organisation of nanocolloids through their ability to self-assemble into ordered nanostructures. Under confinement, such as in droplets and thin films, additional constraints and surface selectivity introduce frustration, enabling complex morphologies and enhanced control over nanoparticle localisation. In this work, we employ a mesoscale phase-field computational framework, combining a time-dependent Ginzburg–Landau description of the BCP with Brownian dynamics for nanocolloids, to investigate self-assembly and morphology control in BCP nanocomposites.

Simulations reveal that nanocolloids preferentially localise at specific regions of the BCP morphology, including internal interfaces and domain boundaries, depending on their interactions, size, shape, and aspect ratio. In confined droplets, increasing nanocolloid loading induces morphological transitions driven by changes in effective composition and solubility, leading to Janus-like and onion-like structures. In thin films, nanocolloids modify phase behaviour and orientation, and can alleviate confinement-induced frustration, promoting transitions away from metastable states such as perforated lamellae.

Anisotropic nanocolloids introduce additional mechanisms of morphology control. Particles with large aspect ratios break local symmetry and induce sphere-to-cylinder transitions, while their orientational (nematic) ordering, guided by BCP domains, enhances lamellar alignment. In circular-forming morphologies, competition between nematic ordering and hexagonal packing leads to deformation of the mesophase at higher concentrations. More generally, particle shape plays a key role in interfacial assembly: square and rectangular nanocolloids can form ordered structures within domains or align along interfaces, with aspect ratio governing aggregation and co-assembly behaviour. These findings are supported by comparison with experimental observations, demonstrating the ability of the phase-field framework to capture key features of nanoparticle–BCP co-assembly. These results demonstrate that nanocolloids actively control BCP morphology across different confinement geometries and particle characteristics. The computational approach provides a flexible and scalable framework for exploring structure formation in complex nanocomposite systems, offering insights for the design of hierarchical materials.

Keywords:

Nanocolloid, Block Copolymer, Computational Modelling, Self-Assembly, Phase Behaviour, Nanostructure



Block copolymer droplet morphology transformation with increasing nanocolloid loading [1].

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Mechanical Degradation Pathways of Thermoresponsive Microgels under Ultrasonic Cavitation

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Ultrasonic cavitation generates intense, localized mechanical stresses that drive irreversible structural changes in soft polymer networks. While degradation of microgels under ultrasound is known, a clear mechanistic link between network state, architecture, and degradation pathways remains unresolved. Here, we investigate thermoresponsive PNIPAM-based microgels under high-intensity ultrasonication, focusing on how temperature-controlled swelling and core-shell architecture govern their response.

Microgel structure is tracked as a function of sonication time and temperature using dynamic light scattering (DLS), small-angle X-ray scattering (SAXS), small-angle neutron scattering (SANS), and atomic force microscopy (AFM). We observe a staged degradation process: at early times, the hydrodynamic radius decreases due to removal of loosely crosslinked chains at the periphery, while the network remains largely intact. With continued sonication, accumulated stress leads to network rupture, increasing structural heterogeneity and partial fragmentation. The degradation pathway is strongly governed by the swelling state, with swollen microgels highly susceptible to damage and collapsed microgels exhibiting enhanced stability.

For PNIPAM–PNIPMAM core-shell microgels, the degradation pathway depends on the swelling state of the core and shell. Distinct degradation behaviors emerge depending on whether each component is swollen or collapsed, reflecting changes in network stiffness and mechanical response. These results establish a direct link between microgel softness, architecture, and cavitation-driven degradation, providing a framework for controlling the mechanical stability of soft colloidal systems.

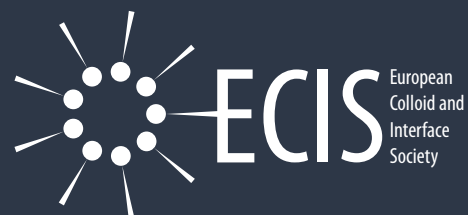
Keywords:

Microgels; Cavitation; Degradation; Scattering; Core-shell

Topic 8

Dynamics, Stability, Self-Assembly,
and Phase Behavior of Complex Fluids

! **KEYNOTE**



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Colloidal and Interfacial Properties of Silicon Nanocrystals and Their Impact on Lithium Ion Battery Performance

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Silicon nanocrystals (SiNCs) are promising candidates for next-generation energy and hybrid materials, yet their practical integration is often limited by interfacial instability, aggregation, and sensitivity to aqueous environments. In this work, we investigate SiNCs of 6, 20, 55, and 100 nm to understand how surface chemistry, particle size, and solid-state properties jointly influence their colloidal behaviour and functional performance. Using hydrogen-terminated SiNCs as a starting point [1], we show that functionalization with poly(acrylic acid) (PAA) and phytic acid (PhA) produces covalent and ionic Si–O–C and Si–O–P linkages that substantially enhance dispersion stability. Spectroscopic analysis (FTIR, XPS), dynamic light scattering, and zeta-potential measurements demonstrate that controlled surface chemistry stabilizes surface charge and suppresses aggregation across a broad pH range, highlighting the central role of interfacial speciation in colloidal control.

Extending this strategy across all investigated sizes enables a direct comparison of how curvature, accessible reactive sites, and initial oxidation state affect functionalization efficiency and colloidal stability. Incorporation of size-defined SiNCs into hydrogel-derived polypyrrole (PPy) networks further reveals the interplay between colloidal stabilization and electrochemical behaviour [2]. Smaller SiNCs show the most favourable electrochemical response, achieving capacity retention up to 85% after 100 cycles, whereas physically blended electrodes display weaker cohesion and accelerated degradation. Electrochemical analyses (GCD, CV, EIS) confirm that optimised interfacial environments enhance charge-transfer stability and mitigate irreversible degradation pathways.

Overall, this work provides a unified framework demonstrating how surface functionalization, size effects, and solid-state properties together determine the colloidal and electrochemical performance of Si nanomaterials. These insights support the development of stable, high-performing Si-based colloids relevant to colloid and interface science, sustainable processing, and next-generation lithium-ion energy technologies.

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Design of colloidal particles to form 3-dimensional axial quasicrystals

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Aperiodic crystals (or quasicrystals, QCs) are materials that display long-range orientational order but lack periodicity. Initially discovered in metallic alloys [1], they have since been identified in a variety of soft matter systems [2]. QCs can be classified according to their symmetry, the main types being icosahedral and axial. While icosahedral QCs are aperiodic in all directions, axial QCs are aperiodic in two dimensions, but periodic in the third one.

We will show two examples of how we designed colloids with directional interactions to assemble into 3D quasicrystals with dodecagonal and octagonal symmetry. In the dodecagonal example, we generalize previous success in forming a 2D dodecagonal quasicrystal from 5-patch discs [3] and binary mixtures of 5- and 6-patch discs [4] by designing particles that forms stacks of such layers [5]. The nature of the interactions between such layers is simple with particles designed to sit directly above the particles in the previous layer.

For the octagonal quasicrystal the model design was obtained by looking at the local environments of a generalization to 3D of the 2D octagonal Ammann-Beenker tiling of squares and thin rhombs [6]. These environments have from 3 to 8 neighbours. An octagonal QCs can be obtained either from a binary system of 5-patch and 8-patch particles, or from a one-component system of 5-patch particles forms an octagonal quasicrystal. In both systems, edge dislocations are common. Additionally, a one-component system of the 8-patch particles assembled into an aggregate with multiple twinned crystalline domains whose diffraction pattern also exhibits 8-fold symmetry.

Finally, we will discuss the formation and stability of a decagonal QC from spherical particles with a soft corona [7]. Despite the fact that the decagonal QCs forms spontaneously upon quenching the fluid phase, our simulations indicate that this phase is less stable than a periodic approximant (i.e. a periodic crystal with local environments similar to those of the QCs).

Keywords:

colloids, self-assembly, quasicrystals, computer simulation, phase diagram, patchy particles

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Structural identification of photonic balls using structural color patterns

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Spherical colloidal clusters (“photonic balls”) (Figure (a)) are formed by the self-assembly of monodisperse colloidal particles within shrinking droplets. Photonic balls exhibit a variety of particle arrangements, including icosahedral, decahedral, and layered face-centered cubic (FCC) crystalline domains [1], and display characteristic structural color patterns such as triangular and teardrop shapes depending on the internal structures [2,3]. Structural color evolution during droplet shrinkage has therefore been expected to serve as an indicator of structural formation [3,4]. However, the interpretation of optical patterns in terms of specific internal structures remains ambiguous, particularly for orientation-dependent reflection geometries.

In this study, we propose an optical approach using different illumination conditions for structural identification of photonic balls formed from shrinking W/O/W double-emulsion droplets. By using bright-field, dark-field, and transmission imaging (Figure (b–d)), we systematically examine how reflection patterns depend on both internal structures and viewing direction. In particular, dark-field illumination enables detection of off-axis reflections that are difficult to observe under conventional bright-field conditions.

We demonstrate that characteristic reflection patterns, such as triangular- or teardrop-shaped features, provide optical fingerprints associated with distinct structural motifs. While the observed patterns depend on droplet orientation, the different illumination conditions enable more reliable structural interpretation across different viewing conditions.

This optical approach provides a practical method for structural identification of photonic balls and offers a framework for more precise *in situ* investigation of self-assembly pathways in confined colloidal systems.

Keywords:

photonic ball, colloidal crystal, structural color

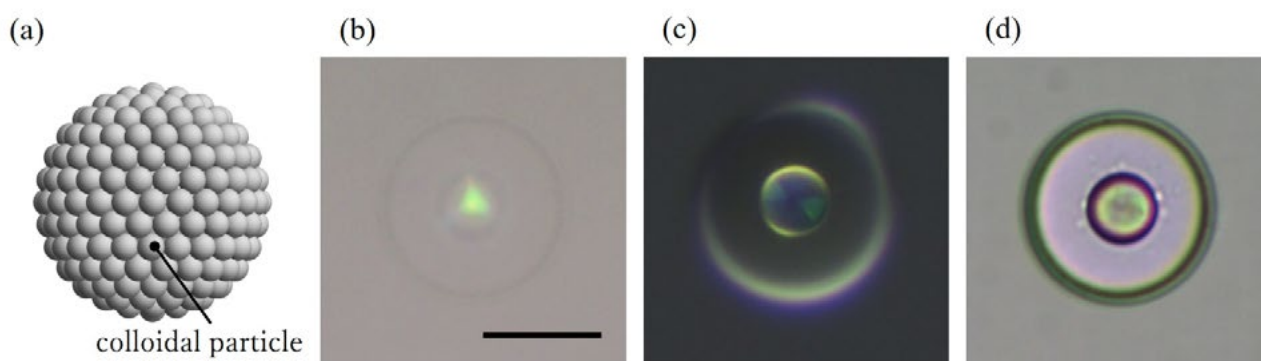


Figure (a) Schematic illustration of a photonic ball. Optical micrographs of a photonic ball during the formation process observed under (b) bright-field illumination, (c) dark-field illumination, and (d) transmission illumination. The scale bar represents 20 μm .

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Acknowledgements:

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Flow-Dependent Retention of Zwitterionic Surfactants in Carbonates

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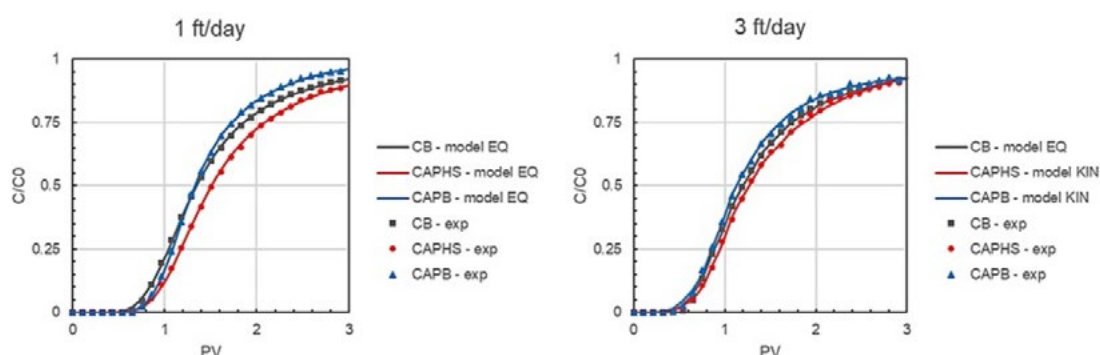
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Retention of surfactants in carbonate porous media emerges from coupled processes at the solid–liquid interface and in the flowing aqueous phase, yet static adsorption and dynamic transport are often analysed separately. Furthermore, although adsorption depends on surfactant structure, brine chemistry, rock properties, and flow conditions, most studies rely on static tests or single-flow-rate experiments, which do not fully represent dynamic reservoir conditions. Here, we relate previously established interfacial adsorption behaviour to new coreflooding results for three zwitterionic surfactants: cocamidopropyl betaine (CAPB), cocamidopropyl hydroxysultaine (CAPHS), and cetyl betaine (CB). Static adsorption studies on mineral surfaces revealed non-monotonic isotherms not captured by classical models and supported a three-step mechanism involving cooperative adsorption, surface aggregation, and micelle-induced desorption [1]. This interfacial framework provides a mechanistic basis for interpreting adsorption under flow, where retention depends on both surface affinity and transport conditions.

Dynamic adsorption was evaluated from Li-tracer and surfactant breakthrough curves in high-temperature/high-pressure coreflooding experiments using the same Indiana limestone core at injection rates of 1 and 3 ft/day, thereby isolating flow-rate effects from lithological variability. Surfactant concentrations were determined by HPLC-DAD/RID, and the breakthrough curves were modelled to assess the effect of injection rate within a consistent transport framework. The results show that increasing injection rate attenuates surfactant-specific retention and shifts the system away from local equilibrium. At low flow rate, longer residence times favour adsorption/desorption equilibration and amplify differences associated with surfactant structure and interfacial interactions. At higher flow rate, advective transport and hydrodynamic dispersion become more influential, limiting mass transfer to the carbonate surface and promoting a more kinetics-dominated response. This perspective places surfactant retention in carbonates within a unified colloid-and-interface framework, with implications for surfactant selection and injection strategies in subsurface applications, including enhanced oil recovery and geological CO₂ storage.

Keywords:

Zwitterionic surfactants; dynamic adsorption; solid-liquid interfaces; adsorption/desorption kinetics; carbonate porous media



Experimental and modelled breakthrough curves for zwitterionic surfactants during coreflooding in Indiana limestone at 1 and 3 ft/day, comparing equilibrium and kinetic adsorption models

References:

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Acknowledgements:

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Nanoarchitectonics in aqueous media containing antennary oligopeptides: general trends and specific phenomena

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The general nanoarchitectonic trend in aqueous media is based on the concept that structure-property relationships of certain molecules may result in the initial onset of nanostructural units, which act further on as building blocks of larger, usually well-ordered, nano-objects. This quasi-equilibrium (self-assembling) tendency is strongly dependent on the specific composition, and on the fine-tuning of the conditions in the solution formulation.

Recent investigations on specific self-assembling phenomena in aqueous solutions of non-toxic and biocompatible antennary oligopeptides (with two, three and four antennae) will be presented [1-3]. The key nanotectonic trend in these systems is initiated by hydrogen-bonding interactions which promote molecular recognition propensities, involving the onset of Polyglycine-II non-canonical architecture portions. The presence of a central connecting element, in combination with peptide antennae of optimal lengths, has a profound effect on the structure and properties of the aqueous formulations. Specific intra-molecular interactions are promoted among the antennae, attached to the central portion of the molecule, thus altering the original molecular conformation. Consequently, auxiliary inter-molecular options for further self-assembly are initiated, resulting in the formation of highly ordered noncovalent supramolecular species – tectomers (ultra-regular coatings, bulk nanoplatforms, peptide hydrogel portions, micellar entities). These structural reorganizations can be precisely regulated and gradually modulated upon variations of the fluid composition. In addition, the system's performance is controlled through fine-tuning of the parameters of the aqueous environment: pH, temperature, ionic strength, presence of low-molecular mass additives, synthetic and natural amphiphiles.

The newly acquired findings about the conditions for the onset and time evolution of the tectomers open novel application prospects, regarding the design of biomimetic and biocompatible materials to be used in medicine, biotechnologies, and for the environmental protection. Several examples related to biomedical procedures and water purification processes, will be discussed.

Keywords:

antennary oligopeptides, Polyglycine II, self-assembly, tectomers

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Acknowledgements:

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Resolving Hierarchical Self-Assembly Pathways of Oppositely Charged Surfactants using Stopped-Flow Time-Resolved (U)SAXS

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Fluorinated compounds have been detected in various ecosystems, from aquatic environments to agricultural soils, and even in wildlife (Evich et al., 2022). Their persistence in the environment can be highly detrimental, with a growing body of evidence linking them to adverse effects in life, including humans (Jagani et al., 2025). Consequently, strategies to remove these compounds from water are urgently needed. A promising approach is to exploit their precipitation via catanionic association in water. In this case, mixing oppositely charged surfactants, even below their individual critical micellar concentrations (CMCs), can lead to rapid molecular association, followed by microstructure formation and precipitation from the aqueous medium (Weiss et al., 2008; Hörmann et al., 2023). However, the transient microstructures and the kinetic pathways that lead to their formation remain only partly known (Gradzielski, 2003; Weiss et al., 2008). In this work, we investigate the time-resolved self-assembly kinetics of equimolar sodium perfluorooctanoate (NaPFO) and octyltrimethylammonium bromide (OTAB) below their CMC, using stopped-flow mixing coupled with time-resolved ultra-small- and small-angle X-ray scattering (TR-(U)SAXS). Data analysis is performed by employing a physically constrained hierarchical scattering model. The results suggest a hierarchical assembly scenario, in which the surfactants organise into composition-dependent unilamellar vesicles, with bilayer composition that may show leaflet asymmetry (Hörmann et al., 2023). The vesicles then associate into polycondensates (Takahashi et al., 2017), which remain correlated via inter-polycondensate electrostatic interactions. This approach, opposite to traditional phenomenological fitting methods, allows for assessing structurally meaningful, time-dependent observables. These include mean vesicle radius, vesicle number density, average aggregation number per polycondensate, bilayer leaflet composition, and the distribution of surfactant between free and associated states. Based on this structural analysis, a kinetic model based on mass-balance relations and rate equations is developed. This connects the SAXS-derived time-dependent observables to potential concurrent growth routes, allowing one to understand whether increases in vesicle size result from surfactant uptake from the free monomer pool, coalescence within polycondensates, or a combination of both processes. We then provide closed-form predictions for the coalescence-only scenario and a regression-based approach for estimating kinetic coefficients in the mixed-growth case. Overall, this work shows how TR-(U)SAXS links hierarchical self-assembly to microscopic kinetic insights in dynamically assembling soft-matter systems. Additionally, it offers a mechanistic understanding relevant to the catanionic capture of fluorinated surfactants from water.

Keywords:

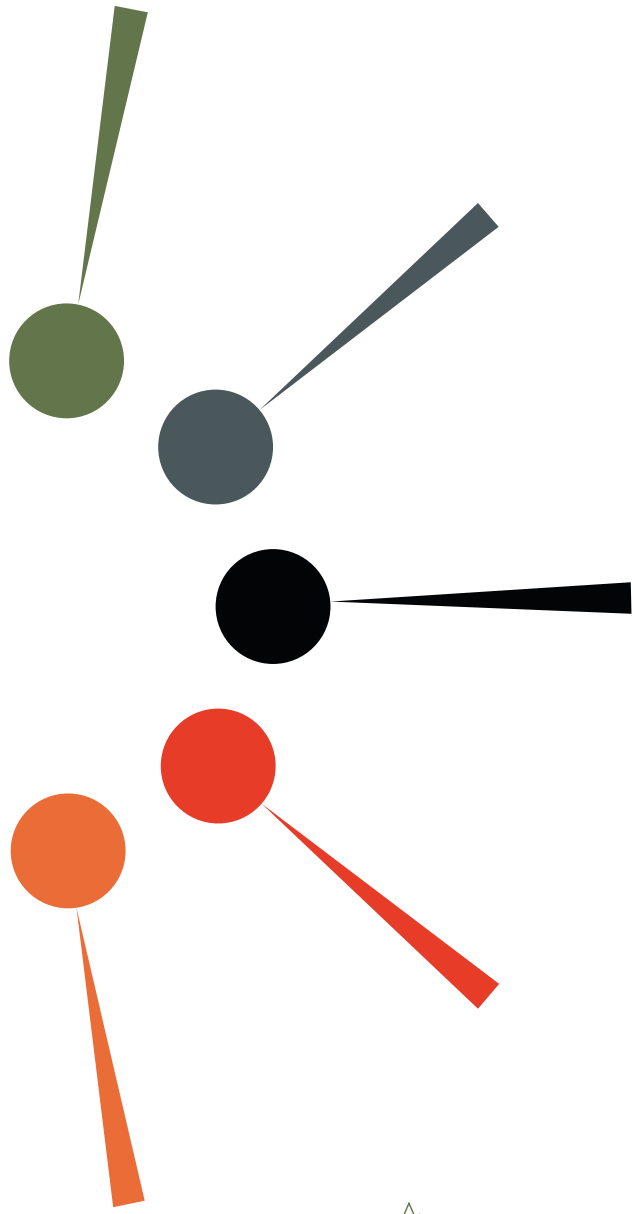
Hierarchical self-assembly; catanionic surfactants; stopped-flow TR-(U)SAXS; self-assembly kinetics; water remediation

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Topic 8

Dynamics, Stability, Self-Assembly,
and Phase Behavior of Complex Fluids

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Data-driven density functional theory for phase coexistence & partitioning in multicomponent colloid–polymer mixtures

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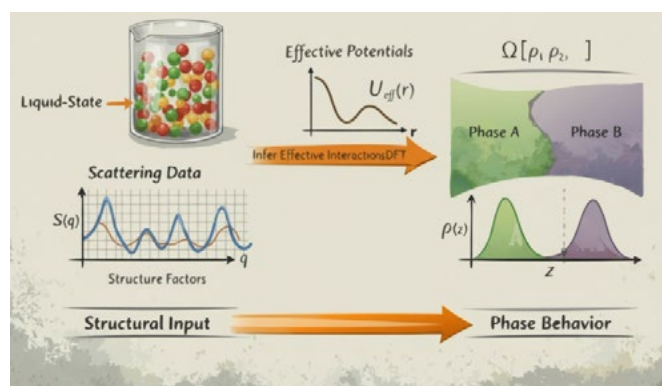
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Partitioning of biomolecules and colloids in multicomponent polymer mixtures underlies phenomena ranging from intracellular organization to separation technologies. Yet, predictive understanding of phase coexistence and interfacial structure remains limited, particularly in systems with many interacting species.

Here, we present a unified theoretical and computational framework to investigate phase behavior and partitioning in multicomponent colloid–polymer mixtures. Building on particle-based simulations of phase-separating polymer systems with embedded nanoparticles [1], we develop an improved classical density functional theory (DFT) capable of resolving phase coexistence in mixtures with multiple polymeric and colloidal components [2]. The framework combines refined free-energy functionals with an efficient scheme to determine equilibrium phase compositions and interfacial properties. Quantitative benchmarking against simulations shows very good agreement, while significantly extending the accessible parameter space.

To bridge theory and experiment, we introduce a data-driven extension of the DFT in which effective interactions are inferred from liquid-state structural input, such as partial structure factors. Using structure factors generated from independent simulations as a proxy for scattering data, we demonstrate how this approach enables predictive modeling of experimentally relevant systems without requiring prior knowledge of the underlying pair interactions, typically needed in both particle-based simulations and conventional DFT [3].

Overall, this work establishes a scalable and experimentally grounded framework to connect microscopic structure with macroscopic phase behavior in complex fluids.



Schematic overview of the conceptual framework presented in Ref. 3. AI-generated image.

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Direct measurement of osmotic pressure and a pair potential in colloidal dispersions

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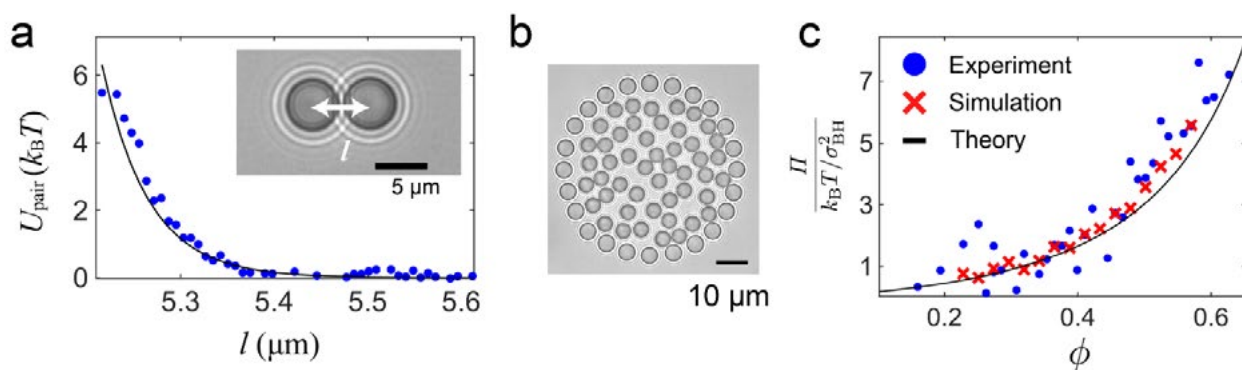
Osmotic pressure in colloidal dispersions is a key measure for their dispersibility, which characterizes the physical properties of colloidal dispersions [1]. Since osmotic pressure is very weak, available measurement methods are limited. In this context, a system that measures both osmotic pressure and interparticle interactions is highly desirable for understanding the relationship between macroscopic osmotic pressure and particle-level properties. In this study, we demonstrate measurement of both osmotic pressure and interparticle interactions within the same experimental system, an optical tweezer system.

For a pair potential U_{pair} measurement, two polystyrene particles were trapped by a Gaussian line trap formed by optical tweezers (inset of Fig. a). In thermal equilibrium, the probability $P(l)$ of finding a pair of particles at a distance is determined by the total potential U , which consists of U_{pair} and the harmonic potential U_{trap} of the optical trap [2]. Since U_{trap} can be estimated beforehand, U_{pair} is obtained from $U_{\text{pair}} = U - U_{\text{trap}}$ (Fig. a). For an osmotic pressure measurement, silica particles were trapped by the tweezers, forming the corral boundary (Fig. b). Polystyrene particles were dispersed inside the corral. Since both types of particles are heavier than the surrounding fluid, they settled at the bottom, and their motion was confined to a two-dimensional plane. Since the trapping force acting on a particle can be regarded as Hookean restoring force for small corral deformation, the force induced by the inside particles is measured by the displacement of the trapped particles, and osmotic pressure Π is calculated (osmotic pressure here is force per unit length).

Figure c shows the dependence of Π on area fraction Φ . The measured pressure agrees well with both the Brownian dynamics simulation and theoretical results based on the hard-sphere model, both calculated using the experimental measured U_{pair} . This agreement demonstrates the applicability of the proposed technique for investigating dispersive properties across multiple scales, linking microscopic particle-level interactions to macroscopic osmotic pressure within a single system. The proposed technique enables bottom-up design of colloidal materials through particle-level modifications.

Keywords:

Colloidal dispersions, Optical tweezers, Osmotic pressure



(a) Pair potential. The inset shows the two polystyrene particles trapped by a Gaussian line trap. (b) Our measurement system for osmotic pressure. (c) Nondimensionalized osmotic pressure in the colloidal dispersion.

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Self-assembly and network formation in difunctional and monofunctional associative rheology modifiers

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Rheology modifiers (RMs) are essential in liquid formulations such as coatings, adhesives, and lubricants. Their concentration-dependent self-assembly into transient associative networks imparts non-Newtonian flow behaviour and governs viscosity and stability. Understanding when and how these networks form is therefore crucial for the rational design and optimisation of commercial formulations.¹

Telechelic associative RMs based on hydrophobically modified ethoxylated urethanes (HEURs) form flower-like micelles at low concentrations and percolated networks at higher concentrations.¹ Network formation causes macroscopic thickening and is a key performance parameter in applications. However, commercial HEURs are not perfectly telechelic; alongside difunctional chains with two hydrophobic end groups, some chains are monofunctional, possessing only one hydrophobe. These monofunctional chains (mHEURs) cannot bridge micelles and therefore reduce network connectivity and alter rheological behaviour.²

Here, we study HEUR:mHEUR mixtures, both based on a 10 kDa PEG backbone with one or two C12 hydrophobes. In earlier work, we studied HEUR network formation using shrinking-gate fluorescence correlation spectroscopy (sgFCS) and the molecular rotor dye Sulfo-Cyanine3.¹ Now we present sgFCS measurements confirming that mHEUR alone produces no slow diffusive component associated with network formation, while in HEUR:mHEUR systems it scales with the fraction of difunctional chains (Figure 1a).

To complement the dynamic information from sgFCS with structural analysis, we performed small-angle X-ray scattering (SAXS) on HEUR:mHEUR mixtures. SAXS reveals systematic steepening of the high- q power-law exponent from ≈ 2 in mHEUR-rich solutions to ≈ 4 in HEUR-rich systems, indicating a transition from polymer chain scattering to Porod-like behaviour associated with compact hydrophobic domains (Figure 1b,c). Combined scattering-FCS analysis establishes a direct link between associative dynamics and nanoscale structure in HEUR:mHEUR mixtures.

Keywords:

Rheology modifiers, Associative polymers, Self-assembly, FCS, SAXS

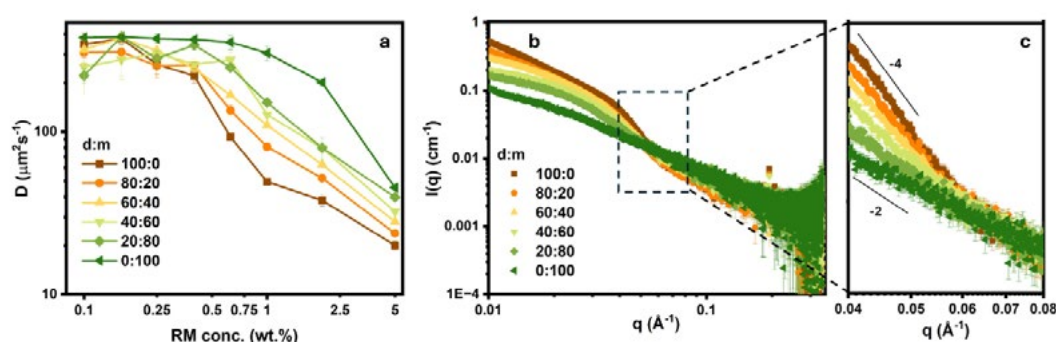


Figure 1: (a) Diffusion coefficients (D) obtained from sgFCS as a function of RM concentration for HEUR:mHEUR mixtures at different difunctional:monofunctional component ratios (d:m). (b) SAXS profiles of the mixtures at 2 wt% RM. (c) Enlarged SAXS curves in the Porod region, offset for clarity.

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Tuning Solid-State Photoluminescence of AuCu₁₄ Nanoclusters: Influence of Dendron-Shell Spacing and Dynamics

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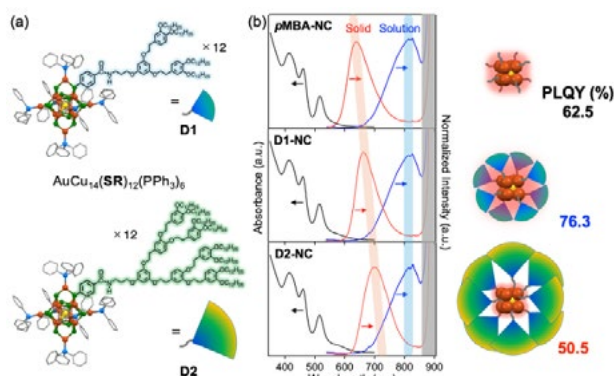
Atomically precise metal nanoclusters exhibit unique optical properties, where intercluster interactions play a crucial role in determining their photophysical behavior in the solid state. Controlling the local packing environment is therefore essential for tuning the emission properties. Ligand-shell engineering offers a promising strategy for modulating the packing and interactions of nanoclusters in the condensed phase. In this study, dendron-functionalized clusters were prepared via post-synthetic modification of a *para*-mercaptobenzoic acid (*p* MBA)-protected AuCu₁₄ nanocluster ([AuCu₁₄(*p* MBA)₁₂(PPh₃)₆]⁺, *p* MBA-NC). Amide coupling between *p* MBA carboxylic acid groups and amine-terminated dendrons (D1-NH₂, D2-NH₂) yielded two dendronized clusters (**D1-NC**, **D2-NC**; Figure a) bearing first- and second-generation dendrons (D1 and D2). These systems enable investigation into how dendron generation influences intercluster separation and the photophysical properties of nanocluster solids.

Photoluminescence measurements revealed a significant solid-state blue shift relative to the solution phase, with its magnitude decreasing in the order: *p* MBA-NC > **D1-NC** > **D2-NC** (Figure b). This trend suggests that closer intercluster proximity in the solid state induces structural constraints that suppress excited-state relaxation, thereby elevating the emission energy. Bulky dendron layers function as effective spacers to modulate the local packing environment. By increasing intercluster separation and alleviating these constraints, the dendrons allow the clusters to exhibit solid-state photophysical behavior more consistent with their intrinsic, solution-like properties. Interestingly, the solid-state photoluminescence quantum yield (PLQY) showed a different trend. The **D1-NC** exhibited the highest PLQY (76.3%), exceeding both the *p* MBA-NC (62.5%) and the bulkier **D2-NC** (50.5%) (Figure b). This result suggests that emission efficiency is governed not only by intercluster separation but also by the dynamic characteristics of the surrounding ligand shell. The D1 dendron presumably restricts ligand-shell motions and suppresses nonradiative pathways, whereas the larger, more flexible D2 dendrons introduce conformational freedom and facilitate vibrational energy dissipation, thereby promoting non-radiative decay as a more significant pathway for excited-state relaxation.

These findings demonstrate that generation-dependent dendronization enables simultaneous modulation of intercluster separation and ligand-shell dynamics, providing a systematic strategy for controlling the solid-state photophysical properties of ligand-protected metal nanoclusters, addressing a common challenge in the design of functional hybrid nanomaterials.

Keywords:

Ligand-protected metal nanoclusters, Dendronized ligand shell, Intercluster interactions, Ligand-shell dynamics, Solid-state photoluminescence



(a) Schematic illustrations of dendron-functionalized AuCu₁₄ nanoclusters (top: D1-NC, bottom: D2-NC). (b) UV-vis absorption (black) and PL spectra in the solid state (red) and solution phase (blue) for AuCu₁₄ nanoclusters.

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Synthesis of Oligothiophene Dendron-Modified Au Nanoparticles and Their Effects on Optical Properties and Self-Assembled Structures

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Au nanoparticles (NPs) exhibit localized surface plasmon resonance (LSPR) in the visible region, facilitating interactions with various optical materials. Among organic soft materials, oligothiophene dendrons [1] have π -conjugated moieties that enable wavelength-tunable photoluminescence (PL) [2]. Our previous study demonstrated that CdS quantum dots modified with phenylethyl ether-based liquid crystalline (LC) dendron exhibited energy transfer from the band edge of CdS to lower-energy states originating from π - π stacking of the dendrons [3]. Furthermore, LC dendron-modified Au NPs were found to self-assemble into a hexagonal phase, which transforms into a cubic LC phase at 150 °C [4]. Based on these findings, this study investigates the synthesis, optical properties, and self-assembled structures of oligothiophene dendron-modified Au NPs (Fig. (i)).

1-Dodecanethiol (DT) modified Au NPs (**A**) and oligothiophene dendron (**T7**) and DT -modified Au NPs (**DA**) were synthesized in three different initial ligand ratios (**T7** :DT = 25:75(**DA25**), 50:50(**DA50**), 75:25(**DA75**). Transmission electron microscopy images of **A** and each **DA** show similar particle sizes of approximately 4.6 nm, while the interparticle distances increased with increasing **T7** content (Fig. (ii)). The optical property of **DA50**, **T7**, and mixture of Au NPs and **T7** with a protected thiol group (**A+T7-THP**) were evaluated via PL measurement in chloroform (Fig. (iii)). While the PL of **A+T7-THP** was quenched relative to an equivalent amount of **T7**, the PL from **T7** covalently bound to the Au core in **DA** showed a more significant quenching of 91%. This indicates the occurrence of energy transfer from **T7** to the Au core, which is significantly enhanced by direct binding of **T7**. Additionally, small-angle X-ray scattering of **DA50** film confirmed a structural phase transition into a face-centered cubic structure at 150 °C. The effect of the **T7** modification ratio on the self-assembled structures will also be discussed.

Keywords:

Au nanoparticles, Oligothiophene dendron, Optical property, Energy transfer, Self assembly

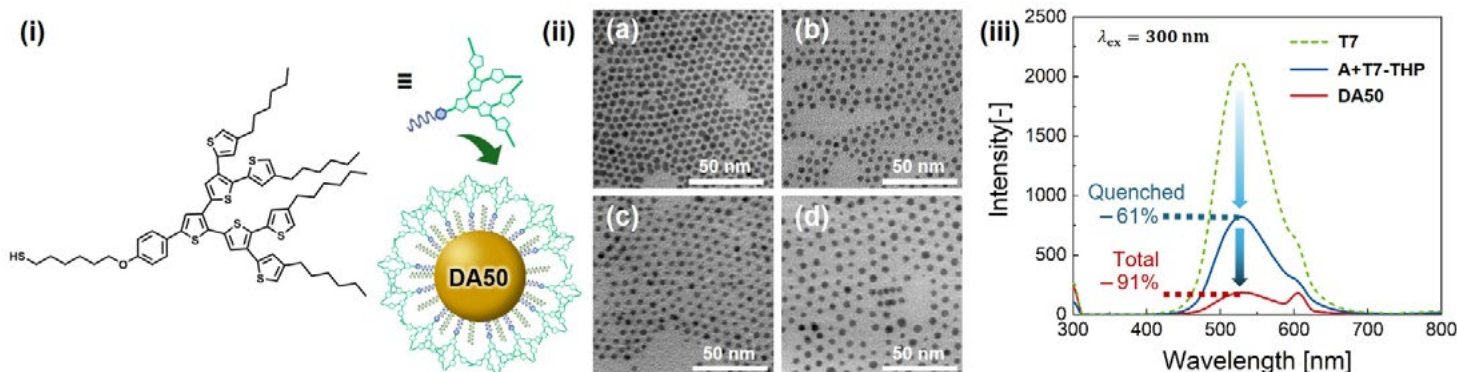


Fig. (i) A molecular structure of T7 and schematic image of DA, (ii) TEM images of (a) A, (b) DA25, (c) DA50, and (d) DA75, and (iii) PL spectra of T7, A+T7-THP, and DA50.

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Self-segregation of polymer and salt along hydration gradients in evaporating aqueous solutions

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Drying multicomponent solutions is a ubiquitous situation in both industrial processes, for instance coatings, and environmental ones, such as saliva aerosols¹. However, as water is removed by evaporation, the remaining non-volatile species may self-segregate along the resulting hydration gradient, strongly impacting both drying kinetics and the final morphology and properties of the material^{2,3}.

To quantify this, we use a model system composed of water, potassium nitrate (KNO₃), and a non-ionic hydrophilic polymer (PNIPAM). Using a one-dimensional microfluidic drying geometry combined with in situ Raman confocal microscopy, we measure spatial composition profiles during evaporation and reconstruct drying trajectories in the ternary phase diagram.

We show that drying does not follow a simple dilution path but instead gives rise to non-trivial composition trajectories. In particular, we observe a robust non-monotonic, S-shaped (serpentine) pathway, reflecting successive regimes of salt enrichment and depletion along the drying direction. This behavior arises from the coupling between evaporation-induced concentration gradients, multicomponent diffusion, and preferential interactions within the mixture.

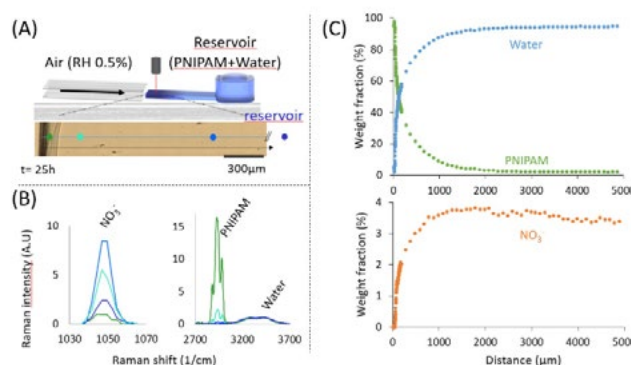
Depending on the initial composition, two additional regimes emerge. At intermediate salt content, the trajectory crosses the binodal, leading to liquid–liquid phase separation and subsequent evolution within the two-phase region. At higher salt concentrations, rapid crystallization at the air–liquid interface dominates, trapping the system out of equilibrium.

Remarkably, for a given initial condition, the drying trajectories collapse onto a single path in the phase diagram, showing that the composition pathway can be rationalized from the interplay between mixture thermodynamics and multicomponent transport coefficients, rather than by time.

Overall, this work establishes a direct link between hydration gradients, self-segregation, and phase behavior, and provides a framework to rationalize non-equilibrium drying pathways in complex fluids.

Keywords:

evaporation, self-segregation, hydration gradient, Raman spectroscopy



(A) Microfluidic drying setup, the chip contains a solution of PNIPAM 2.5% KNO₃ 1.5%. The imaging is performed after 25 h of drying. (B) Raman spectrum of different points in the microfluidic cell. (C) Weight fraction of the water, PNIPAM and NO₃⁻, from the air/liquid interface toward the bulk

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Using wetting, capillary forces, and ultrasonic waves to extract oil from a drop containing oil/water mixtures

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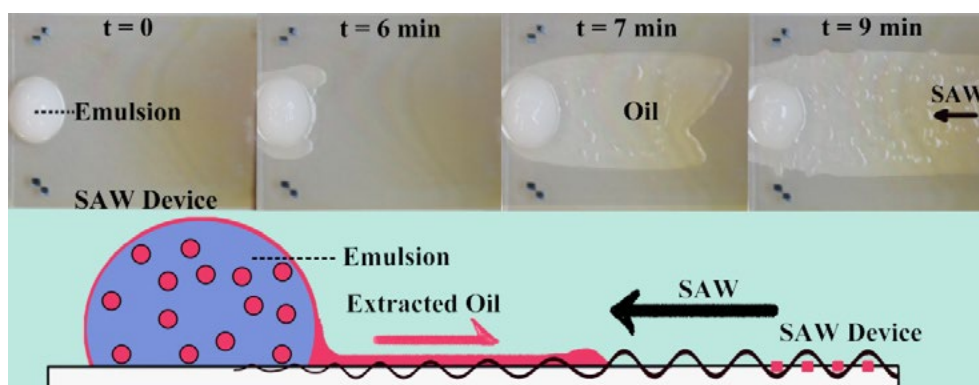
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Oil and water placed atop of a solid surface respond differently to a MHz-level surface acoustic wave (SAW) propagating in the solid due to their different surface wetting properties. We observe that, under SAW excitation, non-organic silicon oil and organic sunflower oil are extracted continuously from sessile drops that are comprised from emulsions of the oil in a solution of water and surfactants. The mechanism responsible for the extraction of oil from the mixtures is the *acoustowetting* phenomenon: Under acoustic stress the low surface tension oil phase leaves the mixture in the form of ‘fingers’ that, away from the drop, spread opposite the path of the SAW. The high surface tension water phase remains at rest. Increasing either the SAW intensity or the oil content in the mixture enhances the rate at which oil leaves the emulsion. We further observe acoustic-capillary flow instabilities at the free surface of the oil film and the formation of spatial gradients in the emulsion oil-concentrations in the presence of SAW. Our study suggests the potential for using SAW for heterogeneous removal of oil from oil-in-water mixtures to complement current phase separation methods.

Keywords:

Dynamic wetting, capillary stress, emulsion, phase separation, liquid film, surface acoustic wave



Time lapse and an illustration of an experiment where oil leaves a drop containing an emulsion of oil in water in the presence of a MHz-level surface acoustic wave

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Influence of Ambient Vapor Composition on the Stability and Breakup of Liquid Jets

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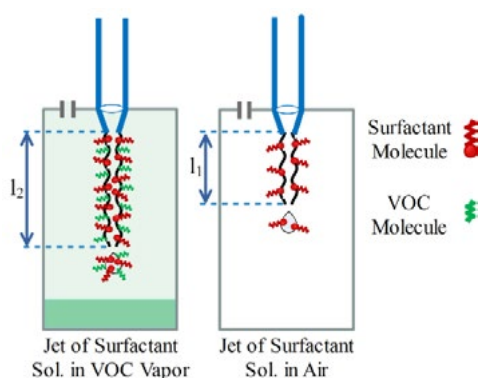
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The stability and breakup of liquid-jets are crucial in both fundamental science and industrial applications, necessitating deeper understanding and precise process control. Although factors such as viscosity, surfactant presence, nozzle geometry, and flow rate have been extensively studied, the influence of ambient vapor composition remains largely unexplored. Building upon our previous studies on the impact of surrounding volatile organic compound (VOC) vapors on the surface tension of water and aqueous surfactant solutions, this study investigates how VOC-saturated atmospheres modulate liquid-jet behavior, particularly in surfactant-laden systems. Capillary pressure measurements were complemented by high-speed imaging to quantify jet stability and breakup. Our findings reveal that exposure of surfactant-laden liquid-jets to VOC vapors reduces capillary pressure, enhancing stability and extending continuous jet length. Barely soluble, non-polar VOCs such as pentane, heptane, and toluene influence the jet through co-adsorption at the liquid-air interface, while polar VOCs such as ethanol and acetone affect it through bulk absorption. We observe that pentane-saturated vapor has the strongest effect on a 4.1 mM Sodium Dodecyl Sulfate (SDS) solution jet, where the capillary pressure reduction is three times larger than that caused by surfactants alone, and the continuous jet length increases by 25 % compared to air. Analysis of characteristic timescales reveals that the diffusion timescales of both surfactants and VOCs are shorter than the timescale of jet instability. Notably, VOC adsorption occurs three orders of magnitude faster than surfactant adsorption, rapidly shaping interfacial dynamics. These findings introduce a novel method for modulating liquid-jet stability and breakup by altering the ambient vapor composition.

Keywords:

Jet breakup, Capillary pressure, Co-adsorption, Surfactant, VOC



Schematic illustrating the influence of VOC exposure on the stability of a surfactant-laden liquid jet.

Stabilization of water-in-water emulsions by complex coacervate core micelles

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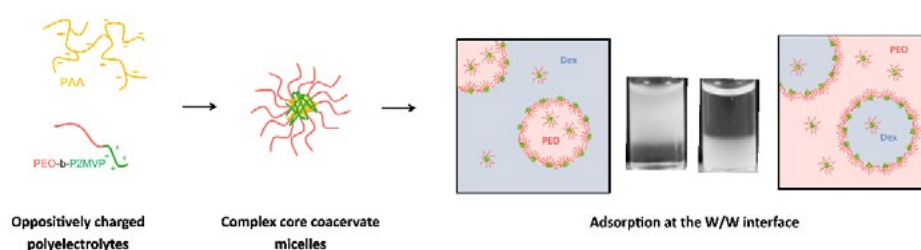
Water-in-water emulsions (WWE) form when aqueous solutions of incompatible polymers are mixed. These emulsions, that do not contain any organic phase, are of growing interest, particularly for applications that involve compartmentalization, and they are deprived of any organic phase. However, they display a large interface and low interfacial tension, making the adsorption of molecular stabilizers, such as surfactants, difficult. Moreover, these all-aqueous systems require fully hydrophilic stabilizers displaying affinity for both phases. Therefore, using particles such as protein microgels or protein-polysaccharide complexes as stabilizers, namely Pickering effect, has proved effective in improving WWE stability. [1] [2] However, the relationship between the chemical composition of the particles and their ability to stabilize WWE is poorly understood. A recent work showed that WWE composed of poly(ethylene oxide) (PEO) and dextran and formulated with dextran copolymer-based microgels displaying affinity for both phases had an excellent stability. Nonetheless, copolymer microgels are inherently ill-defined and allow only a partial comprehension of their conformation, both in bulk and at the water/water interface. [3] Moreover, to our knowledge, no study reported long-term stability (that is, for several weeks or months) for both PEO-in-dextran and dextran-in-PEO with a single stabilizer.

In this context, we designed complex coacervate core micelles (C3M), consisting of polyelectrolyte complexes stabilized by one or several neutral hydrophilic polymer segments attached to one of the polyelectrolytes. C3M are well-defined, all-hydrophilic core/corona soft particles of which size and surface chemistry (thus, affinity for both phases) can be tuned by varying the copolymer composition. [4]

We will introduce the proof-of-concept of the impressive improvement of stability of PEO/dextran WWE in the presence of C3M with a PEO corona. We will highlight the role of C3M concentration to stabilize both PEO-in-dextran and dextran-in-PEO emulsions for several months. We will also discuss the influence of ionic strength on the co-assembly of C3Ms and thus, on the stability of WWE containing them.

Keywords:

Water-in-water emulsions, polyelectrolytes, complex coacervate core micelles, stabilization



Complex coacervate core micelles formed from PAA and P2MVP-b-PEO adsorb at PEO/dextran interfaces and enhance emulsion stability by reducing creaming, sedimentation, and coalescence.

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Double Gradients, Double Control: Advancing Core-Shell Particles

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Core-shell particles are versatile building blocks in colloidal and materials science, where precise control over particle size and shell architecture is essential for tuning functional properties. In template-assisted approaches, removal of the core enables the formation of hollow structures, which are widely used in applications such as drug delivery, waste remediation, and catalysis.[1] Beyond these applications, both core dimensions and shell thickness also strongly influence physical behavior, including optical response, highlighting the need for synthetic strategies that enable independent and continuous control over these parameters.[2] Therefore, our present work focuses on the controlled synthesis of gradient core-shell particles, offering new opportunities for tailoring structure-property relationships in colloidal systems.

Here, we present a double gradient approach to the synthesis of core-shell particles, allowing simultaneous control over core size and shell thickness. Monodisperse polystyrene (PS) particles were first employed as templates to grow silica shells with a controlled thickness gradient via our previously established CrESP [3] method. In a second step, a gradient in core size was introduced using a modified CrEEP [4] approach, yielding PS particles with a well-defined size distribution. Subsequent silica deposition on these gradient cores resulted in core-shell particles exhibiting coupled gradients in both core size and shell thickness. Together, these approaches provide access to mechanistic insights into the silica shell growth process.

The combined control over core size and shell thickness further establishes a versatile platform for designing complex particle architectures with multiple structural gradients. Overall, this approach provides a general route toward advanced colloidal building blocks with independently tunable structural parameters.

Keywords:

Stöber Synthesis, Emulsion Polymerization, Colloidal Particles, Core-Shell, Size Gradient

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Temperature-induced structural transitions of cationic vesicle dispersions

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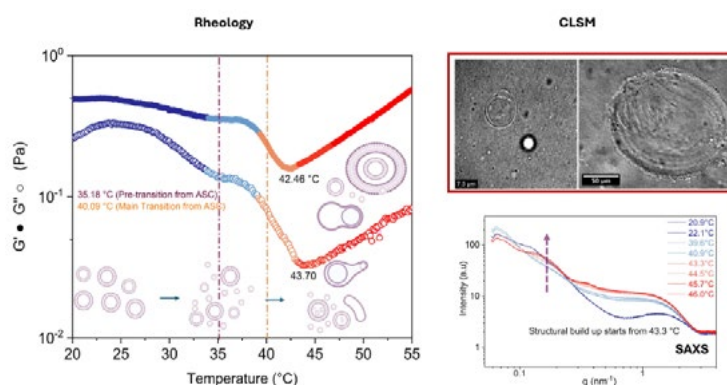
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Double tailed cationic surfactants are common ingredients for laundry, when dispersed in water they can form dispersion of small unilamellar vesicles (200 nm to 1 μm) and they can be formulated with other additives as cross linked cationic polymers (microgel) and perfumes in oily phase. The macroscopic properties of this complex fluid, such as its rheology, are closely linked to its microstructure. In particular, understanding the temperature-dependent behaviour of the cationic vesicles and its altering interaction mechanism with the additives, i.e., perfumes and microgels, is critical for controlling rheology, microstructure and stability over ageing. In this research, we explore the structural transitions of the cationic vesicles with increasing temperature. The observed change in vesicle shape and lamellarity are linked to the counterion type [1], and bilayer phase transitions, heterogeneities and fluidity [2,3], and allows to identify some intermediate shapes such as docking, pear and onion-like. We use rheology, confocal microscopy and scattering (WAXS, SAXS) to connect the nano-to-macro structural changes to macroscopic properties, and to correlate alterations of the bilayer fluidity with the diffusion behaviour of the additives. Combined, our results provide a novel mechanistic description linking colloidal to macroscopic lengthscales that can improve formulation.

Keywords:

Vesicles, bilayer, microstructure, phase transitions, temperature



Thermo-rheology, confocal microscopy, Small Angle X-Ray Scattering (SAXS) at different temperatures display structural build up in cationic vesicles

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Impact of the sapogenin gypsogenin on the structure and phase behavior of DMPC vesicles

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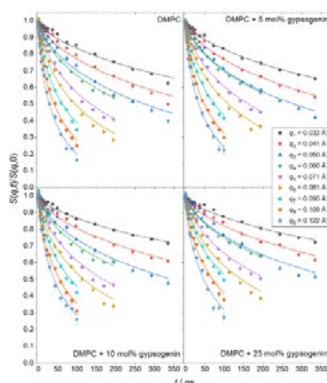
Small unilamellar vesicles (SUVs) composed of phospholipids such as 1,2-dimyristoyl-*sn*-glycero-3-phosphocholine (DMPC) are widely used as model membrane systems. DMPC bilayers undergo a well-defined phase transition from the gel to the fluid phase at approximately $T_m \sim 24^\circ\text{C}$. [1,2] While the interaction of saponins with DMPC membranes has been extensively studied, considerably less is known about the effects of their aglycone counterparts, the sapogenins. Gypsogenin, a pentacyclic triterpenoid found in soapwort (*Saponaria officinalis*) and gypsum herb (*Gypsophila oldhamiana*), has attracted interest due to its reported anticancer activity. [3,4]

In this study, gypsogenin was incorporated into unilamellar DMPC vesicles to investigate its biophysical impact. Structural changes were analyzed using small-angle neutron scattering (SANS), providing insights into vesicle size, morphology, and bilayer thickness. Complementary neutron spin-echo (NSE) spectroscopy revealed a concentration-dependent increase in membrane stiffness above T_m , evidenced by enhanced bending rigidity and suppressed collective membrane undulations. Notably, this stiffening effect increases with higher gypsogenin content and is comparable to the well-known impact of cholesterol incorporation into lipid bilayers. [5]

Thermotropic properties were examined by UV-vis spectroscopy through turbidity measurements, indicating shifts in the main phase transition temperature as well as alterations in transition cooperativity. These results demonstrate that gypsogenin significantly affects the phase behavior of DMPC membranes. Overall, this study shows that gypsogenin modulates both the structural and thermal properties of phospholipid vesicles, contributing to a deeper understanding of membrane interactions.

Keywords:

phospholipid vesicles, model membranes, sapogenin, SANS, NSE



Intermediate NSE scattering functions $S(q,t)/S(q,0)$ for vesicle dispersions composed of DMPC with gypsogenin at concentrations of 0, 5, 10, and 25 mol%, measured at 40°C . Vesicles were extruded through a membrane with a pore diameter of 50 nm.

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Using biology: how softness and shape anisotropy determine the percolation threshold of Red Blood Cell networks

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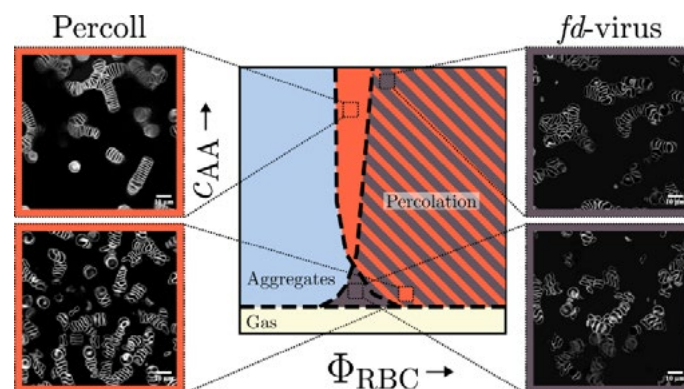
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The phase behavior of hard spheres in depletant-containing solutions, including non-equilibrium gel states, has been the subject of research for decades [1]. More complex colloidal mixtures, including soft and anisotropic particles with directional interactions, have received less attention [2]. However, many real-life systems, like cosmetics, foodstuff or biological systems, are constituted of such complex colloidal particles. Red blood cells (RBCs) are inherently monodispersed, soft, and anisotropic particles (diameter 8 μm , thickness 3 μm). In the absence of flow, RBCs self-assemble into complex space-spanning networks in blood plasma, driven by depletion interactions induced by plasma proteins [3]. RBCs thus serve as an ideal model system for studying the phase behavior of soft, anisotropic colloids. In this work, we use confocal imaging to map the state diagram of RBC-depletant mixtures, varying the length scale of the interaction by the addition of either Percoll (silica nanoparticles; 13 nm) or *fd*-virus (880 nm). We extract the resulting 3D structures using deep neural network segmentation. While Percoll induces rouleaux formation, *fd*-virus gives rise to disordered house-of-cards structures, causing a lower percolation threshold for *fd*-virus than for Percoll at low concentrations. However, at elevated concentrations, Percoll becomes more effective in percolating the network, while induced-shape changes in the RBC aggregates cause an increase in the threshold for *fd*-virus. Our results not only show how depletion range, strength, and RBC deformability together give rise to intricate 3D network structures but also emphasize the added richness in the phase behavior of more complex colloids.

Keywords:

percolation, network structure, red blood cells



Shift in percolation threshold with increasing *fd*-virus (gray) and Percoll (orange) concentration and representative RBC network structures.

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Hydration and Water-Mediated Binding of Superchaotropic *closo*-Dodecaborates

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The binding of *closo*-dodecaborates, $B_{12}X_{12}^{2-}$ with $X = H, Cl, Br, I$ (Fig.1a) to solutes, nanoparticles, polymers and interfaces has been copiously reported as a consequence of a water-mediated chaotropic effect.[1,2,3] However, the role of water has been inferred exclusively and indirectly from thermodynamic measurements. Herein, we use Raman spectroscopy in the O-H stretch region with multivariate curve resolution for solutions of $B_{12}X_{12}^{2-}$ in water to i) reveal their molecular hydration structure as illustrated in Fig.1b, ii) elucidate the temperature sensitivity of their hydration shell, and iii) report evidence for the water-release upon chaotropic binding. We find that all dodecaborates feature a sharp Raman band centered just below 3600 cm^{-1} – strongly blue-shifted compared to bulk water – that represents weakly H-bonded, “almost dangling” OH-groups in the hydration shell, see Fig.1c. Heating blue-shifts the hydration spectra less than the bulk water spectra, which makes hydration and bulk water at high temperature more similar and thus rationalizes the previously reported weaker chaotropic binding at high temperature. Hydration difference spectra along the binding isotherm with the non-ionic polymer hydroxypropylcellulose (HPC) further reveal the shedding of weakly H-bonded hydration water from $B_{12}X_{12}^{2-}$ as well as strongly H-bonded hydration water from $B_{12}X_{12}^{2-}$ and HPC as an associated process. The present study demonstrates weakly bound hydration water and a spontaneous release thereof as a hallmark of the superchaotropic behavior of dodecaborates.

Keywords:

chaotropic effect, nano-ions, ion specific effect, hydration, water, Raman MCR

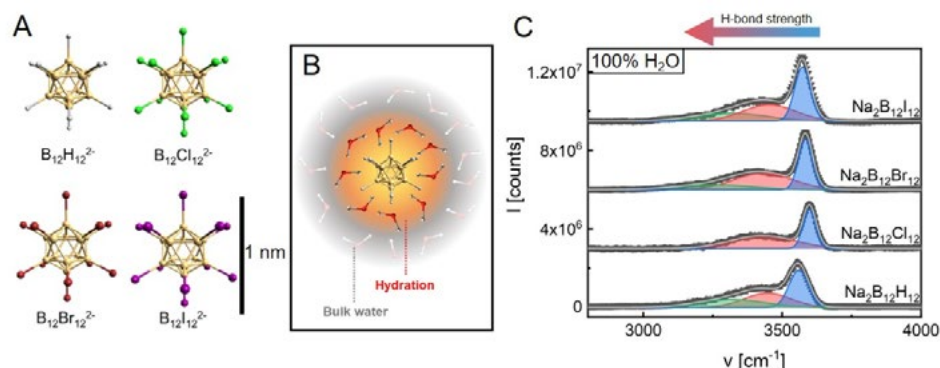


Figure 1. a) Molecular structure of $B_{12}X_{12}^{2-}$, b) Illustration of the hydration shell of $B_{12}H_{12}^{2-}$, c) Hydration spectra of $B_{12}X_{12}^{2-}$ in the OH-stretch region revealing a sharp blue-shifted peak.

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On the self-assembly of Porphyrins and Bile Salts: the supramolecular chiral induction by steroidal surfactants

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Porphyrins are versatile aromatic building blocks that act as chiral probes, able to sense and amplify the chiral information given by a proper environment [1]. Their ability to amplify chirality makes them ideal candidates for designing smart devices for the stereospecific recognition [2]. In this work, bile salts (BS), unconventional chiral surfactant with a peculiar facial amphiphilicity, are used as chiral trigger to induce porphyrin aggregation. The BS sodium cholate (NaC) and deoxycholate (NaDC) are used as inductors to drive the chiral aggregation of the achiral 5-(4-carboxyphenyl)-10,15,20-(triphenyl)porphyrin (H2CTPP). Remarkably, varying the H2CTPP/BS molar ratio in buffered aqueous solution, porphyrin self-assembly leads to the formation of fibrillar aggregates that tend to pack in micrometric bundles of fibres. At a 1/100 H2CTPP/BS molar ratio (i.e. BS at 1 mM), these aggregates feature a pronounced supramolecular chirality (α -factor of ca. 0.1) that can be tuned by adjusting the solvent composition (Figure 1). Conversely, at a 1/1000 molar ratio, i.e. above the BS critical micellar concentration, porphyrin remains in its monomeric form inside the hydrophobic core of BS micelles, with no detectable chirality (Figure 1). The chiral self-assembly significantly affects the optical properties in solution (both absorption and emission), revealing the sensitivity of the system to aggregation. Preliminary results show that deposition of the chiral aggregates on quartz surfaces yields solid-state materials that retain chiral properties.

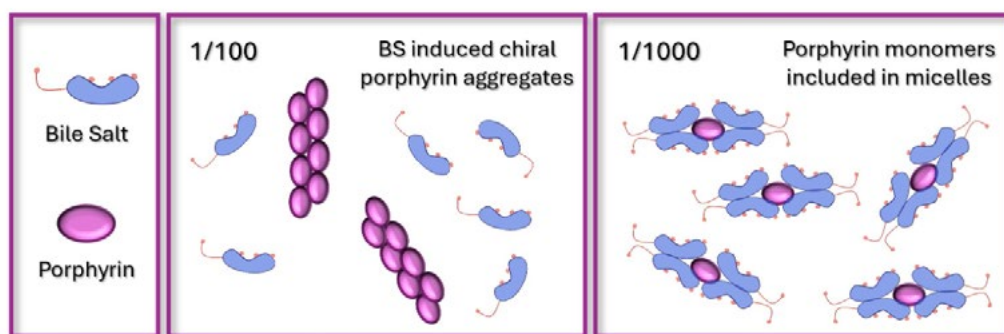


Figure 1. A graphical representation of the supramolecular interaction of porphyrins and bile salts at 1/100 (left) and 1/1000 (right) molar ratio.

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The Hidden Solute: How Dissolved Atmospheric Gases Change Liquid Physicochemical Properties

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Real water is not simply H₂O as atmospheric gases are always dissolved in it, and even more so in many organic liquids, where the solubility of gases may be much greater than that in water. Yet the collective role of dissolved gases as active physicochemical species remains entirely unaccounted for by current theories. This is a blind spot at the very foundation of liquids' physical chemistry.

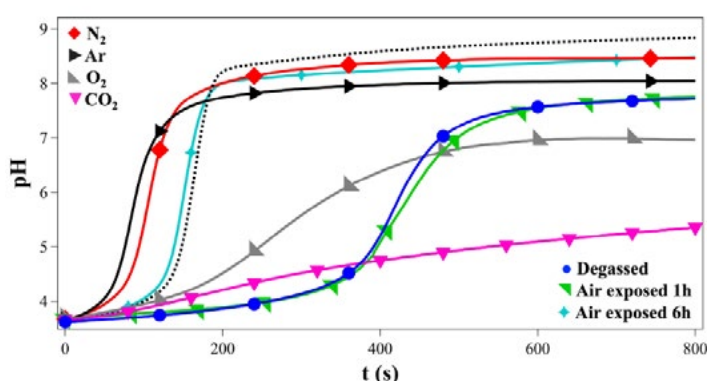
We showed that complete degassing with the freeze-and-thaw process produces dramatic, reproducible effects across aqueous and non-aqueous systems. For example, oil-water and hydrocarbon-perfluorocarbon binary systems remain stable for some time without the intervention of any surfactant, and phase separation times extend by orders of magnitude [1]. Electrolyte conductivity, cloud-point temperatures, and the UV-Vis spectrum of bromothymol blue all change markedly upon the removal of the dissolved gases [1,2]. Urease enzymatic activity is suppressed [3]. Bubble coalescence exhibits ion-specific modulation [1], revealing that gas/liquid nanointerfaces respond markedly to solute identity and yet the molecular origin of this ion specificity remains elusive.

Sequential re-admission of individual gases maps re-adsorption kinetics and shows that the perturbation is reversible but remarkably slow. Full urease recovery requires nearly six hours, with paradoxically, chemically inert N₂ and Ar accelerating urease activity [3]. Oxygen concentration needs about three hours to restore, bromothymol blue spectra 45 minutes [2], triacetin-water demixing over 400 minutes. All these prove that dissolved gases reshape solvent structure rather than act as chemical reagents or inert species.

These results can be interpreted in terms of gas nanobubble interactions with solvent molecules and of the formation of gas/liquid nano- and microinterfaces. Disentangling the physicochemical contributions of dissolved gas species opens a new frontier for molecular, colloidal, and biochemical anomalies that have long resisted theoretical interpretation.

Keywords:

dissolved gas, nanobubbles, chemistry in solution, complex systems



Urease catalyzed urea hydrolysis raises pH in unbuffered aqueous solutions. Sigmoidal pH vs. time curves show blank (dashed), degassed, and gas-readmitted conditions, revealing the role of dissolved gases in modulating enzymatic kinetics.

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Non-aqueous emulsions with high dispersion stability prepared using a novel block-random-block type emulsifier

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Non-aqueous emulsions consist of hardly miscible solvents, where one forms droplets dispersed in the other and they find applications in personal care and ink. However, preparation of non-aqueous emulsions with high dispersion stability has been difficult because of low adsorption efficiency of emulsifiers at the interface¹. We have reported that non-aqueous emulsions can be stabilized by the formation of ion complex between block-random copolymers with amino groups (Fig.1-A) as an emulsifier in the continuous phase and polyacrylic acid as an auxiliary emulsifier in the dispersed phase. In this study, we developed a new block-random-block copolymer with hydrophobic blocks attached to both ends of a random polymer unit (Fig.1-B). Furthermore, we compared its emulsification property with that of the conventional emulsifier.

Non-aqueous emulsions were prepared by adding dispersed phase consisting of polyacrylic acid dissolved in methanol into continuous phase consisting of emulsifiers dissolved in tetradecane, aided by ultrasonication. For both emulsifiers, dispersion stability was improved by the addition of the auxiliary emulsifier to the dispersed phase. The new emulsifier showed improved stability compared to the conventional one regardless of the auxiliary emulsifier concentrations. The interaction between the emulsifier and the auxiliary emulsifier at the interface was examined using FT-IR measurements. Shift in C=O stretching vibration peak of the auxiliary emulsifier was observed, suggesting the ion complex formation between the emulsifier and the auxiliary emulsifier at the interface and this contributes the stabilization of the non-aqueous emulsion.

Keywords:

Non aqueous emulsion, Block-random-block type copolymer, Dispersion stability

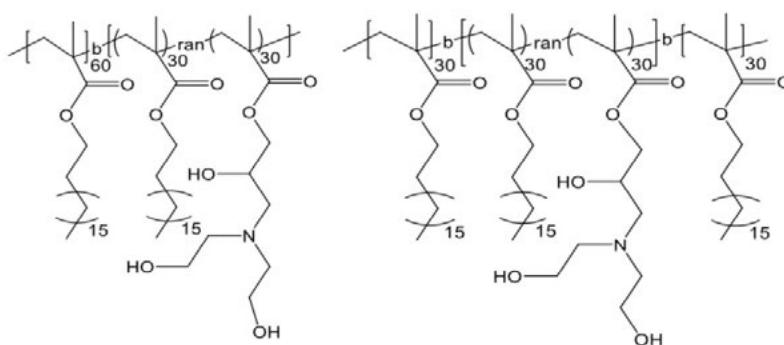


Figure 1 Molecular structure of (A) conventional and (B) novel emulsifiers

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Beyond the Effective Solvent: How Fractionation and Solvent-Solvent Interactions Drive Micellization in Binary Solvents

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We have investigated the role of solvent fractionation on micellization in mixed solvents. Amphiphilic block copolymers can self-assemble into micelles in a selective solvent: one that preferentially solvates the solvophilic block(s). In many practical situations, the solvent consists of two (or more) different species. A common simplification in the theory of block copolymer self-assembly treats binary solvent mixtures as a single effective solvent characterized by averaged interaction parameters. We show that this approximation can break down: solvent fractionation, the unequal partitioning of solvent components between micelle cores, coronas, and interfaces, fundamentally alters micelle properties like aggregation number, and can drive morphology transitions that a single-solvent description fails to predict. We have systematically varied the core-solvent, corona-solvent and solvent-solvent Flory-Huggins interaction parameters to study the effect of solvent fractionation and solvent-solvent interactions using Scheutjens–Fleer self-consistent field lattice computations [1]. We compare the resulting structures with single-solvent reference systems at the same averaged interaction parameter and with an experimental system of poly(1,2-butadiene-*b*-ethylene oxide) (PB-PEO) micelles in water-tetrahydrofuran (THF) solvent mixtures [2]. Additionally, we examine morphology transitions induced by changes in binary solvent composition and selectivity. These results establish that binary solvents cannot be replaced by an effective single solvent without loss of predictive power, and they open a practical route to morphology control through tuning of solvent composition.

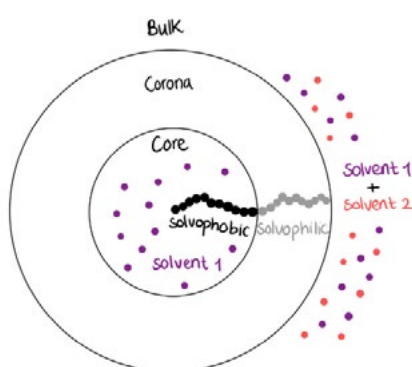


Illustration of solvent fractionation into the core of the micelle.

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Supramolecular Assembly and Morphological Control of Lignin Colloids via Levulinic Acid Solvents

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The development of functional lignin particles (LPs) represents a fundamental challenge in the valorization of industrial byproducts through the lens of colloid science [1]. In this study, the formation of LPs is controlled via a solvent-shifting process utilizing levulinic acid (LA) and its derivatives—specifically its ethyl ester (EL) and the ketal (K) obtained from EL and glycerol—as sustainable solvent media. The physicochemical driving forces governing the nucleation and growth of these colloids are systematically investigated to establish a correlation between solvent nature and the resulting supramolecular architecture.

It is demonstrated that the choice of solvent fundamentally modulates the internal organization of lignin macromolecules, specifically influencing the degree of π - π stacking between aromatic moieties. This molecular-level control translates into distinct morphological transitions: LA promotes the formation of irregular particle clusters, whereas EL induces the assembly of compact, well-defined spheres, and the ketal derivative leads to the generation of planar fragments. Such structural diversity is linked to the varying solubility parameters and the specific interactions between the lignin backbone and the solvent molecules during the anti-solvent addition.

The characterization of these LPs reveals that the composite structure and high surface area achieved through LA-mediated synthesis result in enhanced functional properties, such as antioxidant capacity. Furthermore, the understanding of these assembly mechanisms is essential for governing the interfacial behaviour of lignin in multiphase systems. These tailored LPs are successfully employed as stabilizers for high-performance Pickering emulsions, platforms for the encapsulation of bioactive compounds, and as reinforcing agents in functional composite hydrogels based on polysaccharides such as alginate and chitosan. This work provides a robust framework for the design of bio-based soft materials with tunable properties for advanced interfacial applications.

Keywords:

Lignin, Levulinic Acid, Antioxidant Properties, Morphology Tuning

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Acknowledgements:

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Anisotropy under soft confinement: A new fate for gold nanoparticles?

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The unique properties of confined molecules are dictated by the architecture of their host environment ^[1]. Traditionally, these systems are classified by their dimensionality and structural rigidity, with soft environments, such as reverse micelles (RMs), serving as versatile nanoreactors ^[2]. Within these frameworks, nanoconfined water plays a critical role, as its physicochemical properties differ significantly from the bulk phase ^[3], directly influencing nucleation and growth. Despite numerous studies using isotropic soft systems to control nanoparticle formation, significant discrepancies remain regarding the underlying mechanisms in more complex geometries ^[4]. In this work, we utilize reverse wormlike micelles (RWLMs) composed of lecithin, cyclohexane, and water to investigate how structural anisotropy and the state of confined water influence chemical reactivity (Fig. 1A) ^[5,6]. The reduction of gold nanoparticles (AuNPs) served as a high-sensitivity structural probe, as their morphology and optical response provide a direct "fingerprint" of the nanoreactor's internal constraints and the evolution of the reaction (Fig. 1B). By comparing identical reaction conditions in both anisotropic (RWLMs) and isotropic (RMs) environments, we observed that modulating the nanoreactor's morphology and reactant concentration profoundly alters both reaction kinetics and AuNP shape. In summary, our findings demonstrate that anisotropy could be a decisive factor in dictating structural evolution, offering a new perspective on the behavior of matter under confinement. Looking forward, this work opens possibilities for fine-tuning the optical properties of gold nanostructures by precisely engineering the architecture of their soft host environments.

Keywords:

Soft confinement. Reverse wormlike micelles. Structural anisotropy. Gold nanoparticles.

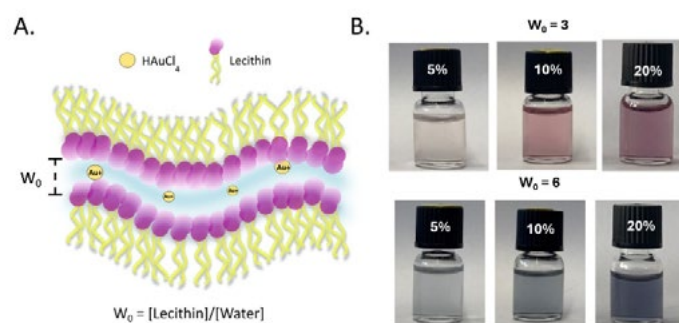


Figure 1. A) Schematic representation of gold ions confined within reverse wormlike micelles. B) Photograph of reverse wormlike micelle systems after reaction, illustrating the color change associated with different gold nanoparticles produced at varying water content (W_0).

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Aqueous supracolloidal assembly of gold nanoparticles guided by hydrophilic triblock copolymers

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Well-defined clusters of gold nanoparticles (AuNPs) have attracted considerable interest due to their remarkable plasmonic, optical and electronic properties. However, unlike conventional 3D colloidal assemblies, controlling the assembling of a limited number of isotropic AuNPs into anisotropic 1D or 2D structures in aqueous suspension remains highly challenging¹. Such assemblies are particularly attractive for biomedical applications, including sensing, imaging, photothermal therapy or as SERS enhancer... While molecular recognition strategies² and approaches based on multivalent ions³ have been explored, simple and efficient methods to precisely control assembly dimensionality, morphology, and interparticle distance are still lacking.

Here, we introduce a versatile strategy based on the surface functionalization of AuNPs with fully hydrophilic triblock copolymers. These copolymers consist of a central poly(acrylic acid) block that electrostatically adsorbs onto the cationic surface of AuNPs and two external neutral blocks (a poly(ethylene oxide) (PEO) derivative block, and a polyacrylamide (PAM)) that form a stabilizing corona around AuNPs. Importantly, the intrinsic incompatibility between the neutral blocks induces nanoscale phase segregation within the corona. This feature is exploited to trigger controlled self-assembly of nanoparticles via selective insolubilization of one of the neutral blocks under external *stimuli*. Specifically, the PEO-based block is selectively insolubilized through non-covalent cross-linking with silica⁴, while the PAM block is selectively collapsed upon addition of a poor solvent. These orthogonal triggers enable precise control over nanoparticle assembly pathways.

The resulting colloidal assemblies were characterized by DLS, UV-visible spectroscopy, cryo-TEM and SAXS. TEM also allowed observing the assembly morphologies on surface after solvent evaporation. A strong dependence of the assembly process morphology was observed on both the copolymer architecture and the AuNPs intrinsic properties. Notably, anisotropic particles (nanorods) exhibit enhanced assembly in suspension, forming either tip-to-tip or side-by-side structures, depending on the applied *stimulus* [figure]. Furthermore, the presence of negatively charged chain ends enables additional control through complexation with multivalent cations, yielding assemblies with increased interparticle spacing.

Overall, this approach provides a simple and modular route to tune the structure of AuNP assemblies in aqueous media, opening new opportunities for plasmonic and biomedical applications.

Keywords:

stimuli-responsive assemblies, steric stabilization by copolymer adsorption, plasmonic properties

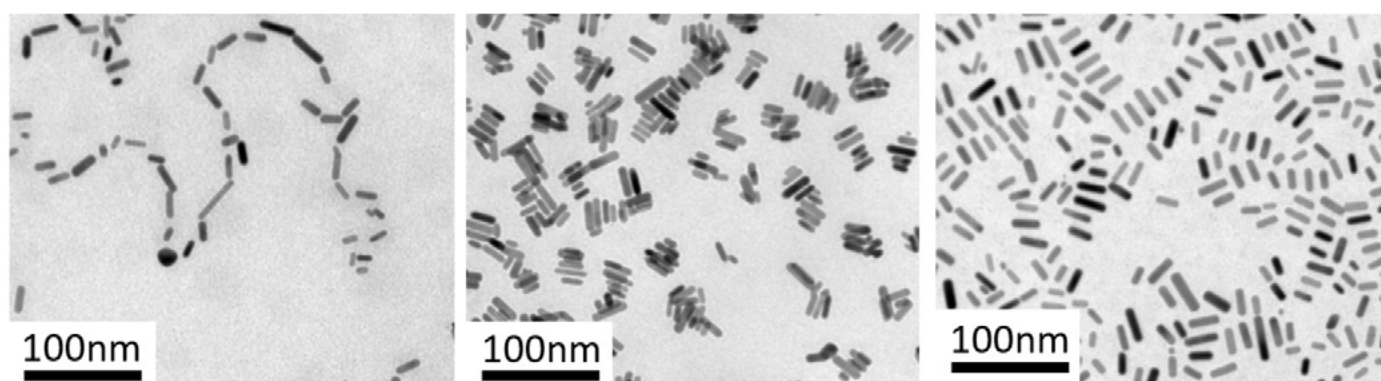


Figure: TEM images of different directional assemblies of AuNP@copolymer suspensions

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Doing the dishes with neutrons: milli-flow SANS-DLS of fat removal

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Understanding the mechanisms and kinetics of the removal of fat components such as triacyl glycerides (TAGs) from surfaces is of importance for the design of novel surfactant-based formulations for enhanced performance. Pairing of the physico-chemical properties of surfactants,¹ fat components,² and substrates³ dictates the macro-scale removal/cleaning mechanism and kinetics,⁴ with simulations reporting a number of nano-to-molecular scale pathways for these mechanisms.⁵ Here, we present a coupled in-line milli-fluidic SANS- microfluidic DLS approach to probe both substrate (glass and PDMS) supported TAG structures and nano-to-microscale dynamic solution structures under constant surfactant solution flow (Fig. 1a), using a model ‘dish-washing’ interesterified TAG and surfactant solution of 3:1 mol sodium dodecylsulfate and N,N-dimethyldodecylamine-N-oxide.

From scattering profiles and correlograms, we obtain a plethora of structural and interaction insights into the range of resulting solution structures and an estimation of surfactant partitioning between them (non-interacting micelles, loaded micelles, nano- and micro-scale emulsions), and we thus infer a ‘monomer economy’, %ME, for both dissolution-emulsification and delamination TAG removal mechanisms. Furthermore, the time-dependence of I_0 acts as a probe for the ingress kinetics of the surfactant solution into the TAG by the increase in the volume fraction of fractal interfaces, and we discover a concentration-time superposition for the dissolution-emulsification mechanism. Overall, we show two limiting cases for TAG removal (concentration-limited and mechanism-limited, Fig. 1b), and thus the balance between removal kinetics and molecule economy, these being valuable insights for the bottom-up development of the next generation of surfactant formulations, either through their synthesis or by leveraging synergistic interactions.

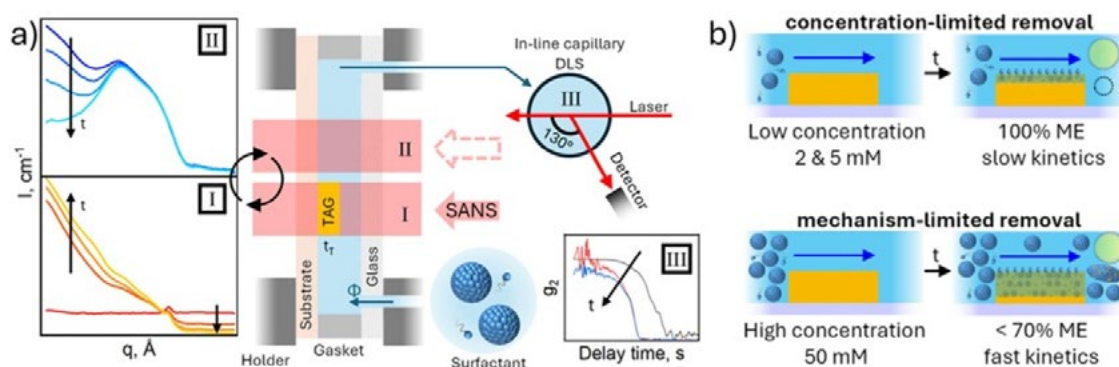


Figure 1: a) SANS-DLS experimental setup. SANS measurements alternate between regions I and II and DLS measurements taken at III. b) The two removal-limiting conditions, with corresponding solutions structures formed, surfactant ingress, and balance between monomer efficiency and kinetics.

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Using Scattering to Probe Superchaotropic Anion Adsorption to Nonionic Polymers

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Classical anions are categorized into kosmotropes (“water structure makers”), such as F^- and SO_4^{2-} , and chaotropes (“water structure breakers”), such as I^- or SCN^- . A high charge density results in kosmotropic behavior, while a low charge density results in chaotropic behavior. The even lower charge density of nanometer-sized ions, such as $B_{12}Br_{12}^{2-}$ and $SiW_{12}O_{40}^{4-}$ (Fig. 1b), leads to more pronounced “superchaotropic” behavior: Strong salting-in of hydrophobic solutes and large shifts in the lower critical solution temperature (LCST) of thermosensitive polymers, such as poly *N*-isopropylacrylamide (PNIPAM) or hydroxypropylcellulose (HPC, Fig. 1b). An important aspect of this behavior is the adsorption of (super)chaotropic anions to the uncharged solutes [1]. Adsorption constants of classical chaotropes to these polymers are typically in the range of $1 < K_A < 10 \text{ M}^{-1}$ (very weak binding) [2–4], and orders of magnitude higher for superchaotropes, $200 < K_A < 2000 \text{ M}^{-1}$ (weak to intermediate binding) [5–7]. Due to the much stronger binding, interactions of polymers and superchaotropes are experimentally easier to examine. Such superchaotrope-nonionic polymer systems are therefore also good model systems to elucidate non-additive salt effects, seen for example in the LCST behavior of HPC as a function of $H_4SiW_{12}O_{40}$ (HSiW) concentration with NaCl as background salt (Fig. 1a).

Typically applied methods like LCST measurements, isothermal calorimetry, or NMR (chemical shifts), all yield somewhat different apparent association constants. Here we explore the possibility of using small-angle scattering and dynamic light scattering to determine the association constant, while at the same time obtaining information on structural changes of the polymer.

Keywords:

superchaotrope, light scattering, small-angle scattering, salt effects, ion adsorption

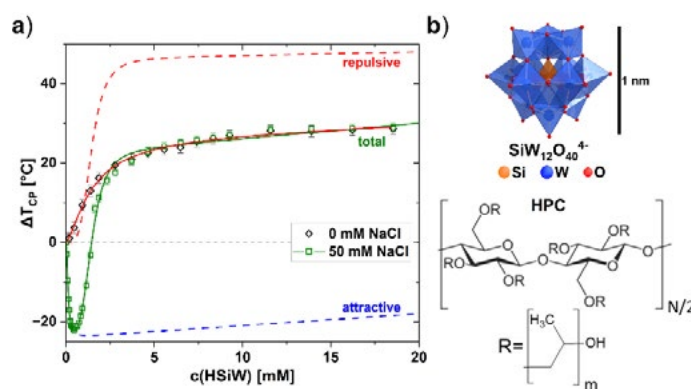


Fig. 1. a) Increase of the LCST of 26 mM HPC in water due to adsorption of HSiW without added NaCl and non-additive behavior in presence of 50 mM NaCl. b) Structures of HSiW and HPC.

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Phase transition in phosphocholine micellar solutions induced by lanthanide salts

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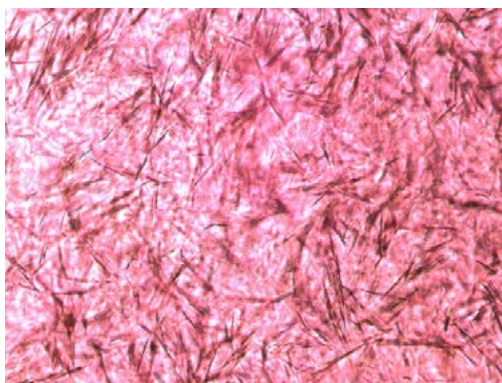
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Lanthanide–lipid interactions are important in both fundamental soft matter research and biophysical applications, including magnetic resonance imaging (MRI) and fluorescence-based cell labelling [1,2]. In this work we investigate the interactions between different lanthanide salts and lipid aggregates of the single-chain phospholipid surfactant dodecyl phosphocholine (DPC). DPC is an excellent membrane-mimetic model, used to solubilize membrane proteins in aqueous solutions. Understanding its interactions with lanthanides is expected to clarify lanthanide interactions with cell membranes. In previous work [3], we showed that at low concentrations lanthanides interact with DPC micelles not only as the bare trivalent cations, but also complexed with the anion of the lanthanide salt (chloride, nitrate, bromide, sulfate). In the present investigation we focus on the phase transition that occurs when lanthanide concentration exceeds a critical threshold. Even at low DPC concentrations (12-24 mM) lanthanides form precipitates with DPC, which have a needle-like shape, and a layered structure, as revealed by X-ray diffraction. We study this phase transition using rheology and optical microscopy and follow its evolution using small-angle X-ray scattering. The picture that emerges is very complex. The phase transition depends on the lanthanide cation but also on the anion of the lanthanide salt, being more pronounced for more strongly coordinating anions (e.g. nitrate or bromide vs. chloride). This is also a temperature-sensitive phenomenon. We have created maps of critical salt concentration vs. temperature for several different lanthanide salts. The effects observed are related to the gelation and fusion of lipid vesicles by lanthanides [4,5], although in the present case the integrity of DPC micelles is destroyed and new structures are formed. A mechanism for the phase transition is proposed

Keywords:

Lanthanide-lipid interactions, specific ion effects, lanthanide coordination, surfactants, phase transitions



Needle-like aggregates formed in DPC-CeBr₃ solutions at room temperature

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Thermo-responsive interpolyelectrolyte complexes (IPECs): reversible colloidal structures governed by composition and temperature

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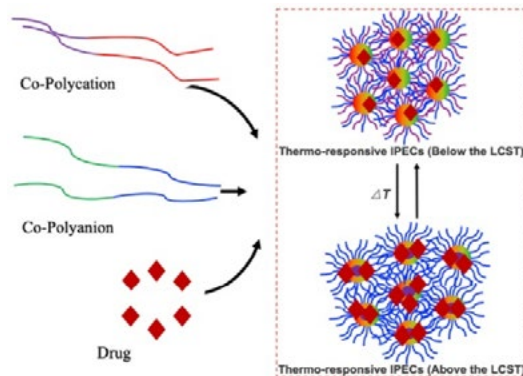
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When two oppositely charged polyelectrolytes are mixed in an aqueous medium, cooperative electrostatic interactions lead to spontaneous formation of interpolyelectrolyte complexes (IPECs). IPECs can adopt various colloidal structures, which will depend on how the polymers interact with each other and the solvent (water). This means by adjusting the copolymer's Mw and segment ratio, the properties of the IPECs can be effectively tuned, thereby establishing a connection between polymer design and IPEC properties. [1-3] To develop IPECs for “targeted drug delivery” that have tunable solubilization properties and temperature-responsiveness, diblock copolymers (poly(2-acrylamido-2-methyl-1-propanesulfonic acid)-b-poly(N-isopropylacrylamide) (PAMPS-PNIPAM) and poly(2-methacryloyloxy-ethyltrimethylammonium chloride)-b-poly(ethylene oxide) (PMTAC-PEO)), with varying molecular weights and length ratios have been synthesized by us to form thermo-responsive IPECs with diverse morphologies. Light scattering and small-angle neutron scattering (SANS) experiments show that the co-assembled IPECs behavior varies not only with the mixing ratio, but also with molecular design and, most importantly, temperature, enabling thermally reversible control over the IPEC structure and thus a deeper understanding of how the IPEC structure can be precisely controlled, paving the way for their further development in targeted drug delivery.

Keywords:

IPECs, copolymers, thermo-responsive, reversible, SANS



Scheme of thermo-responsive IPCEs for drug solubilization and release

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Coarse-Grained Contact-Area Dominated Interaction for Two-Dimensional Colloidal Nanoparticles

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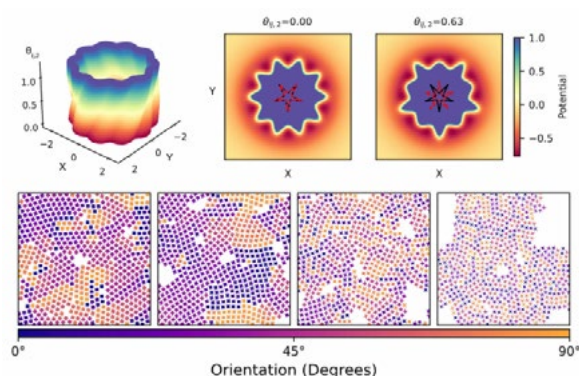
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The self-assembly of anisotropic nanoparticles offers a versatile route to designing materials with tunable optical and mechanical properties [1-3]. However, a significant body of research relies on the hard-particle model [4], which often fails to capture the essential physics of ligand-stabilized colloids. We present a coarse-grained interaction model that bridges this gap by explicitly accounting for the "softness" and contact-area dependence of the ligand shell. Unlike computationally expensive atomistic summations, our method derives an effective pair potential using a Derjaguin-like approximation [5]. This approach allows us to tune the ligand length while ensuring interactions scale correctly with the contact area of arbitrary shapes. By integrating this potential over particle boundaries, we generate tabulated energy landscapes that enable efficient 2D Molecular Dynamics (MD) simulations of arbitrary geometries. We also derive an analytical form of this interaction energy. We demonstrate that introducing shell softness alters the phase diagram, revealing a competition between core anisotropy and ligand-mediated interactions. This framework offers a physically grounded yet computationally efficient tool for predicting the assembly of realistic colloidal nanoparticles.

Keywords:

Anisotropic colloidal nanoparticles modeling, coarse-grained interactions, two-dimensional systems, self-assembly, MD simulations



Visualization of the interaction potential in different spaces and the snapshots of the resulting assemblies.

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Surfactants as molecular switches in the formation of β structures in peptides.

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Surfactants, due to their amphiphilic structure, can simultaneously participate in electrostatic and hydrophobic interactions, influencing the properties of macromolecular systems. The importance of surfactants derives from their ability to change the conformation and aggregation of macromolecules, which translates into the functional properties of the systems. The interaction of sodium dodecyl sulfate (SDS), chosen as a model anionic surfactant, with short peptides containing 19-39 amino acids and its effect on the conformational structure was studied. A hybrid approach was used to capture the mechanisms responsible for the formation of β -structures. Peptide sequences were generated using an improved version of AIMS2.0 deep learning [1]. The stability of the structures and their self-assembly process were analyzed using molecular dynamics (MD) simulations in the GROMACS software. The simulations conducted allow for a detailed understanding of the molecular mechanisms. The obtained results indicate that SDS can induce a transition from a disordered form to stable β -hairpin structures in selected peptides, which has been confirmed experimentally. In addition, such transition results in better mechanical properties of the obtained materials. Collected observations suggest that surfactants can act as molecular switches, process controls, self-organization and formation of β structures. Our results bring new information on designing biomaterials with controlled mechanical properties.

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Modulating Protein-Protein Interactions Using Osmolytes: Implications for Protein Stability and Aggregation

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Organisms such as *Escherichia coli* initially respond to osmotic stress by taking up inorganic ions, which helps partially restore cytoplasmic water concentration and growth rates. However, long-term survival requires a more effective strategy for re-establishing homeostasis. Nature offers a simple solution: the accumulation of small organic molecules known as osmolytes. Classical models often assume osmolytes are preferentially excluded from protein surfaces, overlooking their interactions with surface charges and their influence on protein-protein interactions (PPIs).

We used a two-dimensional microfluidic assay and vapor pressure osmometry to investigate this question. Specifically, we attached a negatively charged protein to two-dimensionally fluid phospholipid membranes mainly made of phosphatidylcholine lipids. Protein and lipid molecules were labeled with dyes and studied within polydimethylsiloxane (PDMS) microfluidic devices on glass substrates. Our research showed that at least three main factors influence how osmolytes modify PPIs. Although trimethylamine N-oxide (TMAO) is known to counteract urea's denaturing effects, we found that the urea-to-TMAO ratio needed for this effect is not the same in all cases. These results challenge traditional views of osmolyte exclusion and reveal a complex, interaction-based mechanism. This work offers new insights into how excipients regulate PPIs and has direct implications for improving protein formulations, stability in crowded environments, and rational biotherapeutic design.

Keywords:

Protein-Protein Interactions, protein stability, osmolytes, TMAO, urea

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Correlations in active nematic defects

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In equilibrium statistical physics, the fluctuation-compressibility theorem states that the variance of the number of particles, in a region of space with size R , scales as $\sigma_N \sim R^d$, with d the spatial dimension. Active systems, however, often exhibit giant number fluctuations (GNF), where $\sigma_N \sim R^\beta$, with $\beta > d$. In contrast, when $\beta < d$, the system is classified as hyperuniform (HU). In reciprocal space, hyperuniformity implies that the structure factor scales as $S(q) \sim |q|^{-\alpha}$, with $\alpha = d - \beta$ and q the scattering wavevector, so that $S(q) \rightarrow 0$ as $q \rightarrow 0$.

We study an active nematic liquid crystal of microtubules at an oil/water interface, driven out of equilibrium by ATP-fueled kinesin-streptavidin complexes. In the active turbulent regime, the system continuously creates and annihilates $\pm 1/2$ topological defects [1]. Previous results in our group showed that $\beta < 2$ for the system of active defects, for values of R as large as the system size. The system of active defects is thus HU. Using both hydrodynamics and particle-based simulations, we unravel how defect-defect correlation and their creation/annihilation processes all conspire to result in this behavior [2].

Recent experiments, however, using larger active nematic cells allow accessing smaller q . In this regime, we observe that $S(q)$ does not vanish at the lowest accessible q , but that instead it decays and saturates to a finite non-zero value. This suggests a crossover from hyperuniform to uniform behavior beyond a characteristic length scale. Uniformity suggests that at sufficiently large length scales random noise, akin to thermal effects, dominates over activity-induced fluctuations. To assess this, we compare our results with those of electric charges in equilibrium, finding that the relation between partial structure factors in this system holds for active nematic defects, thus confirming the transition from HU to uniform behavior.

Keywords:

nematic liquid crystals, topological defects, hyperuniformity, number fluctuations, active matter, structure factor

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Directed assembly of tetrahedral DNA-origami patchy colloids into diamond cubic, hexagonal diamond and S-II clathrates

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Understanding and controlling the self-assembly of colloidal building blocks into open crystal lattices remains a central challenge in colloid science. In particular, accessing distinct polymorphs from the same building block requires precise control over directional interactions and assembly conditions. DNA origami provides a powerful platform for this because it enables colloidal units with well-defined geometry and programmable binding.[1]

Carbon is a classic example of how one building block can generate multiple crystal structures. Through different relative rotations and stacking via tetrahedral bonds, it forms diamond cubic, hexagonal diamond (lonsdaleite), and other polytypes. Tetrapod DNA-origami building blocks were recently shown to assemble into a diamond cubic structure through single-stranded DNA binding extensions at their four tips with threefold symmetry.[2] Extending this concept to a two-component system allows the relative rotation between neighboring monomers to be programmed through the binding pattern. A 60° relative rotation favors diamond cubic formation, whereas enforcing a 0° rotation on one arm biases the system toward hexagonal diamond. To introduce competing pathways within one system, a mixed binding-extension design was implemented that allows neighboring monomers to adopt either the 60° or the 0° configuration.

This competition between local binding geometries, together with variations in crystallization conditions such as temperature and salt concentration, produces rich structural phase behavior. Depending on the assembly conditions, diamond cubic and hexagonal diamond stacking variants, interpenetrating lattices, and S-II clathrate lattices form. The clathrate phase is particularly notable because its energetic minimum is reached when all monomers adopt the 0° configuration, despite the distortions required to stabilize this structure (Fig. 1A).

The resulting clathrate has a lattice constant of about 440 nm and a unit cell containing 136 monomers. After stabilization by SiO₂ growth via a sol-gel process[3], this structural length scale gives rise to an optical response in the visible range. After drying, the crystals exhibit blue or green structural reflections under dark-field illumination, depending on crystal orientation and angle of incidence (Fig. 1B).

These results establish DNA origami as a model platform for controlling polymorphism and phase selection in programmable tetrahedral patchy colloids, while opening a route toward the bottom-up assembly of open photonic materials.

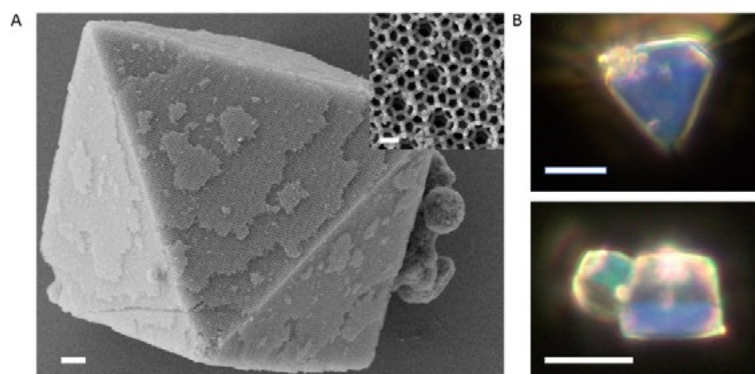


Fig 1. (A) SEM image of clathrate lattice with zoomed in image of its (111) plane (top right inset). Scale bars: 2 μm , inset: 200 nm. (B) Reflection-mode dark-field microscope image of clathrate single crystal (up) and twinned crystals (bottom). Scale bars: 10 μm (up), 15 μm (down).

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Coordination-Driven Modulation of Chiroptical Properties in Terpyridine-Functionalized Supramolecular Gel Assemblies

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Supramolecular metal complexes exhibit unique optical, electronic, and magnetic properties, making them promising candidates for applications in various advanced materials and devices. We have previously reported the circular polarization properties of supramolecular gels derived from molecules containing a dialkylated glutamide (G) unit, as well as their tunability through external stimuli. The G unit promotes the formation of supramolecular gels via intermolecular hydrogen bonding, which can induce significantly enhanced circular polarization properties due to the chiral orientation of chromophores linked to the G unit through covalent or non-covalent interactions. Supramolecular gels formed from G-linked ligand molecules exhibit significant changes in their circular polarization properties upon coordination with metal ions [1–3].

Here, we demonstrate the modulation of circular polarization properties in supramolecular gels formed from a G-linked terpyridine (G-tpy) [3] by complexation with various metal ions, followed by coordination with achiral guest ligands. Upon addition of metal ions to G-tpy in a 1:1 molar ratio in a cyclohexane/ethanol (9:1) solvent system, enhanced circular dichroism (CD) and circularly polarized luminescence (CPL) signals were induced, whereas almost no signals were observed in the absence of metal ions. These CD and CPL signals appeared near the absorption bands and emission wavelengths of the metal–G-tpy complexes, respectively, with both intensity and spectral pattern strongly dependent on the metal ion used.

Furthermore, the addition of achiral guest ligands induced notable changes in the CD and CPL spectra. When an equimolar amount of 2,2':6',2''-terpyridine (Tpy) was added to the G-tpy complex with Zn²⁺ (G-tpy(Zn)), a significant enhancement in the CD spectra accompanied by a red shift in absorption was observed (Fig. 1). Interestingly, the CPL signal of G-tpy(Zn) exhibited a sign reversal upon addition of Tpy. The aggregate morphology of G-tpy also changed dramatically from fibrous to plate-like aggregates upon addition of Zn²⁺, and reverted to fibrous structures after addition of Tpy.

Keywords:

Self-assembly, Circularly polarized luminescence (CPL), Nano-fibrous aggregates, Metal ion complex

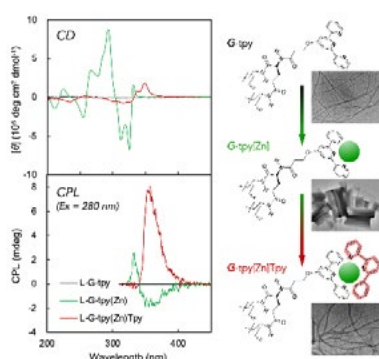


Fig. 1 CD and CPL spectra, and TEM images of G-tpy, G-tpy(Zn) and G-tpy(Zn)Tpy.

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Molecular Dynamics of Choline Chloride: Phase Behavior, Structural Evolution, and Transition Mechanisms in Deep Eutectic Solvents

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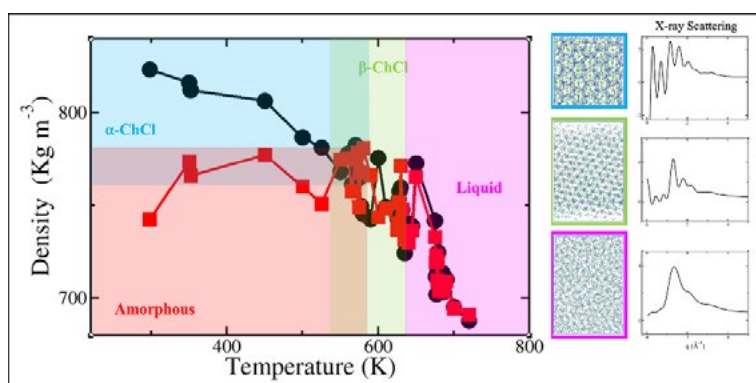
Deep eutectic solvents (DES) represent a new class of complex ionic fluids with tunable properties and emerging applications in separative chemistry and biomaterials.¹ Choline chloride (ChCl) - a key component in DES formulations including ethaline (ChCl + ethylene glycol) and reline (ChCl + urea), serves as an ideal model system for understanding the fundamental dynamics and phase behavior of DES.² While binary ChCl mixtures are technologically important, the difficulty in precisely locating their eutectic points indicates they are not true eutectics in the thermodynamic sense, yet this distinction has minimal practical consequence. Understanding ChCl's intrinsic molecular-level thermodynamics is essential for rational design of DES with optimized phase stability and transport properties for industrial separative applications.

Using comprehensive molecular dynamics simulations with optimized force fields,³ we characterize ChCl's complete phase diagram across three interconnected investigations. **1-Structural Characterization:** We establish baseline metrics for amorphous and crystalline α -ChCl including density, density fluctuations, octahedral order parameters (Q_4 , Q_6), radial distribution functions, coordination numbers, hydrogen bonding network topology, rotational dynamics, survival probabilities, and complementary SAXS/structure factor analysis. **2-Temperature-Dependent Thermodynamics:** Coexistence simulations reveal spontaneous formation of a previously uncharacterized metastable β -phase and subsequent melting, with extraction of temperature-dependent density, heat capacity, and transition enthalpies. All metrics are recomputed for β -phase and liquid states. **3-Phase Transition Mechanisms:** Real-time trajectory analysis, hydrogen bonding network evolution, and molecular mechanism investigation elucidate the three observed transitions: amorphous $\leftrightarrow\alpha$ (crystallization), $\alpha\leftrightarrow\beta$ (solid-state transformation), and $\beta\leftrightarrow$ liquid (melting).

Key Findings: The β -phase exhibits intermediate structural order between crystalline and amorphous states, with anomalously high local density fluctuations explaining its metastability. Transition mechanisms reveal distinct pathways: nucleation-and-growth kinetics for crystallization, geometric reorganization and H-bond network restructuring for $\alpha\leftrightarrow\beta$ transformation, and diffusion-driven disordering for melting. These results establish ChCl's complete phase diagram at atomic resolution, reconcile computational-experimental discrepancies, and provide molecular design principles for engineering DES with optimized thermal stability, and transport properties for separative chemistry applications.

Keywords:

DES, ChCl, Phase transition



ChCl Phase Diagram and X-ray Diffraction Analysis. Density evolution across four phases (amorphous, α -crystalline, β -phase, liquid) validated by XRD patterns showing sharp Bragg peaks (crystalline), intermediate diffraction (β -phase), and diffuse scattering (liquid).

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Is spontaneous emulsification in ternary solutions a common occurrence in nearly miscible solvents, or is it an urban legend caused by unavoidable impurities?

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We consider pairs of solvents that are not fully miscible with each other, such as water and octanol, water and ethyl acetate, fatty phosphoric acids and water, and water and 2-butanol. All of these have miscibility gaps that can be 'closed' at room temperature by adding a third compound. Depending on the context and the amount required to close the miscibility gap, this third component can be a co-solvent, a hydrotrope or an antagonistic salt.

The recently developed 'Gouy' method, which uses Static Light Scattering (SLS) in absolute units (the Rayleigh ratio expressed in cm^{-1}), enables the determination of both the apparent radii and the number concentration of droplets formed by slow dilution within the single-phase domain. This effect has been observed many times and is sometimes attributed to critical fluctuations only. The rest of the reported observations were dismissed as urban legends or attributed to the presence of impurities.

However, ultra-sensitive light scattering (micro-Rayleigh, software-filtered) reveals that critical fluctuations are consistently present near the critical point. In most cases investigated using the Gouy method with static light scattering, two types of aggregates are always found far from the critical point when the solvent is a solvo-surfactant or the surface-active species is an electrolyte.

The smaller aggregates, with a diameter of a few nanometres at most, have been named 'pre-ouzo' solvent-free microemulsion (SFME) aggregates. These aggregates are due to the competition between entropy and hydration forces¹.

A smaller number density of larger spontaneous aggregates, always between 50 and 400 nm in diameter, is also often reported. We argue that spontaneous emulsification results from favourable combinations of three factors: (i) the configuration entropy of large droplets, (ii) surface tension effects related to surface-active electrolytes, and (iii) the entropy cost of microphase separation. The aforementioned three mechanisms involved in the formation of large droplets in ternary fluids, reported as monophasic systems, have been quantified by H. Reiss², A. Onuki³ and S. Marcelja⁴. We propose that these large, spontaneous emulsion droplets are present in ternary systems for thermodynamic reasons, meaning they are not merely an urban legend or an effect due to uncontrolled impurities.

Keywords:

Nano-ions ; antagonistic salts ; hydrotropes ; critical phenomena ; entropy ; emulsification

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Structural Insights into Liquid–Liquid Phase Separation and Aggregation of TDP-43 Low Complexity Domain

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The aggregation of TDP-43 is a significant pathological feature of neurodegenerative disorders, notably Amyotrophic Lateral Sclerosis (ALS) and Frontotemporal Lobar Degeneration (FTLD-TDP). In pathological states, TDP-43 relocates from the nucleus to the cytoplasm, leading to the formation of harmful inclusions, characterized by nuclear depletion and cytoplasmic aggregation. These aggregates can trigger additional protein misfolding, interfere with intracellular transport, and are frequently observed to co-aggregate with other proteins. While TDP-43 aggregates are recognized as pathological entities in the final stages of these conditions, the molecular alterations that trigger the start of aggregation remain largely unclear [1].

This study aimed to explore the impact of phase separation on both self-aggregation and aggregation initiated by pre-existing aggregates of TDP-43, either the low-complexity domain (LCD), its mutant A321V, or its short aggregation-promoting regions (APRs). First, we applied various experimental techniques, theoretical calculations, and modelling to determine the fundamental physicochemical parameters of the studied biomolecules, such as monomer size, cross-sectional area, dependence of the nominal charge on pH, and isoelectric points. Additionally, molecular dynamics modeling was applied to gain insights into the mechanism of pH-driven changes in protein molecule conformations and their influence on the oligomerization process. By systematically altering the physicochemical conditions, we found that liquid–liquid phase separation (LLPS) facilitated spontaneous aggregation. However, seeded aggregation was less efficient under phase-separation conditions. By examining a wide array of conditions using the Hofmeister series of buffers, we verified that stabilizing hydrophobic interactions dominate over destabilizing electrostatic forces. RNA influences the cooperation between LLPS and aggregation in a "reentrant" manner, exerting the most significant positive effect at moderate concentrations. In summary, we conclude that conditions favoring LLPS enhance the subsequent aggregation of the TDP-43 LCD with a complex dependency but also adversely impact seeding kinetics.

Keywords:

Amyotrophic Lateral Sclerosis; Phase Separation; Biocondensates; Aggregation; TDP-43

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Chirality-driven interparticle interactions in plasmonic colloids revealed by optical spectroscopy

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Noble metal nanoparticles (NPs) are versatile colloidal building blocks whose stability and aggregation behavior are highly sensitive to surface chemistry. Their localized surface plasmon resonance, arising from the collective oscillation of free electrons, is strongly affected by both interfacial chemistry and interparticle coupling, providing a direct all-optical readout of colloidal assembly and phase behavior at the nanoscale. For this reason, in the last decades silver and gold NPs have been widely exploited as high-performance colorimetric [1] and spectroscopic [2] optical sensors.

Here, we explore chirality-driven interactions in suspensions of spherical citrate-capped gold NPs by combining UV-visible spectroscopy and surface-enhanced Raman scattering (SERS). We investigate the colloidal behavior of a single gold NP batch in the presence of different chiral organic analytes and observe a pronounced enantioselective response. This is evidenced by selective NP aggregation, detectable through changes in the optical response of the colloidal dispersion. Despite the nominally achiral geometry of the NPs, these results indicate the emergence of enantioselective interparticle interactions. While previous studies attributed this effect to structural asymmetries within the NP core [3], we instead identify the molecular stabilizing layer as the dominant source of chirality. SERS measurements reveal that citrate molecules bind asymmetrically to the gold surface, effectively generating a chiral interfacial environment.

To test this hypothesis, we systematically tailor the nanoparticle interface by replacing the citrate layer with achiral and chiral ligands and by varying NP size. We find that achiral interfaces suppress enantioselectivity, while chiral ligands enable a programmable and tunable enantioselective response.

These results demonstrate that chirality in plasmonic colloids is not an intrinsic nanoparticle property, but rather an emergent feature arising from interfacial molecular organization.

Keywords:

plasmonics, colloids, chirality, interparticle interactions.

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Acknowledgements:

This project has received funding from the European Research Council (ERC) under the European Union's Horizon 2020 research and innovation programme (CHIROLE, Grant agreement No. 101163391).

Water Models Matter: From Bulk Solvent Properties to Casein Macropeptide Association and Lipid Vesicle Stability

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Water is usually treated as the background medium in biomolecular simulations, but its molecular representation can determine the reliability of the predicted structure, dynamics, and thermodynamics. Here we connect three simulation studies in which water is not a passive solvent, but the common physical variable linking model validation, protein association, and lipid-vesicle stability.

We first evaluated widely used explicit water models by comparing the temperature dependence of density, heat capacity, self-diffusion, shear viscosity, dielectric response, and radial distribution functions. In the biologically relevant range of 280-350 K, four-point models such as TIP4P/2005 and TIP4P-D reproduced experimental trends substantially better than the commonly used TIP3P model. This benchmark provides a reference for choosing solvent models in simulations where temperature, electrostatics, hydration, and molecular mobility are central to the observed behavior.

We then applied this perspective to the casein macropeptide (CMP), an intrinsically disordered peptide obtained from kappa-casein hydrolysis and relevant for whey valorization. Coarse-grained and all-atom simulations, combined with titration models, were used to investigate how pH, salt concentration, glycosylation, and peptide concentration affect CMP charge regulation, conformational properties, self-association, and adsorption on charged surfaces. Because CMP lacks a stable folded structure, its size, compactness, and association pathways are expected to be especially sensitive to the balance between peptide-peptide and peptide-water interactions. Extending these simulations to compare water models is therefore a direct route to assess the robustness of predicted CMP aggregation and purification mechanisms.

Finally, we studied water confined in lipid vesicles composed of ceramides, cholesterol, and fatty acids, motivated by stratum-corneum transport. All-atom molecular dynamics simulations using TIP3P, TIP4P, TIP4P/2005, and TIP4P-D showed that the water model affects vesicle compactness, correlation times, interfacial hydration, internal water layering, interfacial tension, and internal-external pressure differences. In particular, the organization of confined water and its interaction with polar lipid headgroups depended on the chosen model, highlighting the need to validate solvent descriptions before interpreting mechanical stabilization or transport properties.

Together, these results show that water-model selection is a methodological decision with direct biological consequences. A consistent strategy that begins with bulk-water validation and continues through protein and membrane applications can improve the predictive power of molecular simulations of soft and biological matter.

Keywords:

Water models, Computational biophysics, Confined water, Biomolecular hydration

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From Molecular Nano-Aggregates to Microemulsions: A Comprehensive Description of the Ternary Phase Diagram of Water and Mono-Alcohols mixtures

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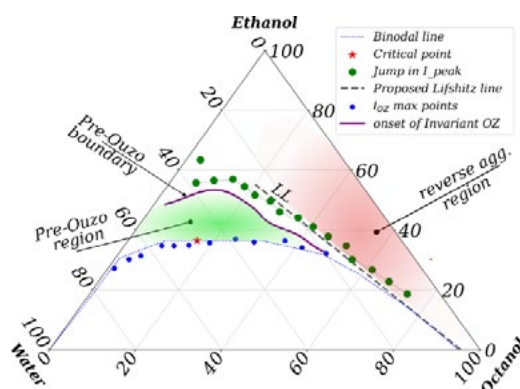
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The aim of our work is to understand how supra-molecular structuration drives nano-to-meso-to-macroscopic organization, phase transitions and affects the dynamics in ternary systems. To achieve this, we examined the ternary mixture of 1-octanol, ethanol, and water, in which several organized phases were identified, among which an Ouzo and pre-Ouzo region [1,2]. Using Small Angle X-rays Scattering, we mapped the entire composition range through successive auto-dilution lines (figure 1, left). By analyzing key structural parameters across the phase diagram, we provided a detailed description of organization at different scales. Beyond the transition from monophasic to biphasic states, we determine the full extension of distinct domains within the monophasic area. These range from hydrogen-bonded molecular clusters to mesoscopic structures characteristic of the pre-Ouzo domain, separated by a so-called Lifshitz line.

Next, using a combination of Neutron Scattering, NMR, rheology, and classical molecular simulations, we present a detailed description of molecular dynamics across the different structural domains. A subtle shift in individual dynamics appears upon crossing the Lifshitz line. Neutron Spin-Echo experiments reveal the collective nature of molecular dynamics, with a de Gennes narrowing effect slowing diffusion in the nano-structured octanol-rich region and a dramatic slowdown in droplet diffusion in the pre-Ouzo zone. We eventually discuss a method for the estimation of the droplets lifetime in such transient organisation, here close to 20 nanoseconds.

Keywords:

Ternary phase diagram, Microemulsions, Ouzo effect, SAXS, Neutron and X-ray scattering



Phase diagram of the 1-octanol, ethanol water ternary system. The blue points align on the binodal, the red and green aligns on the different estimations of the Lifshitz line. IN background, the autodilution lines followed by SAXS are drawn.

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Confining Geometry Drives Dynamics in Lipidic Mesophases

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In biological and advanced nanomaterial environments, water and other non-aqueous solvents often exist in confined settings, where dynamics are strongly coupled to surrounding interfaces [1]. While the size of confinement plays a major role, the effect of confining geometry on solvent dynamics remains an open question [2,3]. Lipidic mesophases (LMPs) serve as a versatile platform to study soft confinement effects by offering a range of self-assembled phase structures with nanometer-sized solvent-domains [4]. By tuning composition and temperature, LMPs transition from structures with planar interfaces to curved interfaces with interconnected solvent channels, and further to highly curved, isotropic phases, such as the lamellar (L_α), cubic $Ia3d$, and reverse micellar (L_2) phases, respectively. Combined X-Ray Scattering and Calorimetry reveal that transitions between these phases occur with modest enthalpic input but trigger discontinuous shifts in lipid- and solvent-dynamics, as probed by complementary spectroscopic techniques: In both water- and glycerol-based LMPs, conductivity increases when systems transition into more fluid phases and solvent-connectivity is increased. H-bonding strength increases as interfaces curve towards planar membranes, revealing dynamically different interfacial and core water populations, while lipid tail packing tightens. Together, these findings establish a clear geometric principle: interfacial curvature and solvent connectivity jointly control the packing of lipids, hydrogen-bonding, solvent dynamics, and charge transport in lipidic mesophase, providing a conceptual framework for the rational design of lipid-based systems.

Keywords:

lipidic mesophase, phase structure, dynamics, spectroscopy

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Kinetic Monte Carlo Simulations for Twinned Nanoparticles Growth

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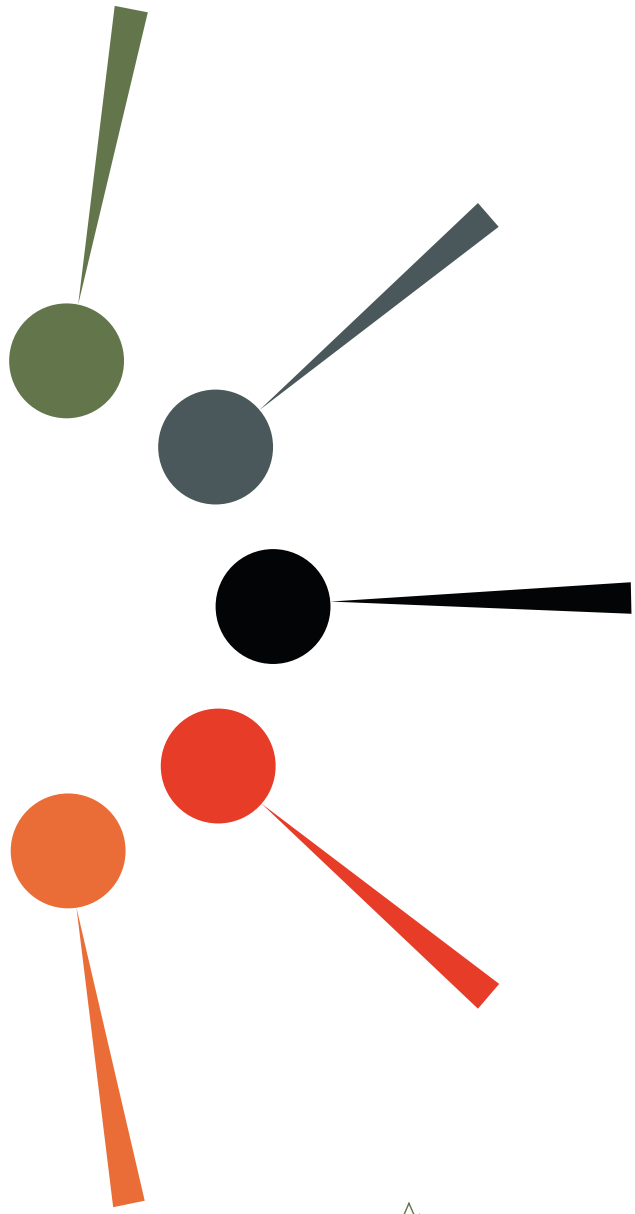
The growth of face-centered cubic (fcc) metal nanoparticles in solution is often governed by kinetic effects rather than equilibrium thermodynamics, giving rise to stacking faults and twin boundaries. Owing to their low formation barriers, these defects promote the emergence of multiply-twinned particles (MTPs), including decahedral and icosahedral morphologies. Such structures are distinguished by nonuniform strain fields and defect-rich interiors, which are widely associated with enhanced catalytic and functional properties. Although successive twinning has been proposed as a dominant mechanism for their growth, the atomic-scale pathways remain unresolved. Here, we employ kinetic Monte Carlo simulations to explore the defect-mediated growth of twinned metal nanoparticles and to resolve the kinetic origins of morphological diversity. By modeling their formation, we reveal how subtle variations in kinetic barriers redirect growth trajectories, producing distinct nanoparticle shapes under otherwise identical conditions.

Keywords:

Nanocrystal growth, Multiply Twinned Particles(MTPs), Stacking Faults, Twin Boundaries, Anti-Mackey Cluster, pent-twinned nanorods

References:

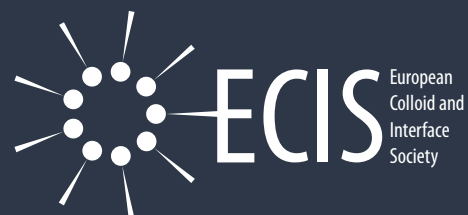
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Topic 9

Individual and Collective Behaviors
of Colloids under External Fields

! KEYNOTE



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Shear-direction-sensitive mechanoelectric transduction in a soft ionic paste under anisotropic interfacial boundary conditions

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Soft ionic materials can generate electrical signals under mechanical deformation, but the origin of these responses is often difficult to assign because bulk piezoelectricity, interfacial polarization, leakage, and electrochemical effects may all contribute. Here, we report a water-rich arginine–dodecanoic acid (ARG–DA) soft ionic paste that exhibits reproducible, shear-direction-dependent mechanoelectric transients when confined between grooved aluminum electrodes. The system was designed as a simple two-electrode sandwich cell in which unidirectional surface texturing imposes anisotropic interfacial boundary conditions.

Open-circuit potential and chronoamperometry measurements show that, when shear is applied parallel to the electrode grooves, opposite stroke directions generate opposite-signed electrical transients. In contrast, when shear is applied orthogonal to the grooves, the response remains detectable but loses its direction-resolved character. This collapse of directionality under misaligned boundary conditions indicates that the observed behavior is governed by anisotropic interfacial coupling rather than by an orientation-independent bulk response of the paste. A polarity-swap control, performed by reversing the electrode assignment, inverts the sign convention while preserving the association between stroke direction and response sequence, confirming that the effect is device-intrinsic.

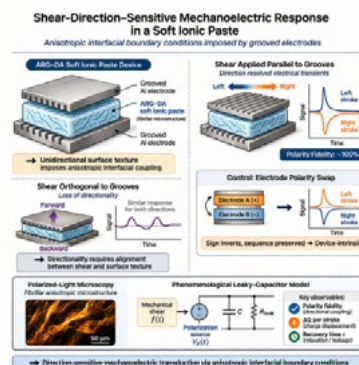
Cyclic voltammetry within a narrow operating window shows smooth, largely featureless loops whose magnitude increases with scan rate and stabilizes after conditioning. This behavior is consistent with a predominantly polarizable interface with finite leakage, rather than with a dominant Faradaic process in the measurement range. Polarized-light microscopy further reveals a fibrillar mesoscale microstructure, suggesting a plausible structural basis for anisotropic engagement between the paste and the textured electrode surface.

To interpret the data conservatively, we use a minimal phenomenological framework in which the device is treated as a mechanically driven polarization source in parallel with capacitive and leakage pathways. Within this picture, three experimentally accessible observables are especially useful: polarity fidelity, stroke-integrated charge, and recovery time. These metrics capture, respectively, the extent of directional coupling, mechanically induced charge displacement, and electrical relaxation after deformation.

The results show that direction-sensitive mechanoelectric transduction can be achieved in a simple hydrated soft ionic paste without invoking a specific microscopic bonding mechanism. More broadly, they highlight how electrode texture and interfacial boundary conditions can be used to encode directional mechanical information in soft matter systems, which is relevant to tactile sensing, low-frequency motion detection, and interface-enabled mechanoionic devices.

Keywords:

mechanoelectric transduction, soft ionic paste, interfacial polarization, anisotropic boundary conditions, shear direction sensing



Shear-direction-sensitive mechanoelectric response of an arginine-dodecanoic acid soft ionic paste between grooved aluminum electrodes. Parallel shear resolves stroke direction, whereas orthogonal shear loses directionality, consistent with anisotropic interfacial polarization.

Surface-selective hybridization of magnetic nanoplatelets for the manipulation of ferrofluids with magnetic and electric fields

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We demonstrate a proof-of-concept for coupling electric and magnetic dipoles within a nanoparticle using a surface-selective hybridization technology [1]. The magnetic and electric dipoles, which are aligned orthogonally to the basal plane of barium hexaferrite nanoplatelets, ensure the magnetic and electrical sensitivity of these nanohybrids and their dispersions. While the origin and alignment of the magnetic dipole are intrinsic to the core barium hexaferrite nanoplatelets, the electric dipole is induced by a monolayer assembly of polar ligands on a single basal plane of the nanoplatelets (Figure 1). The specific ligand structure, containing a push-pull segment, a strong phosphonic anchor, and a solvent-adjustable backbone, aligns the electric dipole orthogonally to the nanoplatelet basal plane.

The surface-selective hybridization is achieved by hybridizing the exposed basal plane of the nanoplatelets assembled on a substrate under an applied magnetic field, followed by harvesting of the magneto-electric nanohybrids and their dispersion in nonconductive solvents. The coupled dipolar response was confirmed by our custom-made technique, a multidipole electrophoresis in a magnetic field (Figure 1), and by the external-field-induced optical birefringence.

Keywords:

magneto-electric, nanoplatelet, hybridization, ferrofluid, external field, electrophoresis

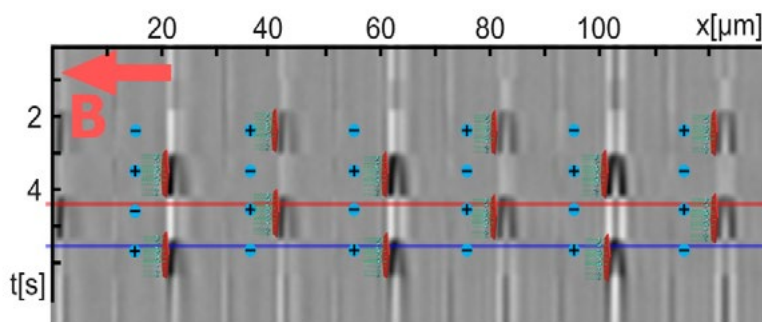


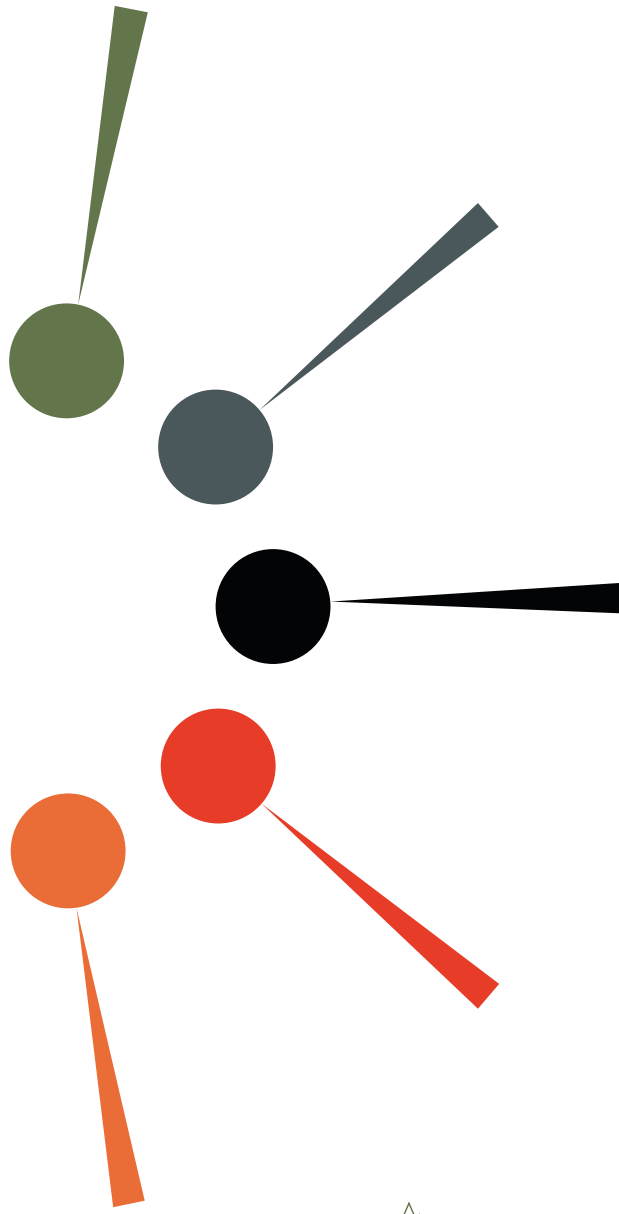
Figure 1. Multidipolar electrophoresis: the presentation of a magneto-electric dipolar response of dispersed Janus nanohybrids. The magnetic field (B) direction is denoted by a red arrow, while the electric charge of the electrodes is denoted by plus and minus.

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Topic 9

Individual and Collective Behaviors of Colloids under External Fields

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Directed Transport and Current Reversal of Active Colloids under Traveling Wave Illumination

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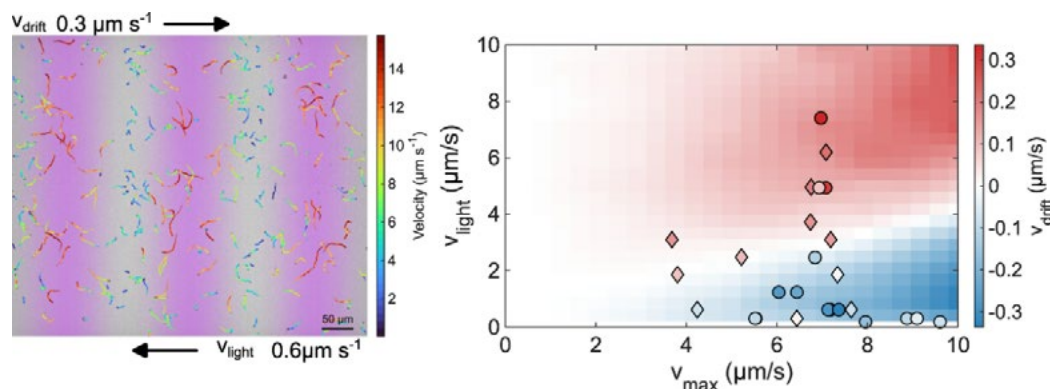
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Synthetic active colloids offer a versatile platform to engineer directed transport through spatiotemporal control of motility. In recent work, we demonstrated that silica–titania Janus microswimmers driven by Induced-Charge Electrophoresis (ICEP) can autonomously adapt their propulsion speed through material-encoded sensory delays, whereby photoconductive titania caps couple particle velocity to local UV illumination intensity with a finite response time [1]. These sensory delays were shown to reshape steady-state density distributions and enhance localization under patterned illumination.

Here, we extend this framework to traveling wave activity modulation, where a periodic illumination pattern is translated at a controlled phase velocity across the sample. This dynamical protocol induces net particle transport whose direction and magnitude depend on the interplay between wave velocity, particle swim speed, and sensory delay. When wave and particle velocities are well-matched, particles tend to drift co-propagating with the wave; at mismatched velocities, transport can reverse. Sensory delays introduce a phase lag between illumination and velocity adaptation that further modulates the transport direction. These findings suggest that traveling wave illumination provides a non-contact route to directed transport and velocity-based sorting in active colloidal systems, and highlight sensory delay as a key parameter linking particle-level temporal response to emergent transport behavior.

Keywords:

photoresponsive microswimmers, motility control, colloidal transport



Directed transport of active colloids. (Left) Photoresponsive Janus microswimmers under moving sinusoidal UV illumination, trajectories color-coded by velocity. (Right) Net drift velocity vs. active and pattern speed, experiments (symbols) and simulations.

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Photoconductive nonpolar liquids based on azobenzene

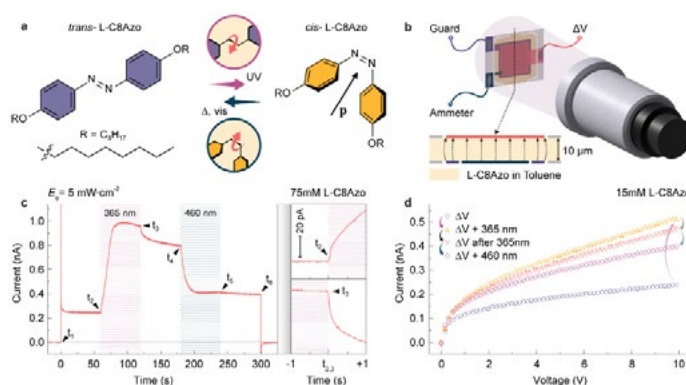
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The weakly conductive properties of mixtures of organic surfactants in nonpolar liquids are fundamental in many electrohydrodynamic phenomena and central for several cutting-edge applications, in particular in the field of the nowadays ubiquitous electrophoretic displays. As of now, the way to tune the electrical properties of these systems is to regulate their composition: surfactant concentration, water content, and the choice of carrier liquid set the properties from the outset. Here, we use of photoresponsive molecules to tune electric phenomena in nonpolar liquids externally by light irradiation, thereby making them photoconductive. In particular, we focus on the properties of dispersions of azobenzenes in toluene as their conductivity can be regulated using two different wavelengths with opposing effects: shining UV light induces *trans*→*cis* isomerization leading to an increase in conductivity while irradiating with blue light stimulates the back-isomerization, causing a decrease in conductivity. The findings of this research offer a path to expand the applications of weakly conductive organic fluids, for example, towards self-regulating devices exposed to sunlight or externally programmable displays.



a. Scheme of the transition between *trans* and *cis* L-C8Azo. b. Schematic of the experimental set-up. c. Example of current measurement performed to evaluate the photoresponsivity of the mixture. d. Current-voltage profiles of the dispersion under different irradiation states.

Lyotropic Liquid Crystals Alignment using Magnetite NPs for Production of Anisotropic Mesoporous Materials

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Lyotropic liquid crystals (LLCs) are mesophases, a state of matter with a behaviour between liquids and solids, which are formed when amphiphiles such as surfactants are dissolved in water at specific concentrations and temperatures. Depending on the latter, LLCs can manifest into different phases, including bicontinuous cubic, hexagonal and lamellar.

In recent years, LLCs have been widely exploited as templating agents to fabricate mesoporous inorganic materials that retain the original structure of the templating system ¹, for catalysis, drug delivery, pollutant adsorption and chromatography. In particular, the hexagonal LLCs are extensively used, consisting of cylindrical micelles packed into randomly oriented domains of hexagonal arrays, ² therefore lacking a long-range anisotropic order.

Imposing a preferred overall orientation remains a major challenge; however, the resulting templated porous materials could benefit from enhanced mass transport and reduced pressure drop. Although several strategies have been explored to orient such domains, ² these attempts have not yet been translated into the preparation of monoliths with anisotropic porosity.

Here, we propose a strategy to fill this gap using LLCs containing oils ³, which can swell the lipophilic domains of both the direct (H_1) and reverse (H_2) hexagonal phases. Remarkably, these “swollen” LLCs can host hydrophobic magnetite nanoparticles (MNPs). ⁴ In a static magnetic field, such MNPs-doped LLCs are expected to align parallel to the field, thereby providing anisotropic templates. To prove the versatility of this approach, we propose two strategies. First, we explore a sol-gel process templated by MNPs-doped H_1 , using a common silica precursor (i.e., tetramethoxysilane). Second, we investigate an H_2 phase containing MNPs dispersed in a polymerisable oil (i.e., methyl methacrylate), which is then photopolymerised. Upon condensation or polymerisation in a magnetic field, and after surfactant removal, porous, anisotropic monoliths can be obtained.

Preliminary results demonstrated the production of MNPs-doped H_1 and H_2 , and that MMA-based systems can retain their structure after polymerisation in the absence of MNPs. As next steps, optimisation of the composition will be considered for both inorganic and organic systems, and tests will be carried out in mild magnetic fields to produce anisotropic materials. Once obtained, the resulting monoliths can be tested to assess the effect of anisotropy on mass transfer compared with analogous isotropic samples.

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Clustering of Active Colloids in Crowded Environments

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Active colloids are microscopic particles that propel through aqueous media by converting the externally available energy into directed motion. Understanding interactions of active colloids with crowded systems, and emergent phenomena of ensembles of active particles, remain an important and open question in non-equilibrium physics.

Active colloids are known to form clusters spontaneously due to motility induced interactions^{1,2}. But what happens when these particles move through crowded environments? Here we investigate the dynamics of AC-field activated Janus particles (gold coated silica microspheres) in a passive crowd of uniform silica microspheres. The alternating electric field is used to control: i) the velocity of active particles and ii) the inter-particle interaction between passive colloids. We show experimentally that a passive crowd has a non-monotonic effect on the clustering of active particles: intermediate crowd densities accelerate the cluster growth dynamics compared to the free case, while higher crowd densities suppress it. This counterintuitive behaviour arises from a competition between the reduced motility of active particles in crowded environments and the increased stability of formed clusters in a crowded environment.

Our findings demonstrate that passive crowding can act as a tunable parameter for controlling self-organisation in active matter systems, with broader implications for understanding clustering in biological environments.

Keywords:

Active Matter, Active-Passive Interactions, MIPS, Induced Charge Electrophoresis (ICEP)

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From Light to Motion: IR-Driven Actuation in Adaptive Lanthanide MOF Crystals

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Dynamic crystalline materials represent a class of out-of-equilibrium systems capable of converting external stimuli into mechanical motion at the microscale. Such systems are of growing interest within active matter and soft materials communities due to their ability to couple energy dissipation with structural transformations and mechanical responses. [1,2]

Metal-Organic Frameworks (MOFs) are porous crystalline materials that have demonstrated structural and morphological flexibility. [3-7]

Here, we report light-driven actuation in a class of flexible metal–organic frameworks (MOFs) acting as stimuli-responsive crystalline micro-actuators. Upon irradiation with low-power infrared light (~ 100 mW) (Figure), these materials undergo reversible structural transformations that result in mechanical responses at the micrometer scale, including crystal contraction, morphology changes, and rotational or jumping motions.

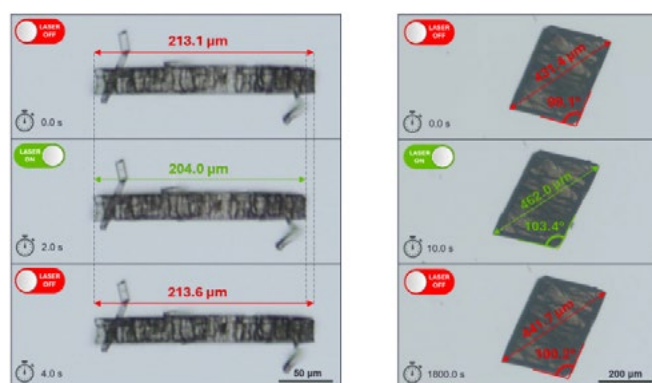
The actuation is enabled by efficient photothermal conversion within the framework, arising from IR absorption at lanthanide-based coordination nodes. The resulting localized heating triggers a phase transition responsible for the observed mechanical motion. Importantly, incorporation of additional lanthanide dopants introduces upconversion-mediated energy transfer pathways, enhancing non-radiative relaxation processes and enabling actuation at reduced IR power densities.

These light-induced transformations are spatially addressable, reversible over multiple cycles, and stable over extended time scales. The coupling between optical excitation, local thermal gradients, and mechanical response is supported by in situ structural characterization under irradiation.

Overall, this work establishes MOF-based crystalline materials as a versatile platform for light-driven adaptive matter systems, bridging photothermal effects, phase transitions, and microscale mechanical actuation, with potential applications in soft microrobotics and remotely controlled adaptive materials.

Keywords:

Stimuli-responsive materials, Active matter, Light-driven actuation, Adaptive materials



Optical microscopy images of lanthanide-based Metal-Organic Frameworks with and without IR laser irradiation.

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Electric and Magnetic Field-Driven Assembly of Patchy and DNA-Linked Anisotropic Colloids

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Anisotropy in particle shape and surface properties provides a powerful tool for directing the assembly of colloidal systems into complex structures. When combined with external fields and selective interactions, it enables programmable and reconfigurable organisation. In this work, we study programmable assembly of anisotropic colloids using two complementary systems.

In the first system, TPM-encapsulated magnetic hematite cubes behave as patchy particles with an off-centred magnetic patch. By varying electric field parameters, we obtain tunable open lattices, stacked structures, and clusters. The displaced magnetic patch further enables the formation of chains, flocks, and reversible oligomers under combined electric and magnetic fields. These assemblies arise from the interplay between electric dipolar repulsion and magnetic dipolar attraction, allowing controlled transitions between configurations. In the second approach, DNA linkers are used to assemble size-asymmetric magnetic particles into dimers and short chains, which can then be reconfigured under external fields.

Overall, this work highlights how coupling particle anisotropy, selective binding, and external fields enables access to a wide range of adaptive and reconfigurable colloidal architectures, relevant for smart materials and microscale devices.

Keywords:

Programmable self-assembly, DNA colloids, Field-induced assembly

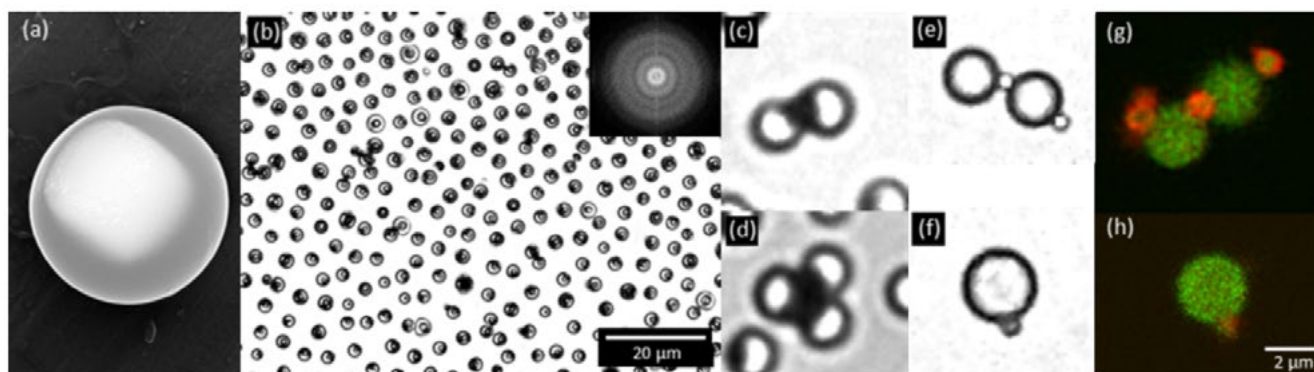


Figure 1: (a) SEM image of cube-TPM conjugate. (b-d) Structures formed by these conjugates in electric and magnetic fields. (e-h) Alternating chains and dimers formed by DNA mediated assembly (bright field and confocal microscopy images)

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Bubble dynamics-driven control of local microstructure in colloidal gels using ultrasound

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The microstructure of colloidal gels determines their rheological response and is therefore critical in applications such as battery electrode slurries, personal care and food products. We demonstrated [1] that ultrasound-driven, confined microbubbles induce particle bond alignment along specific orientations ($\pm\pi/4$), similar to those observed under oscillatory shear at 70 Hz [2]. The mechanism causing this orientational order is not fully understood, but structures appear normal to the velocity plane. To elucidate the origin of $\pm\pi/4$ orientational order, we complement particle-resolved confocal microscopy with flow visualisation. The model colloidal gel used in confocal microscopy experiments consists of fluorescent PMMA dispersed in squalene with linear polybutadiene as polymer depletant. Microbubbles are embedded in the gel in a confined, quasi-2D geometry. We drive the bubbles into volumetric oscillations with ultrasound at 10-100 kHz. The locally ordered microstructure (Figure 1, left) is characterised using a previously introduced order parameter that captures the local bond orientation around the bubble [1]. Using a dilute suspension of charge-stabilised latex particles, flow visualisation with brightfield microscopy reveals the secondary flow caused by the confined bubble oscillations (Figure 1, right), which is found to vary with bubble confinement. The combination of microstructure characterisation and flow visualisation supports the hypothesis that the distinctive $\pm\pi/4$ orientational order is caused by the flow component normal to the observation plane. This finding opens a new avenue for the use of ultrasound as a tool to control the microstructure of colloidal gels in industrial processes.

Keywords:

colloidal gels, flow-induced structuring, orientational order, ultrasound, oscillating microbubbles

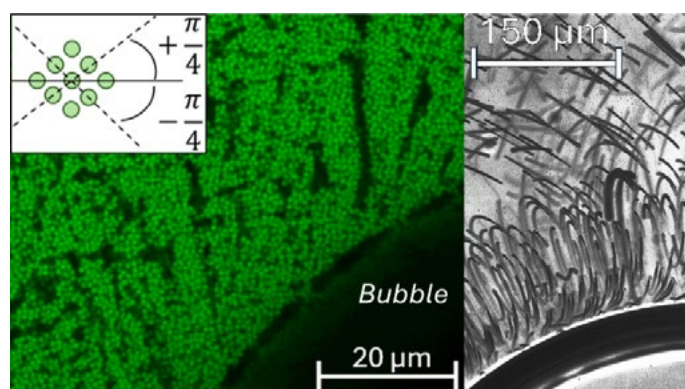


Figure 1. Left: Confocal microscopy image of the colloidal gel after ultrasound exposure showing square-like structural order (inset). Right: Brightfield flow visualisation revealing toroidal vortices near the bubble.

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Acknowledgements:

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Interaction of protein-functionalized silica with f-block elements

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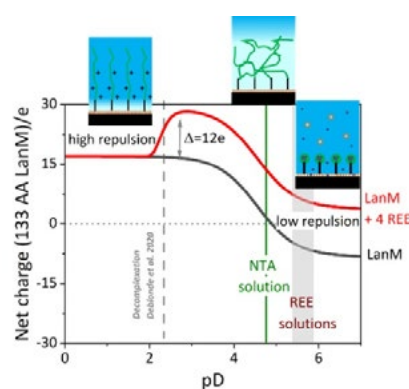
The f-block elements are essential across a wide range of industrial sectors, from advanced high-tech products, batteries, light-emitting diodes, liquid crystals displays, magnets, auto industry, solar panels, wind turbines, electric vehicles, nuclear industry and emerging innovations. As global demand continues to rise and geopolitical tensions intensify, securing self-sufficiency in the supply of these elements has become a critical challenge for the European Union. There is now an urgent need to reduce waste and develop low-energy, cost-effective extraction methods—particularly from industrial by-products.

Recently bioinspired materials have emerged as a promising alternative to conventional extraction methods [1]. Especially, the use of proteins such as the lanmoduline (LanM), a small protein with a mass of 12 kDa and a size of 5 nm (133 amino acids) having a stable disordered structure in complex environments, has shown very interesting extraction properties. In the presence of f-block elements, the protein folds to fit the high-affinity complexation sites required for their retention. This peptide chain folding during complexation drives selectivity: only f-block elements can provide the activation energy required for this folding. In aqueous solution, LanM has picomolar affinities on three complexation sites (from 5 to 35 pM), and a selectivity 5-6 orders of magnitude higher for lanthanides than for classical competing cations such as Ca^{2+} , Cu^{2+} or Zn^{2+} . In addition, this protein releases f-block elements at pH 2 [2].

To prepare functionalized materials for f-block element extraction, we have studied the functionalization of silica surface with this protein and if its functionality was maintained when the protein is grafted, *i.e* if LanM is able to fold and unfold when it complexes and releases f-block elements. To reach this goal, X-ray reflectivity was used to ensure that protein was properly grafted onto the surface of solid quartz substrates. Combined with atomic force microscopy, we were able to determine the arrangement of the immobilized LanM and highlight a surface density around 1 LanM per 5 to 8 nm². To go deeper in the behavior of grafted LanM during complexation and release of f-block elements, *in situ* neutron reflectivity analyses were performed on D17 beamline at ILL (Grenoble, France). Several cycles of complexation/ release have been performed with XCl_3 at 10⁻³ M deuterated solutions (X = Nd and Dy). **The results highlighted that grafted LanM keeps its functionality to complex and release f-block element. In addition, we found that the protein's structure varies with pH and that this structure depends on its effective charge.**

Keywords:

bioinspired materials, surface functionalization, f-block elements, AFM, X-ray and neutron reflectometry



Grafted LanM behavior as a function of pD and of the net charge of the amino-acids present in the LanM filaments (AA).

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Acousto-responsive microgels: A non-invasive approach for microgel dehydration

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Poly(N-isopropylacrylamide) (PNIPAM) microgels are archetypal stimuli-responsive soft materials that undergo a reversible volume phase transition (VPT) upon heating. Below the VPTT (~ 32 °C), the polymer network remains highly hydrated through hydrogen bonding with water; heating disrupts these interactions, triggering cooperative dehydration and network collapse. This thermo-responsive behavior underpins a broad range of applications, from smart coatings to biosensing platforms. Here, we introduce **high-frequency**, **low-amplitude** ultrasound as a **non-invasive** and fully reversible stimulus capable of inducing PNIPAM microgel dehydration without bulk heating. **MHz-frequency** ultrasound was applied at low amplitudes such that the macroscopic temperature remained well below the VPT threshold. We attribute the observed dehydration to localized viscous dissipation: acoustic energy absorbed by the surrounding liquid disrupts PNIPAM–water hydrogen bonds locally, driving network collapse while leaving the bulk temperature unaffected.

To probe this effect, we developed an innovative integration of ultrasound into a conventional dynamic light scattering (DLS) setup. DLS measurements reveal a pronounced and fully reversible reduction in microgel size upon ultrasound exposure; microgels reswell to their original dimensions upon cessation of the acoustic field, confirming the **non-destructive** character of the stimulus. Complementary small-angle neutron scattering (SANS) experiments provide direct structural insight into the internal network reorganization induced by ultrasound.

Beyond size changes, DLS autocorrelation functions exhibit well-defined oscillations at microsecond timescales matching the applied acoustic frequency. These ultrasound-induced features represent an additional characterization modality, offering sensitivity to the vibrational response of soft microstructures as a function of network stiffness – varied here through cross-linker density – and opening prospects for microrheological investigations.

Collectively, these findings establish ultrasound as a powerful, contact-free tool for the controllable and reversible modulation of microgel hydration and dynamics, with implications for the design of acoustically addressable soft matter systems.

Keywords:

Poly(N-isopropylacrylamide) (PNIPAM) microgels, Ultrasound, Volume Phase Transition

Mean-field calculation of the electrophoretic mobility of hard colloid and charged liquid droplets

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Electrophoresis of both soft and hard colloids exhibits a range of complex phenomena with important implications for phase separation and transport in biological systems. In this presentation, I will review our recent work on the electrophoretic mobility of charged liquid droplets [1], as well as on charge-regulated hard colloids in saline aqueous solutions [2]. Liquid droplets, in particular, display rich and nontrivial behavior due to ion partitioning, the internal degrees of freedom of dissolved ions, and the non-rigid nature of the fluid–fluid interface. Our investigations are primarily conducted at the mean-field level and are complemented by simulations using a Color-Gradient multicomponent lattice Boltzmann method to study freely suspended liquid droplets under an applied external electric field. For the case of charge-regulating colloids, we further examine the influence of CO₂ on electrophoretic mobility, revealing additional interesting and unexpected effects.

Keywords:

colloidal electrophoresis

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Distribution of molecular solutes in phase-separated systems containing charged macromolecules

Peter Košovan

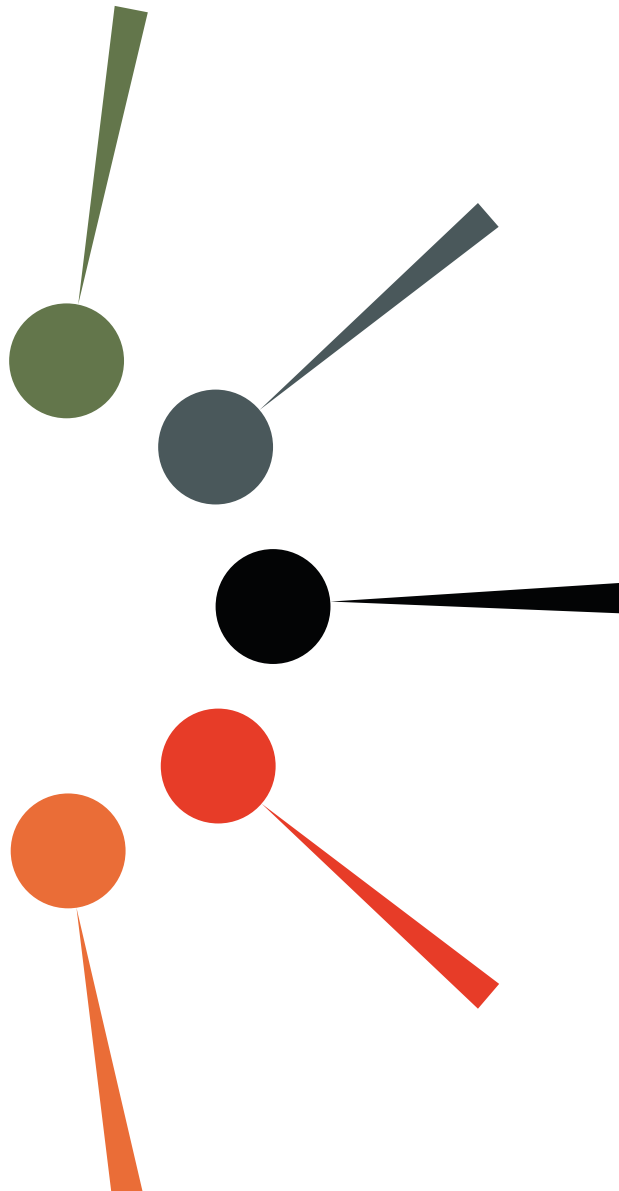
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Phase separation occurs spontaneously in aqueous systems which contain macromolecules with oppositely charged groups. In synthetic polyelectrolytes, this process yields a condensed polymer-rich phase, termed polyelectrolyte complex, and a polymer-poor phase, termed supernatant. In biomolecular systems, the same process yields biomolecular condensates, which often form liquid-like droplets. In this lecture, we discuss how the charge of solutes determines their distribution between the condensed polymer-rich phase and the supernatant. We show that while monovalent ions distribute quite evenly between both phases, the multivalent ones prefer the condensed phase, even if it contains an excess of macromolecules which have the same charge as the solute. The latter observation seemingly contradicts the Donnan theory but can be explained by explicitly considering the effect of electrostatic interactions between the solute and the condensate. Finally, we show that the distribution of oligomeric solutes is determined not only by their net charge but also by how the charges are distributed on the solute.

Keywords:

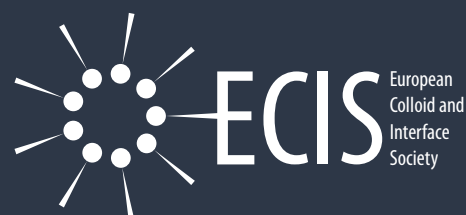
polyelectrolyte, coacervate, condensate, phase-separation



Special Sessions 1

Machine Learning and AI-Based
Methods for Colloids and Interfaces

! KEYNOTE



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Data-driven approaches to investigate intermolecular interactions and self-assembly in complex fluids: from data fusion to 2D correlation analysis

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Understanding intermolecular interactions and self-assembly processes in complex fluids remains a central challenge in colloid science. In systems such as polysaccharides and wormlike micelles the presence of ions, cosolutes or polymers with different charge and nature can induce significant changes in the interfacial structuring, hydration properties and rheological response [1]. However, their interpretation is often hindered by the complexity of the underlying interactions. In this work, we present a novel data-driven framework that combines chemometric tools, machine learning, data fusion strategies, and two-dimensional correlation analysis (2D-COS) to investigate interaction mechanisms in soft matter systems by extracting and integrating relevant information from multiple techniques. First, polysaccharide dispersions are used as model systems to investigate Hofmeister effects on their hydration and thermal behavior. ATR-FTIR and thermogravimetric (TGA/DTG) data are combined through a data fusion approach, enabling sample differentiation according to the kosmotropic/chaotropic nature of the cosolutes (Figure 1a). This combined analysis reveals ion-specific trends not evident from single techniques, providing a comprehensive description of cosolute-dependent structuring. Second, 2D correlation spectroscopy is applied to ATR-FTIR data to elucidate the interaction pathways in polyelectrolyte–wormlike micellar systems. The analysis identifies distinct sequences of molecular rearrangements depending on polymer charge, separating direct electrostatic binding from mechanisms mediated by hydration and hydrogen bonding (Figure 1b). These results establish a direct link between molecular-level interactions and the resulting modifications of the micellar network, which determine the macroscopic rheological properties [2]. Finally, an extension of 2D-COS to non-spectroscopic datasets is proposed, combining rheological and calorimetric (DSC) data to investigate cosolute effects on wormlike micellar systems. The correlation of thermodynamic features with viscoelastic responses provides a comprehensive description of how cosolutes modulate molecular interactions, self-assembly, and bulk dynamics. Overall, this work demonstrates the potential of data fusion and data-driven strategies for the investigation of complex interaction phenomena in soft matter, offering a framework that can be extended to different macromolecular systems, cosolutes, and analytical techniques to advance the understanding of structure–property relationships in colloidal systems.

Keywords:

Machine learning, chemometrics, multiblock analysis, Hofmeister, IR, calorimetry, rheology

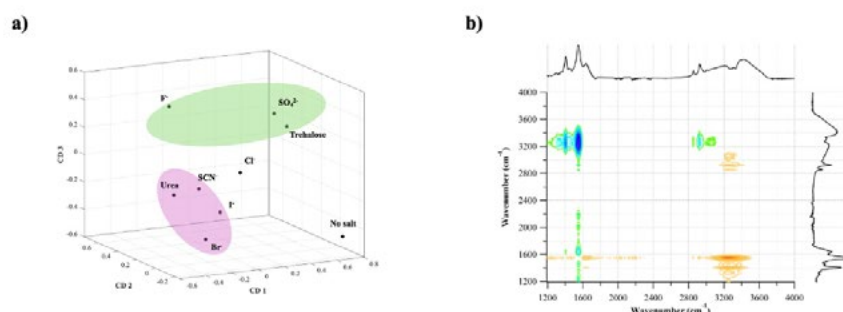


Figure 1. ComDim score plot obtained from the ATR-FTIR and TGA data (a) and asynchronous 2D-COS (b) spectra obtained from the ATR-FTIR data.

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Programming ionic colloidal crystals into nanoelectronic architectures

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While ionic colloidal crystals can adopt a rich variety of lattice structures, controlling which specific symmetry emerges from a given pair of building blocks remains a central challenge in programmable self-assembly. We demonstrate that micromolar concentrations of small molecules, specifically, the charged amphiphiles SDS and CTAB, provide a simple yet robust mechanism for directing this process by continuously tuning the colloidal surface charge. By modulating the charge balance between oppositely charged colloids, we can steer assembly between multiple distinct crystal structures within a single particle combination. This approach reproducibly yields four lattice types: Th₃P₄, CsCl, Cu₃Au, and Ni₃Sn, the latter representing a lattice not previously observed in colloidal systems. Integrated experiments and simulations reveal that this structural selection is driven by a competition between global Coulombic attraction and lattice-specific like-charge repulsion.

Beyond these fundamentals, we explore the relevance of these controlled architectures for nanoelectronics. Specifically, discovering lattice types that map onto 3D geometries useful for memory and computation, where clusters of metallic colloids function as discrete electronic components. Our results establish surface charge as a general control knob for the self-assembly of colloidal ions, paving the way for self-assembled colloidal hardware.

Keywords:

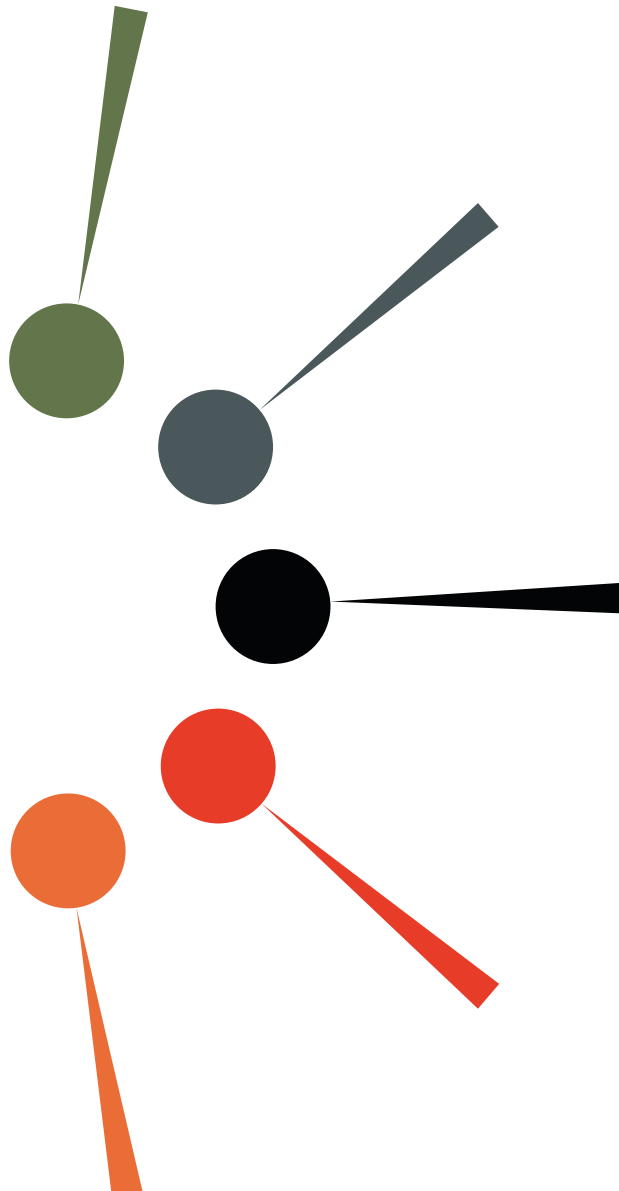
Colloidal crystals, Surfactants, Self-assembly, Nano-electronics, Brain-inspired computing



The ζ -potential of positively charged and negatively charged colloids can be directly tuned by the addition of oppositely charged surfactants, which changes the ratio of attraction and repulsion, leading to different crystals structures

Acknowledgements:

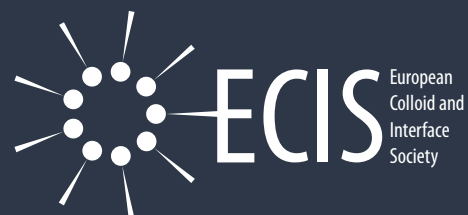
This research was supported by the US Army Research Office under award number W911NF-21-1-0011 to S.S. and G.M.H.. S.v.K was supported by the Swiss National Science Foundation under the Postdoc Mobility Grant number 217966. The authors thank Nicole Smina for initial simulation setups and Philipp Hoellmer for additional PACSim support and development.



Special Sessions 1

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Methods for Colloids and Interfaces

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Modified Poisson-Boltzmann models capturing ion correlations: a machine-learning approach using molecular dynamics data

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The Poisson-Boltzmann (PB) model is classically used to predict the electrostatic potential and ion density fields in colloidal dispersions, a preliminary step for the calculation of effective colloid-colloid interaction potentials. The PB model ignores ion correlations, which precludes it from producing reliable predictions for concentrated or multivalent electrolytes. Several modified Poisson-Boltzmann (mPB) models have been built to try to overcome these limits based on theoretical arguments.

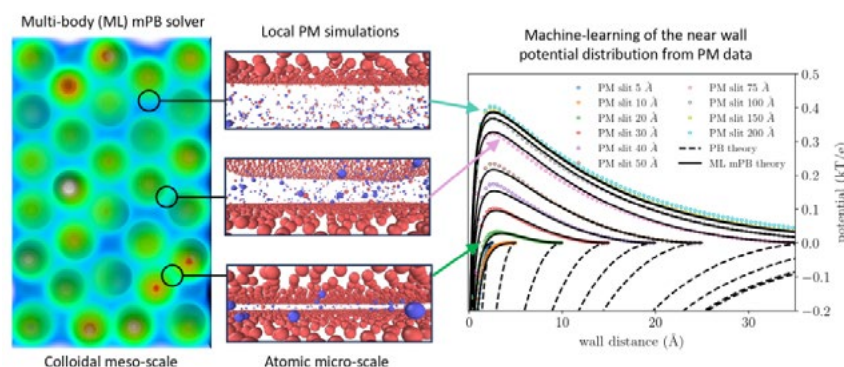
Here we show how it is possible to use ion density fields from near-wall molecular dynamics simulations to build machine-learned mPB models yielding accurate data for multivalent electrolytes.

Two methods will be discussed. In the first method, the classical PB equation is retained and supposed to be valid in the far field, while near-wall ion correlation effects are recast in a machine-learned boundary condition linking an effective surface charge density and an effective surface potential. In the second method, the classical boundary condition is retained but a correction to the chemical potential of ions is introduced in the PB equation, and its parameters are machine-learned to produce a new mPB scheme. In both cases the machine-learned relation is modeled with a GPR. Far-field predictions are correct with both methods, which allows to build colloid-colloid interaction potentials accounting in particular for charge inversion in multivalent electrolytes. Near-wall ion densities are also quite accurate with the second method in the physico-chemical conditions investigated.

We will also discuss how a many-body particle-field (m)PB solver [1] can be coupled to molecular dynamics through active-learning with a GPR building the closure relations on the fly.

Keywords:

ion correlations, electrostatics, machine learning



The electrostatic potential field is computed at meso-scale in a colloidal dispersion (left) using the mPB model built from primitive model simulation data (center) and machine-learning (right).

References:

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Data Fusion and Machine learning for the Particle sizing of Lipid nanoparticles

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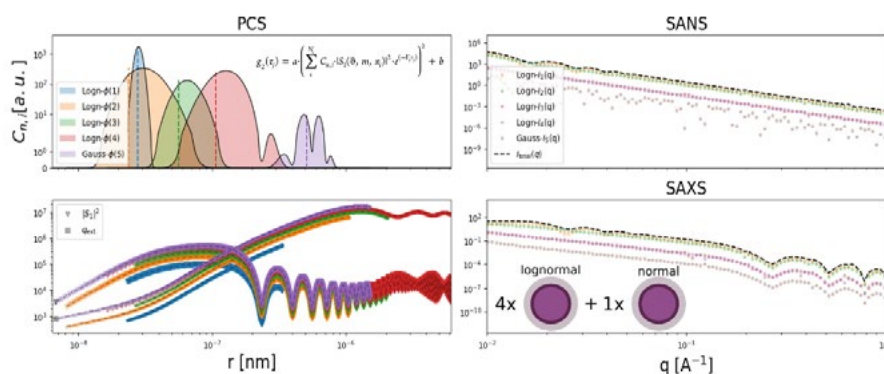
Lipid nanoparticles (LNPs) have established themselves as an essential drug delivery system, with widespread adoption during the SARS-CoV-2 pandemic. LNPs are versatile non-toxic carriers that offer efficient encapsulation of fragile polar cargos and its targeted delivery. LNPs self-assemble into a dispersion of Core multi-shell nanoparticles through liquid-liquid phase separation.[1,2]

Knowledge of the size distribution and the contributions of the individual components in the mesoscopic structure are crucial for a better understanding of environment dependent changes in structure and size. This leads to a better understanding of the release process and how to optimize it. Our group has developed a consistent method to determine the mesoscopic structure of LNPs by combining SAXS/SANS and PCS iteratively.[3] The method involves modeling multiple fractions of core dual shell particles that differ only in core radius, volume-fraction and system-dependent parameters. Small-angle scattering (SAS) data are fitted to derive a theoretical photon correlation spectroscopy (PCS) curve based on Mie theory (see Fig.). The particle fractions are adjusted and the fitting process is repeated until convergence with the experimental data has been reached. The complexity of the model makes it impractical to screen larger sample batches or to analyze environmental responses.

To address these limitations, recent advances in machine learning (ML) have achieved growing success in small-angle scattering (SAS) analysis.[4,5] These approaches provide new strategies to accelerate model convergence, improve parameter estimation, and enable automated interpretation of large and heterogeneous experimental datasets. Building on these developments, we integrate machine learning into our model-refinement workflow, using it both to guide parameter optimization and to reduce the computational burden of these high dimensional fits.

Keywords:

LNP, ML, SAXS, SANS, PCS, Data-Fusion



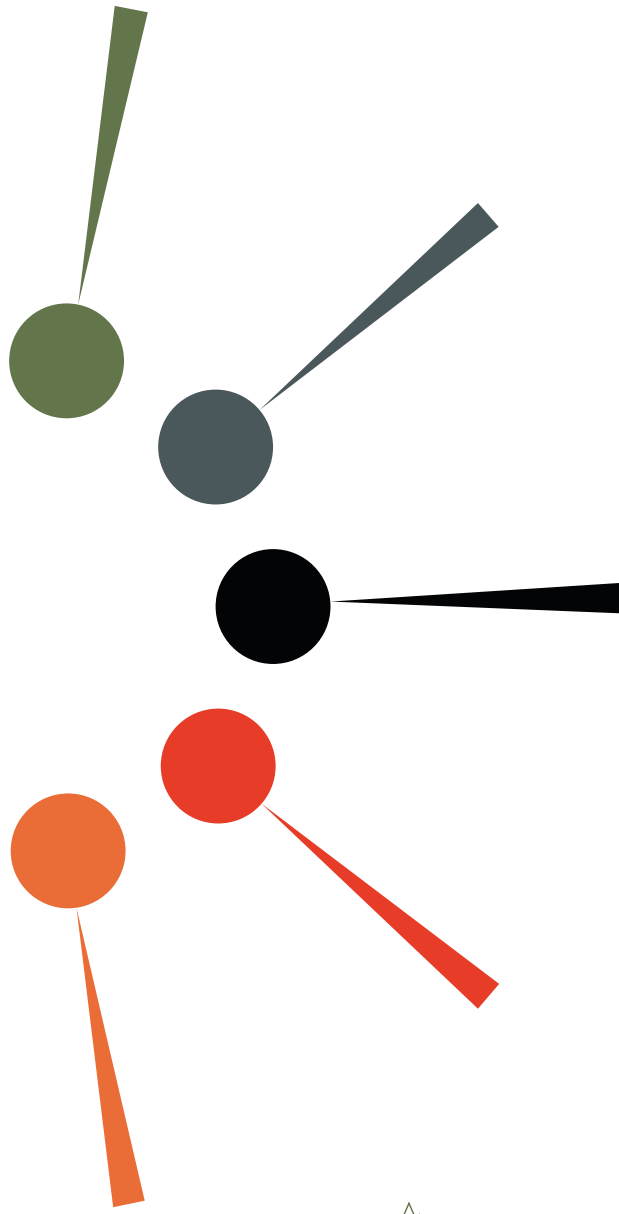
Individual components and sum for SAS (left). Mie theory scattering amplitudes, extinction and PCS coefficients (right).

References:

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Acknowledgements:

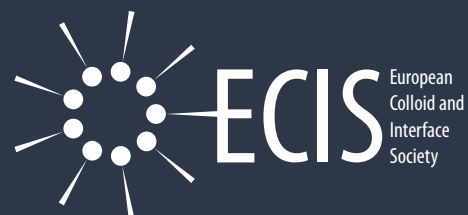
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Unraveling the microfluidic assembly kinetics of lipid nanoparticles under laminar flow conditions: an *in situ* Time-resolved SAXS study

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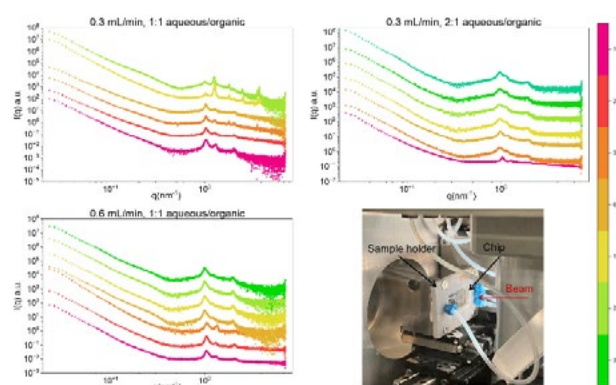
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The development of effective drug delivery systems for therapeutics and diagnostics is a challenging matter at the forefront of nanomedicine. Lipid-based nanocarriers (LNPs) currently represent the emergent technology to achieve functional delivery with controlled and targeted drug release and enhanced intracellular uptake [1]. Advances in the development of precision microfluidic devices allow high-throughput screening and optimization of synthetic parameters (i.e. chip geometry, flow velocity and ratios) and lipid/polymer compositions. Thus, highly reproducible nanovectors with desired structural and surface properties can be obtained. However, a lack remains of systematic investigation of fundamental processes, i.e. mechanism and kinetic of assembly in conditions that closely mimic microfluidic assembly. These latter constitute crucial knowledge to control assembly in laminar flow conditions and aggregate stability, since the transient and metastable states influence the final equilibrium states. Moreover, knowledge of relevant synthetic parameters to obtain specific structural and dynamic properties is fundamental to optimizing nanosystem development. In this work, microfluidic-synthesized LNPs were designed and optimized by employing varied molar fractions of lipid components and polymer coatings, and the structural evolution occurring during microfluidic mixing with a laminar flow was investigated with high spatiotemporal resolution. Static and Time-resolved synchrotron SAXS measurements using an *in situ* microfluidic setup showed that the supramolecular assembly and dynamics depend not only on lipid composition, but on total flow velocity and aqueous/organic flow ratios as well (Figure 1). Supramolecular and kinetic characterization was complemented by Dynamic Light Scattering and Zeta potential measurements. The fundamental understanding of the mechanism and kinetics of assembly of these systems is essential to control aggregation and stability, and correlate structural and dynamic properties to carrier functionality [2].

Keywords:

Lipid nanoparticles, Time-resolved SAXS, microfluidics, *in situ* kinetics



Dependence of assembly kinetics of LNPs according to total flows (mL/min) and flow rate ratios with colour-coded time evolution; (bottom right panel) custom chip setup on P12 beamline of EMBL Hamburg.

References:

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Fractionation-Free Quantification of Nanoparticle-Protein Interactions by Synchrotron SAXS

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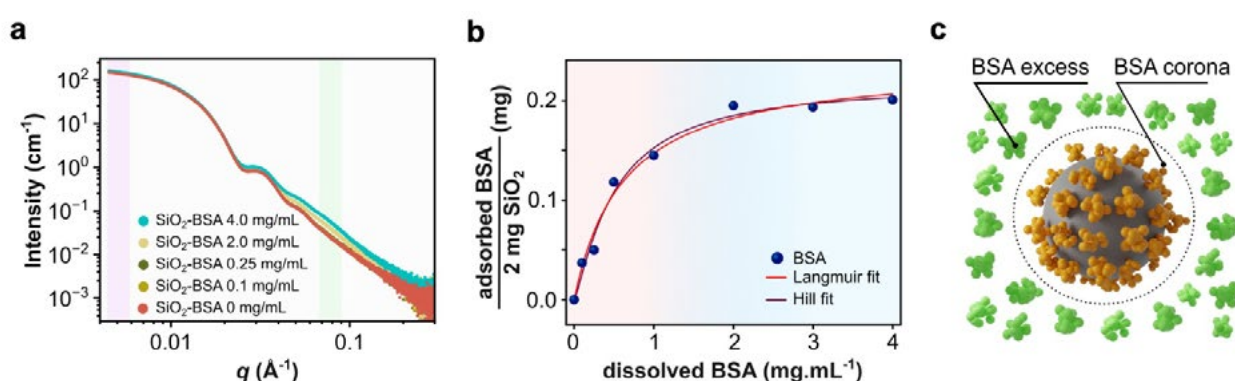
¹ Brazilian Synchrotron Light Laboratory (LNLS), Brazilian Center for Research in Energy and Materials (CNPEM). ² Institute of Chemistry, University of Campinas (UNICAMP). ³ Laboratory for Interface Science and Biology, Institute of High Energy Physics, Chinese Academy of Sciences. ⁴ Diamond Light Source Ltd, Harwell Science and Innovation Campus.

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The protein corona (PC) at the nanoparticle (NP) biointerface governs biological identity and fate, yet its quantitative characterization remains limited by separation steps that perturb equilibrium and introduce artifacts [1,2]. Herein, we present a fractionation-free approach based on synchrotron small-angle X-ray scattering (SAXS) to directly quantify protein adsorption under native, *in situ* conditions. Experiments were performed at a high-throughput synchrotron beamline using an automated setup, ensuring sample integrity and statistical robustness (<0.3% intensity variation). The method exploits the proportionality between scattering intensity ($d\Sigma/d\Omega$) and mass concentration to decouple the contributions of free and adsorbed proteins, directly extracting the adsorbed mass in both single-protein (bovine serum albumin, BSA) and complex proteomic (human serum) systems in 30 nm silica NPs. Distinct SAXS signatures were observed, with corona formation dominating the low- q regime and free protein contributing primarily at high- q , as validated by analytical simulations. For SiO_2 -BSA systems, adsorption isotherms were well described by Langmuir and Hill models, yielding a maximum protein adsorption capacity of ~ 0.20 mg/mL, in agreement with theoretical predictions (0.22 and 0.23 mg/mL). Synchrotron radiation circular dichroism (SRCD) confirmed preservation of protein secondary structure upon adsorption. Zwitterionic-functionalized NPs suppressed low- q intensity changes, validating the sensitivity of the method to PC formation. Extension to human serum revealed markedly different behavior, with higher adsorption (~ 0.96 mg/mL) and isotherms best described by the Hill model, indicating negative cooperativity and competitive, multilayer adsorption. The absence of a clear saturation plateau and increased low- q slopes further support a heterogeneous, multilayer PC [3,4]. Hence, this work establishes synchrotron SAXS as a quantitative, non-invasive tool for probing PC formation without fractionation, preserving the corona's unique fingerprint and true physicochemical nature.

Keywords:

Small-Angle X-ray Scattering, protein corona quantification, fractionation-free, synchrotron SAXS



a) SAXS profiles of SiO_2 and SiO_2 -BSA mixtures. b) BSA adsorption isotherm (Langmuir/Hill). c) Schematic of BSA corona.

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Acknowledgements:

Authors are acknowledged to Fundação de Amparo a Pesquisa do Estado de São Paulo (FAPESP) (grants n° 2021/12071-6, 2023/13208-0, 2023/02144-1, and 2024/00989-7), and Diamond Light Source for access and support at beamline B21 (proposal SM35502).

Not-so-model systems: Quantification of multilamellar sub-populations in phospholipid vesicles with increasing cholesterol

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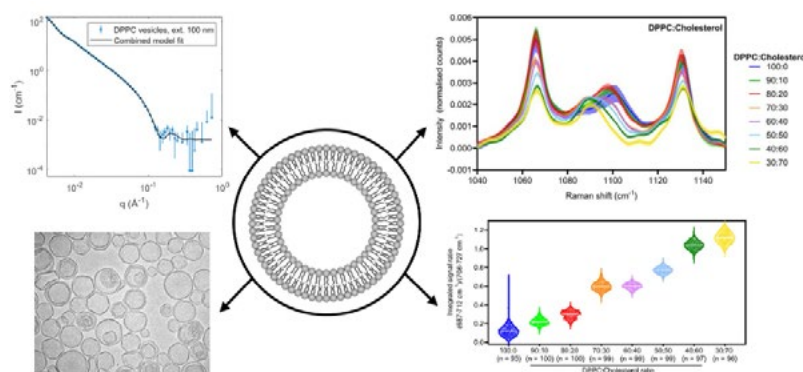
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Vesicles, particles composed of one or more lipid bilayer(s) enclosing an aqueous core, have found applications in a wide variety of research areas. This includes models of biological membranes, as drug delivery vectors, and to reconstitute and study membrane proteins, among many others (Pick, et al., 2018). The vesicle lipid composition can vary from simple one-component systems to complex multi-component biomembranes with leaflet asymmetry, with cholesterol highlighted as a key component (Doktorova, et al., 2025). Vesicles have a simple structure and well-established preparation protocols, therefore formulations are often assumed to contain a monodisperse distribution of uniformly spherical unilamellar particles. It has previously been shown, however, that multilamellarity strongly depends on the lipid composition and preparation method (Nele, et al., 2019). In this project, we have studied the structure of vesicles prepared via extrusion and composed of i) DOPC, ii) POPC, or iii) DPPC with varying amounts of cholesterol on the single particle level. Using single particle Raman trapping analysis (SPARTA), the PC/cholesterol composition variation between individual particles, the saturation limit of cholesterol, and changes in lipid ordering, such as the transition from gel phase to liquid disordered phase for DPPC, were clearly visible. The shape, size, and structure of the vesicles were characterised by small-angle neutron scattering (SANS) and cryogenic transmission electron microscopy (cryoTEM). Comparison of the SANS and cryoTEM data enabled us to develop a combined model containing unilamellar, bilamellar, multilamellar, and elongated particles, which was required to fully describe the data. In this work, we demonstrate the prevalence of multilamellar vesicle sub-populations even in the simplest one- and two-component systems. This can have important consequences for healthcare applications including vesicle-mediated delivery of nucleic acid therapeutics.

Keywords:

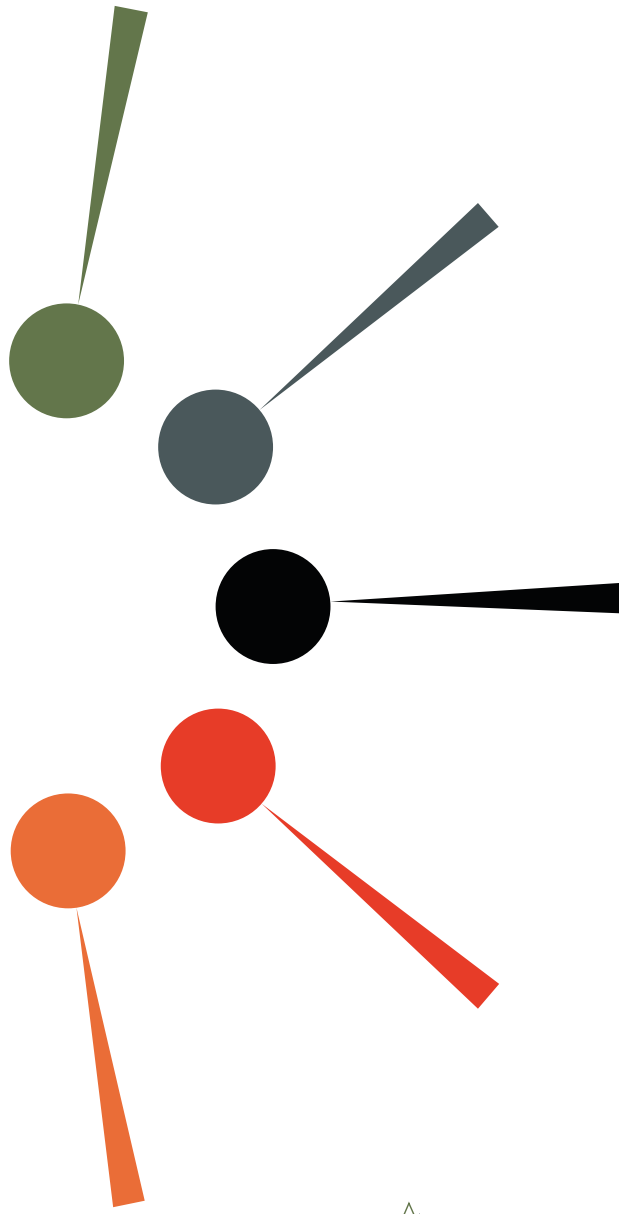
small angle neutron scattering, vesicle, drug delivery, cryoTEM, single particle analysis



Summary of the vesicle characterisation approaches including SANS, cryoTEM and SPARTA for the example of DPPC.

References:

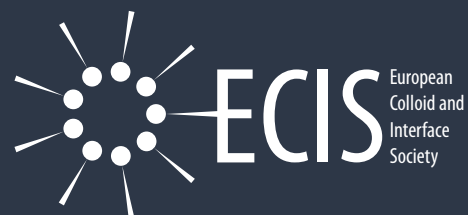
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Differential Dynamic Microscopy as an Alternative to Dynamic Light Scattering for Turbid Nanoemulsions

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Differential Dynamic Microscopy (DDM) is a powerful method for studying soft-matter dynamics, combining the statistical advantages of scattering techniques with the flexibility of optical microscopy. By analyzing time-resolved bright-field images in Fourier space, DDM provides access to sample dynamics while requiring only a few tenths of a microliter of sample and standard microscopy equipment, thus offering clear practical advantages over conventional Dynamic Light Scattering (DLS) [1]. In addition, because image formation in DDM relies on near-field microscopy rather than the collection of singly scattered light at a well-defined angle, the technique often remains effective under conditions where multiple scattering severely compromises DLS measurements [2]. This makes DDM particularly attractive for concentrated, turbid, or highly scattering samples.

In this work, we compare DDM with DLS to investigate oil-in-water nanoemulsions over a broad range of droplet concentrations. Unlike ideal hard-sphere suspensions, nanoemulsions exhibit more complex interparticle interactions and, at higher concentrations, increasingly pronounced multiple-scattering effects, making them an excellent test case for assessing the general applicability of DDM. Through a systematic comparison of both techniques, we show that DDM reliably captures the dynamic behavior of these soft colloidal systems not only in the dilute regime, where both methods perform similarly, but also at higher concentrations where DLS progressively loses accuracy because of multiple scattering. In contrast, DDM continues to provide robust measurements under these challenging conditions, while also benefiting from smaller sample volumes and the versatility of microscope-based measurements.

These results establish DDM as a robust and broadly applicable tool for characterizing non-ideal colloidal suspensions, particularly in regimes where conventional light scattering becomes difficult or impossible.

Keywords:

Multiple Scattering

Nanoemulsions

Differential Dynamic Microscopy

References:

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Characterizing Complex Colloidal Systems via Advanced Light Scattering Techniques

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This talk presents research case studies on multi-target systems, proteins, gene therapy, and functionalized nanoplateforms, demonstrating how advanced light scattering techniques can characterize complex colloidal dispersions.

As nanotechnology advances in materials science, biopharmaceuticals, and renewable energy, accurate and reliable characterization of colloidal size, charge, concentration, and molecular weight is essential. BeNano is a high-precision, versatile analyzer that integrates multiple optical techniques into a single platform. Its key functions include dynamic light scattering (DLS) for particle size, microrheology, and fluorescence filters; electrophoretic light scattering (ELS) for zeta potential and automated pH titration; and static light scattering (SLS) for molecular weight and distribution. Patented modules further enable refractive index measurement, concentration determination, and micron-scale size analysis via optical sedimentation.

By covering sample types from nanoscale to microscale and from dilute to concentrated colloidal systems, BeNano provides comprehensive, high-resolution insights that support both fundamental research and industrial innovation.

Keywords:

Colloidal dispersions, Light scattering techniques, Nanoparticle characterization, Biopharmaceuticals, Particle size, Zeta potential, Concentration

Photoactivated Modulation of Lipid Nanosystems: A Structural and Kinetic Study

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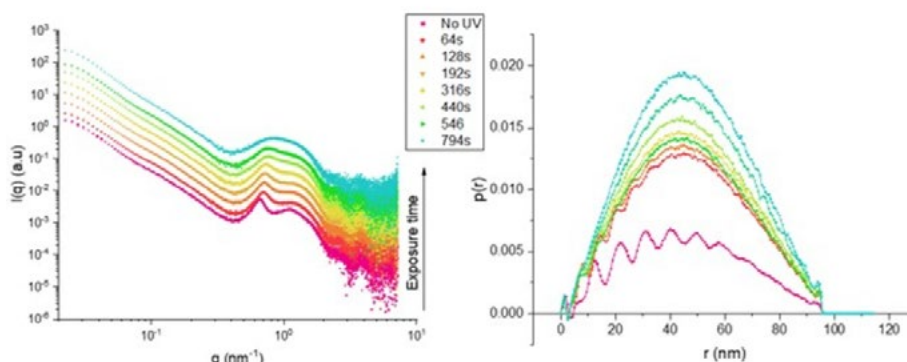
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Functionalized lipid nanocarriers with precisely tunable light-responsiveness represent a promising route to overcome the intrinsic limitations of conventional PEGylated systems, such as poor targeting efficiency and hindered interactions with biological membranes—the so-called PEG dilemma. While PEG functionalization provides stealth properties and enhanced circulation time, it can also suppress endocytic uptake and membrane fusion. To address this challenge, we developed and characterized photoresponsive lipid-based nanocarriers capable of controlled PEG removal and reversible structural modulation under light irradiation. Two complementary strategies were explored: (i) the incorporation of stimuli-responsive PEGylated amphiphiles that undergo selective photocleavage under monochromatic near-UV light, and (ii) the embedding of azobenzene-based molecular switches within the lipid bilayer to induce reversible trans–cis isomerization. Upon near-UV (365 nm) irradiation, PEG shedding and photoisomerization processes were triggered in situ during Time-Resolved Small Angle X-ray Scattering (TR-SAXS) experiments, enabling direct observation of structural transitions at millisecond timescales. UV–visible and fluorescence spectroscopies complemented these measurements to monitor kinetic profiles and confirm the efficiency of light-triggered transformations. Photoresponsive ethosomal nanocarriers were prepared via microfluidic synthesis and featured three distinct azobenzene-based amphiphiles intercalated in the bilayer. The reversible photoisomerization of these switches altered bilayer geometry, packing, and permeability, leading to light-controlled modulation of membrane structure and, in some cases, transient pore formation. Depending on the molecular design, structural rearrangements were found to be fully or partially reversible upon white-light irradiation. Overall, our work elucidates the kinetic and structural dynamics underlying light-induced PEG cleavage and azobenzene-driven bilayer remodeling in lipid nanocarriers. These insights pave the way for the rational design of next-generation stimuli-responsive nanosystems capable of on-demand drug release and fine-tuned control over nanocarrier functionality.

Keywords:

light-triggered structural modifications, lipid nanoparticles, azo-lipids, photo-lipids, azobenzene-based amphiphiles, Tr-SAXS



Scattering profiles of photoactivated PEG cleavage (left) and corresponding pair distribution functions (right)

References:

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Wonmin Choi, Claudia Battistella, Nathan C. Gianneschi. *Biomater. Sci.* **2021**.

Mahmoudreza Doroudgar, Johannes Morstein, Johanna Becker-Baldus, Dirk Trauner, Clemens Glaubitz. *JACS* **2021**.

The crosstalk between DOSY NMR and neutron spin echo spectroscopy: what can we learn about the chain dynamics of block and gradient poly(copoly-2-oxazoline) micelles and relative unimer population?

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Although gradient copolymers have been known for almost 50 years, there is a lack of detailed knowledge of corona chain mobility in polymeric micelles and how this is different from the chain mobility of block copolymer micelles. This knowledge could be very useful, especially for polymers that are highly potent for drug encapsulation due to the strong correlation between internal dynamics and loading and release efficacy. This holds true for poly(2-alkyl-2-oxazoline)s, considering the superior biocompatibility of poly(2-methyl-2-oxazoline) and poly-(2-ethyl-2-oxazoline) in comparison with classical polyethylene glycol [1]. Here, we report on a comprehensive study of the chain dynamics of copolymer micelles composed of amphiphilic poly(2-methyl-2-oxazoline)-*grad*-poly(2-phenyl-2-oxazoline) gradient copolymers in comparison to their block copolymer analogues. Apart from the chain dynamics, we also focused on the presence of unimers, single polymer chains that coexist in solution with the polymer micelles. It is expected that gradient copolymers should have a higher number of unimers than their block copolymer analogues, as they commonly have a higher critical micellization concentration. We varied the hydrophobic/hydrophilic balance and water/ethanol ratios to understand their impact on chain dynamics and unimer-micelle equilibrium. The results highlight the clear impact of the polymer monomer distribution on the shell polymer chain dynamics. Neutron spin echo (NSE) and diffusion ordered spectroscopy (DOSY NMR) experiments evidenced that the polymer chains in a micellar hydrophilic shell composed of gradient copolymers have additional slow motion, making it distinct from their block copolymer analogues [2]. The existence of such an additional chain dynamic could be explained by several plausible theories, including rotational diffusion, Zimm dynamics, or their combination. In addition, we were able to extract the relative populations of unimers and micelles in solutions of both gradient and block copolymers, and our results provided direct proof that the equilibrium between micelles and unimers is indeed shifted to more unimers for gradient copolymers, probably due to lower interphase tension. The reported findings contribute to the understanding of polymer dynamics in polymeric micelles and provide valuable insights for the design of functional polymer-based materials.

Keywords:

poly(2-alkyl-2-oxazoline), poly(2-methyl-2-oxazoline), polyoxazoline, NSE, DOSY, polymer dynamics, unimer, micelle, drug delivery, gradient copolymer

References:

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- [2] Anastasiia Murmiliuk, Olaf Holderer, Zdenek Tosner, Bart Verbraeken, Ondrej Sedlacek, Richard Hoogenboom, Sergey K. Filippov, submitted to the *Journal of Colloid and Interface Science*, 2026

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Isolating interfacial scattering in emulsions: A SAXS-based bulk subtraction approach for pro-teiin-stabilized emulsion systems

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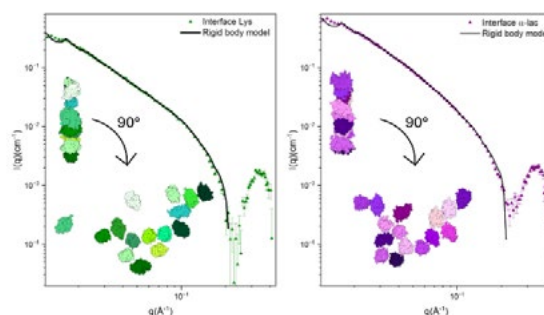
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Interfaces are central to the behavior of colloidal systems, yet their structural characterization remains difficult due to their small and weak scattering signals compared to the bulk of the solution. Emulsions -prototypical soft matter systems- scattering illustrate this challenge well: although interfacial phenomena largely determine macroscopic properties, the interface itself is easily masked by bulk scattering.

In this study, we introduce an advanced small-angle X-ray scattering (SAXS) approach designed to isolate interfacial scattering in model oil-in-water emulsions stabilized by proteins. By combining centrifugation-induced phase separation with a theoretical reconstruction and subtraction of the bulk contribution, we extract the interfacial signal and analyze it through rigid-body modeling of model proteins. Our findings indicate a planar arrangement of protein monomers at the interface, with α -lactalbumin forming a denser interfacial layer than lysozyme—likely reflecting differences in molecular flexibility and destabilization of the protein at the interface. This methodology overcomes key challenges in conventional SAXS analyses, such as buffer mismatch and ambiguity between free and bound particles and provides a general framework for studying interfaces in complex fluids, biological assemblies, and functional materials.

Keywords:

Emulsions, Food interfaces, SAXS, Rigid body modeling



Absolute scale data results after bulk subtraction and corresponding fit for model proteins in a planar structure used in the study, Lysozyme and alpha-lactalbumin.

Probing the Nucleation and Growth of High-Entropy Alloy Nanoparticles in Dropwise Synthesis by Small-Angle X-ray Scattering

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Understanding how multimetallic precursors evolve into high-entropy alloy (HEA) nanocrystals remains a central challenge in colloidal synthesis, particularly under dropwise addition where precursor reduction, nucleation, growth, and atomic mixing are closely coupled. Here, we use ex situ small-angle X-ray scattering (SAXS) to investigate the early-stage formation kinetics of PdPtRhIrRu HEA nanocrystals prepared by dropwise synthesis, with monometallic Pd nanoparticles as a benchmark. The SAXS profiles collected at different reaction times were analyzed using the Q invariant and the Avrami equation to follow the transformed fraction and extract kinetic signatures of nucleation and growth. Distinct two-stage kinetic behaviors were observed for the HEA and Pd systems, indicating that HEA nanocrystal formation follows a kinetically different pathway from that of monometallic Pd under the same synthetic conditions. This difference is consistent with the added complexity arising from the concurrent incorporation of multiple metal species during nucleation and growth. Direct comparison with the Pd system highlights that alloy formation in the HEA sample cannot be described as a simple extension of monometallic nanocrystal growth, but instead involves a more complex kinetic evolution during the early stages of synthesis. Electron microscopy further supported this interpretation, showing branched HEA nanocrystals in contrast to the more isotropic Pd nanoparticles. These results demonstrate that SAXS-based kinetic analysis provides a useful mechanistic framework for probing HEA nanocrystal formation and offers guidance for the rational design of multimetallic synthesis strategies with improved control over alloy nanostructure formation.

Keywords:

high-entropy alloy nanoparticles, small-angle X-ray scattering, nucleation and growth, dropwise synthesis, formation kinetics

Morphology Evolution During the Drying of Polyurethane Dispersions for High-Performance Coatings

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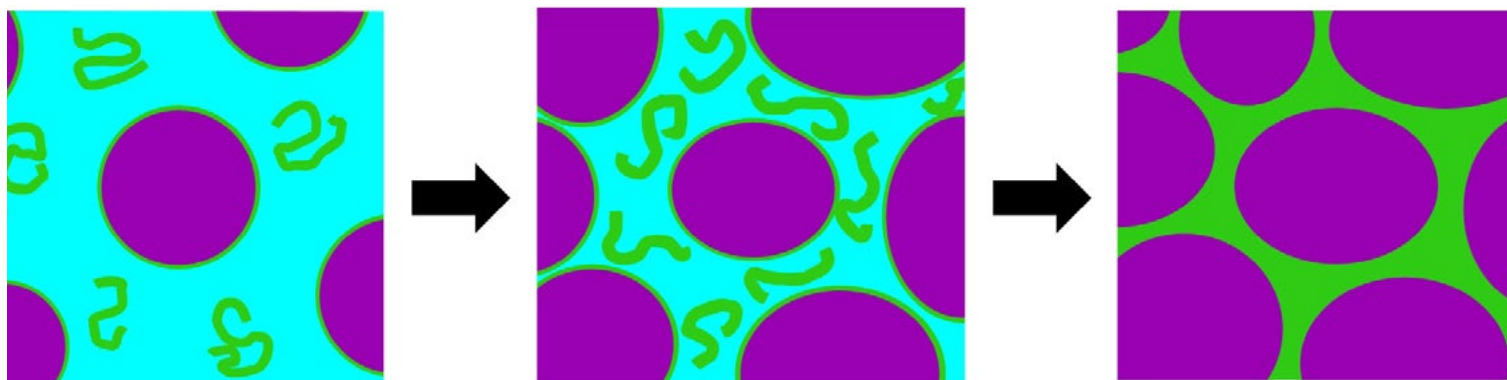
The morphology of resin dispersions plays a crucial role in the film formation and performance of waterborne coatings. Small angle X-ray scattering (SAXS) is a crucial technique for revealing these morphologies as the dispersions transition from liquid to dried films. It has recently been reported that polyurethane dispersions (PUDs) synthesised via the pre-polymer process can contain a two-population system: spherical PU particles and a secondary phase of hydrogen-bonded hard-block oligomers forming supramolecular structures.¹

At high concentrations, SAXS patterns of these PUDs exhibit up to three pronounced peaks driven by complex interparticle interactions. These features map perfectly to a dual-population system, representing sphere-sphere, supramolecular-supramolecular, and cross-particle interactions. These observations can be accurately fitted using a model that incorporates mass balance and all three interactions into a single structure factor using a modified solid-spheres interaction solved by a Percus-Yevick enclosure.^{2,3}

In-situ SAXS measurements during the drying of PUDs (varying in hard-block percentage and soft-block molecular weight) reveal that correlation distances between neighbouring particles decrease throughout film formation. However, complete particle coalescence is prevented by the minor population of acid-rich supramolecular structures aggregating at the particle interfaces. As confirmed by AFM, this results in a distinctive honeycomb structure: soft-block PU particles embedded within an acid-rich hard-block matrix.

Keywords:

SAXS, X-rays, polyurethane, dispersions, colloids, AFM,



Structural morphology evolution during the drying of a polyurethane dispersion, showing PU particles (purple) with acid rich interfaces (green), and a second population of supramolecular structure (also green).

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Dose and Cell Division Drive Intracellular Nanoparticle Redistribution Revealed by Correlative Synchrotron Imaging

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Silica nanoparticles (SiNPs) have emerged as promising nanoplatforms for disease diagnosis and treatment [1]. Understanding nanoparticle–cell interactions is essential for advancing nanomedicine, yet most studies rely on static observations and lack volumetric information under near-native conditions. Protein corona formation plays a key role in modulating nanoparticle behavior [2] and reducing cytotoxicity [3]. Here, we establish a synchrotron-based correlative X-ray microscopy framework to investigate how nanoparticle concentration and successive cell-division cycles govern the intracellular fate of SiNPs in macrophages. Fluorescent SiNPs internalized by RAW 264.7 macrophages were analyzed using a multimodal workflow combining cryo-soft X-ray tomography (cryo-SXT), cryogenic structured illumination microscopy (cryo-SIM), coherent X-ray ptychography, and confocal fluorescence microscopy. Experiments were conducted at the B24 beamline of Diamond Light Source, Mistral beamline of Alba Synchrotron, and the Cateretê beamline of Sirius. Correlative cryo-SXT and cryo-SIM reveal a concentration-dependent redistribution of nanoparticle-containing vesicles toward the perinuclear region while maintaining vesicular confinement. At higher concentrations, nanoparticles approach the nuclear region via vesicles associated with nuclear-envelope invaginations, an effect not observed at lower concentrations (Figure 1a). Successive cell divisions redistribute the intracellular nanoparticle load and promote stable perinuclear clustering, indicating a long-term sequestration pathway (Figure 1b). Confocal fluorescence microscopy supports these findings, showing concentration-dependent increases in ATTO-633 signal intensity, associated with SiNPs, and progressive clustering over time. After two doubling times, fluorescence is predominantly localized in the perinuclear region, suggesting accumulation mediated by late endocytic processes or vesicle maturation, as corroborated by our recent published work [4]. Coherent X-ray ptychography further reveals nanoscale deformations of the nuclear envelope associated with perinuclear vesicle accumulation. These results establish correlative multimodal synchrotron imaging as a powerful multiscale platform for resolving the dynamic intracellular fate of nanoparticles.

Keywords:

Correlative X-ray Microscopy; Intracellular Trafficking; Nano–Bio Interactions; Silica Nanoparticles; Macrophages

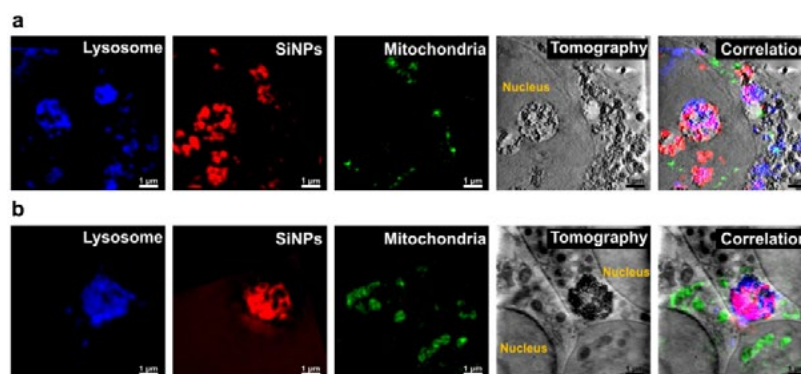


Figure 1. Correlative cryo-SXT/cryo-SIM: (a) 1 h; (b) 32 h (second cell division) at 0.3 mg/mL SiNPs in RAW 264.7 cells.

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Gradient Particle Dispersions: A Versatile Platform for Polymeric Colloids, Photonic Materials, and Responsive Assemblies

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Continuous gradient particle dispersions offer access to colloidal systems with spatially and statistically varying properties that are not achievable with traditional discrete particle libraries. In this contribution, we present a versatile and general approach for synthesizing gradient dispersions, focusing on polymeric particles and microgels, and demonstrate how these systems enable new structure–property relationships and functions. The core idea uses time-dependent seeded growth in semi-batch processes to create dispersions with intentionally designed continuous particle size distributions, rather than uniform monodisperse populations. Using the Controlled Emulsion Extraction Process (CrEEP), gradient latex dispersions can be produced with precise control over particle size and compositional parameters such as glass transition temperature by adjusting the monomer feed. ¹ This principle is also applicable to inorganic systems, as shown by the Controlled Extraction Stöber Process (CrESP), highlighting the broad versatility of this synthetic platform. ²

We further demonstrate that such gradient dispersions can act as building blocks for functional materials. In hard-sphere-like colloidal systems, gradual size distributions produce photonic colloidal glasses with a continuous structural gradient, resulting in vivid, position-dependent coloration and increased light scattering. Extending this idea to soft polymeric core–shell microgels allows access to gradient assemblies, where swelling and deswelling can be monitored across an entire particle population. When incorporated into continuous materials through gradual filtration, these soft gradients show amplified thermoresponsive actuation, opening new prospects for self-actuating particle-based matter.

Taken together, these examples demonstrate that gradient particle dispersions are a versatile materials platform with applications in photonic scattering optimization, adaptive filtration media, and soft robotic or actuator systems. More broadly, they provide a general pathway to create mesoscopic gradients in colloidal matter and, as a result, enable emergent functionalities from controlled dispersity.

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Angle-Dependent Absorption Correction for Reliable Absolute-Scale SAXS and SWAXS in Kratky-Type Geometry

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Reliable absolute-scale SAXS and SWAXS analysis requires an accurate correction for X-ray absorption by the sample. In line-collimated Kratky-type instruments with cylindrical capillaries, this is commonly performed using a scalar transmission factor derived from the measured attenuated primary beam [1]. While this approach is often adequate for sample series with similar X-ray absorption, it can become unreliable when the sample, reference solvent, and empty capillary exhibit substantially different X-ray absorption. This becomes particularly evident in extreme cases in the wide-angle region of SWAXS, where background subtraction may even yield unphysical scattering results [2]. Here we introduce a numerical angle-dependent absorption correction for SAXS and SWAXS in a realistic Kratky-type geometry. The method combines tabulated attenuation coefficients with an explicit description of the experiment, including the constrained scattering volume, measured primary-beam profiles, self-absorption of the scattered radiation, and attenuation in the quartz capillary wall. It therefore provides a physically consistent alternative to conventional experimental scalar transmission correction, with direct relevance for reliable background subtraction and absolute-scale calibration. The performance of the correction is assessed by comparing corrected experimental SWAXS data with theoretical scattering intensities calculated for the same systems using the complemented system approach [3–5]. The numerical correction yields markedly improved agreement, supporting its use for quantitative SWAXS analysis. A simplified Beer–Lambert-type scalar correction can still give similar results in the small-angle range, whereas the comprehensive numerical treatment is required for physically consistent angle-dependent SWAXS correction. The present approach thus offers a practical correction procedure for line-collimated SAXS/SWAXS experiments, especially when measurements with substantially different absorption must be combined within the same data-reduction and absolute-scaling procedure.

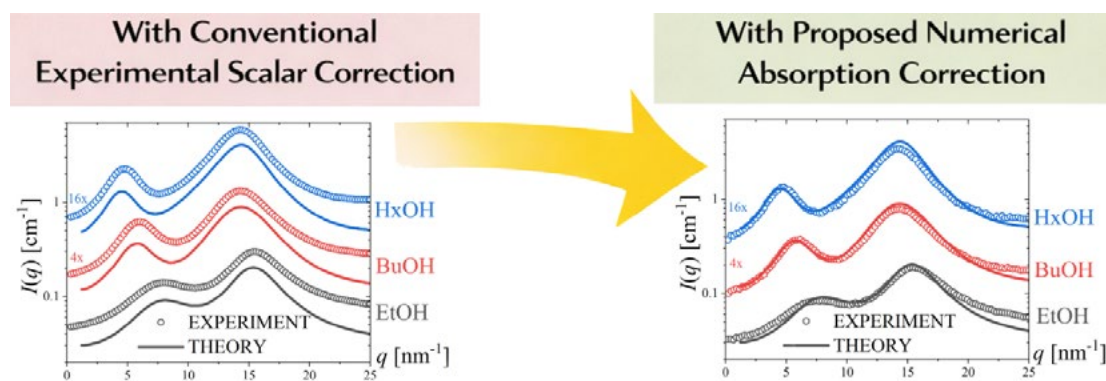


Figure: Experimental (circles) and theoretical (lines) SWAXS profiles for EtOH, BuOH, and HxOH. Left: conventional scalar correction shows major deviations. Right: proposed numerical absorption correction improves agreement.

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Impact-induced millisecond clustering during shear melting of colloidal crystals

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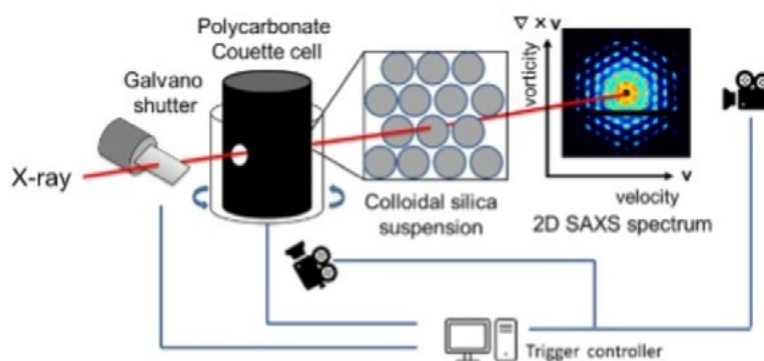
An high-speed shear to a colloidal silica and polymer suspension causes a rapid increase in viscosity called shear thickening. While the phenomenon is well known, it is difficult to investigate thickening process and its mechanism is not understood enough. One reason is that the phase transition of shear thickening occurs in less than one second, making it difficult to observe the transition process in a short time.

Here we investigated time-resolved small/ultra-small angle X-ray scattering (SAXS/USAXS) with a minimum resolution of 1 millisecond using high-brilliance synchrotron radiation in SPring-8 BL19B2 and BL40XU beamline. Simultaneous measurement of viscosity and SAXS/USAXS demonstrated the time development of shear thickening.

Rapid shear increasing on silica suspension showed a shear thickening process in which the particles start to aggregate in few seconds. Our results found a new manner of shear thickening, different from conventional rheo-SAXS under steady shear.

Keywords:

Colloidal crystal, Non-Newtonian fluid, Small angle X-ray scattering



Schematics of a time-resolved Rheo-SAXS system.

References:

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Acknowledgements:

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3D Imaging and Understanding the Structure of the Chiral Nematic assembly of Cellulose Nanocrystals in Suspension

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We exploited the inherent confocal effect of Second Harmonic Generation (SHG) microscopy to acquire highly resolved 3D images of the chiral nematic phase of ribbon-like cellulose nanocrystals (CNC) and CNC tactoids in the “isotropic” phase in a label-free manner and in the liquid state. The response to the polarization of the laser beam agreed with a single dominant tensor component along the director axis of the (chiral) nematic liquid crystal planes, showing that the anisotropy of the CNCs dominates their assembly. Rotation of the director results in variations in SHG intensity which can be directly linked to the helical pitch and used to determine directionality of the chiral nematic assembly. This gave us access to high contrast 3-dimensional images of the aligned liquid crystal phase, providing unprecedented detail into their structure in the bulk liquid state. Local alignment, morphology, and the presence of defects are readily visible and can be determined. In addition, through 3D-FFT analysis, we were able to fully characterize the periodicity of the helicoidal structures and allowed for a precise estimate of the helicoidal pitch and identification of preferred directions within the investigated volume. Tomographic images of the “isotropic” phase further enabled us to visualize and measure tactoids in 3D, making it possible to determine a volume range within which tactoids morph from the nematic to cholesteric state and obtain a value for the twist ratio.

In this presentation, we will discuss how SHG microscopy can be used to characterize CNC self-assembled structures in the bulk liquid state (but the fully developed chiral nematic state and tactoids formed in the “isotropic” state). We will further illustrate the numerous benefits SHG microscopy offers and discuss the framework for interpreting the images obtained through this technique.

Keywords:

Second Harmonic Generation Microscopy, Cellulose Nanocrystal Assembly, Chiral Nematic Structure

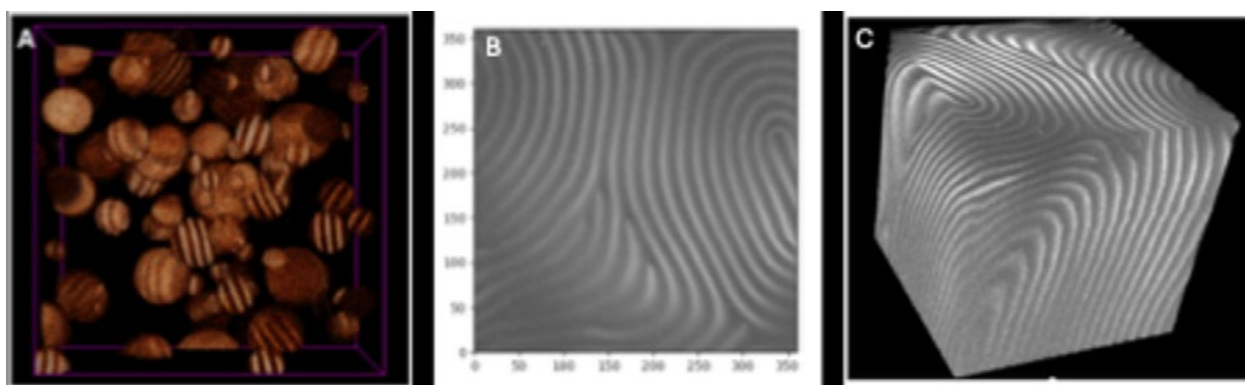


Figure 1. (A) 3D SHG image of an “isotropic” phase of a 2 wt% CNC suspension showing nematic and cholesteric tactoids, (B) 2D SHG image of a plane in a CNC chiral nematic phase (8 wt% CNC suspension), and (C) 3D SHG image of chiral nematic phase (8 wt% CNC suspension) by SHG focus stacking of 2D SHG

Acknowledgements:

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ShearView: An Open-Source Compact Rheometer for Integrated Rheo-Microscopy

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Understanding the microscopic origin of the rheological response of complex fluids requires instruments capable of simultaneously measuring macroscopic mechanics and microscopic structure. However, commercial rheo-microscopy platforms are often expensive, bulky, and difficult to customize, limiting their accessibility and integration with advanced optical techniques.

Here we present ShearView, a compact, low-cost, and fully open-source linear rheometer designed for integrated rheo-microscopy. The instrument combines stress- and strain-controlled operation with optical transparency and compatibility with standard upright and inverted microscopes. ShearView is constructed primarily from off-the-shelf components and is operated through custom control software implementing dual feedback loops for either imposed strain or imposed stress.

The platform enables the application of arbitrary shear waveforms, including sinusoidal, large-amplitude oscillatory shear, chirped, and transient protocols, while simultaneously acquiring synchronized microscopy images. Calibration and control procedures provide accurate and reproducible operation over a broad range of frequencies and deformation amplitudes. Validation against a commercial rotational rheometer shows excellent agreement in both linear viscoelastic frequency sweeps and nonlinear oscillatory shear measurements.

We further demonstrate the capabilities of ShearView through representative rheo-microscopy experiments, including echo, recovery, and shear-cessation protocols, in which the rheological response is directly correlated with the evolution of the sample microstructure. These experiments highlight the potential of the instrument to investigate yielding, restructuring, memory effects, and flow-induced organization in colloidal and other soft-matter systems.

By combining mechanical simplicity, modularity, and open access to hardware designs and software, ShearView provides an accessible platform for scattering, imaging, and rheological studies of complex fluids, with applications ranging from research laboratories to teaching environments.

Keywords:

rheology, rheometry, rheo-microscopy, complex fluids, colloids, soft matter, open-source instrumentation, yielding



Schematic view of ShearView platform integrated on an inverted optical microscope. The compact linear rheometer is mounted around the sample stage and coupled to a computer for real-time acquisition and control.

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Optimizing Neutron Reflectometry Experiments for Soft Matter Systems using HOGBEN

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Neutron Reflectometry (NR) measurements are both time-consuming and resource-intensive, making it vital to optimize the experimental approach in order to gain the greatest amount of relevant information about a system within a given time. However, determining how best to perform NR experiments is an unintuitive problem: which regions of a reflectivity profile contain the most information about a system? How long do you measure at each angle for? How many, and which, solvent contrasts are needed? These are questions HOGBEN was developed to help answer.

HOGBEN is a software tool designed to simulate and optimize Neutron Reflectometry experiments[1, 2]. Using a sample model defined in Refnx, and the neutron flux profile and set-up of a chosen NR instrument, it can be used to optimize the measurement angles, respective times at each angle, solvent contrast, and even the composition and thickness of reference layers within a substrate. By altering these, a significant increase in the amount of information gained within a given time for the parameters of interest can be acquired, which ultimately produces either a reduction in count time or an improvement in fit-uncertainties. Recently, experimental work has been performed using HOGBEN to demonstrate the improvement of information gained when measuring a simple bilayer system by up to 50% in comparison to a measurement at conventional measurement and angle times.

We present here an overview of the capability and applicability for HOGBEN to optimize neutron reflectometry measurements of soft-matter systems, and provide experimental confirmation of the information gain possible through such optimization.

Keywords:

Neutron Reflectometry, Fisher Information, Soft Matter, Simulation

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Acknowledgements:

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Effect of selective deuteration on particle compressibility for SANS studies with contrast variation

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Selective deuteration is a key procedure that enables contrast variation in neutron scattering experiments used for the structural characterisation of synthetic and bio-relevant colloids. It relies on the assumption that selective deuteration does not alter the size, structure, or compressibility of the microgels. However, a poor experimental knowledge is available on the effects of partial deuteration on the properties of soft colloids. Therefore, the influence of selective deuteration is investigated through the analysis of the structure and softness of poly-N-isopropylacrylamide-based (pNIPAM) microgels.

Small-angle neutron scattering with contrast variation is employed to determine the bulk modulus of microgels synthesised from partially deuterate monomers with varying degrees of deuteration (isotopic substitution of 3, 7 or 10 atoms of hydrogen by atoms of deuterium). Dynamic light scattering and viscosimetry techniques are also used to determine the swelling ratio and individual mass of the different microgels.

Our results show that, the structural differences induced by monomer deuteration make the partially deuterated microgels harder. The higher the degree of deuteration, the harder the microgel becomes.

Keywords:

pNIPAM Microgels, Selective Deuteration, SANS, Contrast variation, Bulk modulus

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Superchaotropic Nano-ions Control the Phase Behavior of Lipid Monolayers at the Air/Water Interface

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Nano-ions with low charge densities, such as polyoxometalates and polyhedral boron clusters, exhibit a strong propensity to adsorb at hydrophilic interfaces due to their superchaotropic character.[1] While their accumulation at lipid layers is well-known and has been applied to facilitate the transport of drug through biological membranes,[2] the underlying structural organization and driving mechanisms remain incompletely understood.[3]

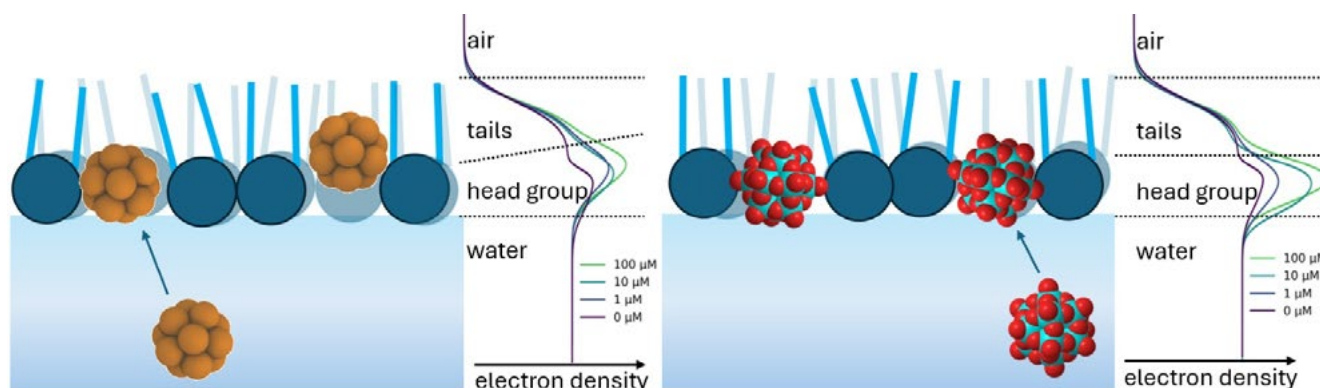
Here, we investigate lipid monolayers at the air–water interface as model systems for biomembranes, combining synchrotron-based X-ray fluorescence with grazing-incidence X-ray scattering techniques and complementary structural characterization methods. We observe pronounced adsorption of nano-ions already at micromolar concentrations, leading to the formation of a laterally organized interfacial layer that overlaps with lipid headgroups and partially penetrates the hydrophobic region.

Importantly, we show that nano-ions strongly modify the lateral phase behavior of lipid monolayers. Depending on their chemical nature, they either stabilize the liquid-expanded phase or suppress the phase transition to the liquid-condensed phase entirely, suggesting the emergence of a distinct compromised state. These effects occur already at sub-micromolar concentrations and cannot be rationalized solely by charge density.

Our results demonstrate that the interaction is governed by a pronounced chemical selectivity of both lipid headgroup and nano-ion and provide detailed structural insight into their interfacial organization. The observed phase behavior is analyzed in the context of established structural characterization approaches for lipid monolayers.[4]

Keywords:

Lipid monolayers, Nano-ion adsorption, Superchaotropicity, Ion-specific effects, Phase transitions, Grazing-incidence X-ray scattering



While icosahedral boron clusters (left) protrude into lipid tail region, polyoxometalates (right) only adsorb near the head group, as revealed by electron density profiles. In both cases, this correlates with distinct changes on lipid phases and structure.

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Influence of Small Molecules on Hydration-Induced Phase Distribution in Lipid Liquid Crystalline Depots

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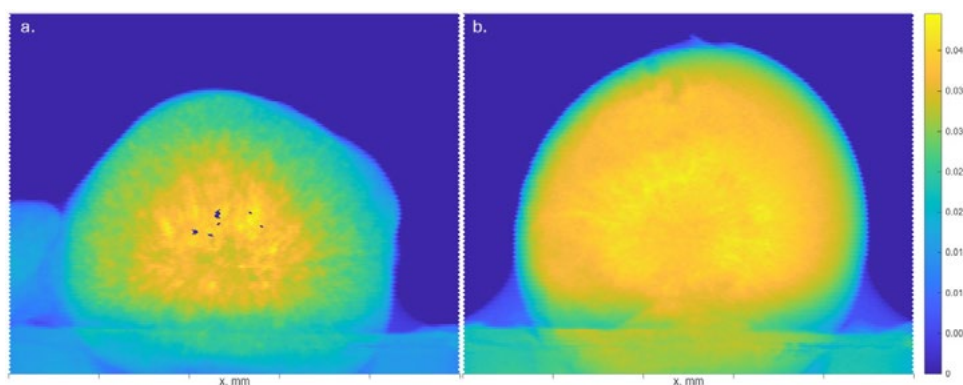
Lipid liquid crystalline depots are formed through the self-assembly of amphiphilic lipids into liquid crystalline phases upon hydration and are widely used as biocompatible systems for sustained and controlled drug release. While previous work has highlighted the role of hydration-driven lipid redistribution and resulting spatial phase heterogeneity [1], the influence of lipid composition and additives on these processes remains less understood.

This study extends earlier findings by investigating how variations in lipid composition, additives and chemical environment affect phase distribution within lipid depots. Systems based on soybean and egg phosphatidylcholine, which differ in average fatty acid composition and exhibit distinct phase behavior during hydration, are combined with Span 80 and studied both in the absence and presence of additives such as ibuprofen, trimethylamine N-oxide, and urea. Advanced synchrotron SAXS is employed to resolve phase behavior within the depot across hydration times from 5 hours to 3 weeks, providing direct insight into structural organization and its temporal evolution.

The results show that both lipid composition and the presence of additives influence the phase distribution within the depots, with coexisting cubic and hexagonal structures forming distinct spatial arrangements. These findings highlight the sensitivity of lipid self-assembly to compositional and environmental factors, providing further insight into the mechanisms governing structure formation in lipid-based drug delivery systems and supporting continued efforts toward rational design of such systems.

Keywords:

Small angle x-ray scattering, Phase behavior, Liquid crystalline depots, Lipid-based drug delivery, Hydration-driven structural reorganization



Initial lipid composition and additives influence hydration kinetics and phase behavior. Comparison of a) SPC/Span 80 and b) EPC/Span 80 depots, both containing 2% TMAO, shows differences in cubic phase distribution after 3 days of hydration (2 mm spacing; intensity reflects cubic fraction).

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Acknowledgements:

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Engineering X-ray Visibility in Soft Colloids: Iodine-Loaded PISA Nanoparticles

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Polymeric nanoparticles are attractive colloidal building blocks due to their tunable size, surface chemistry, and deformability. However, characterization by X-ray scattering and imaging techniques is often challenged by the low intrinsic contrast of organic soft matter systems. ¹ Here, we present a strategy to engineer X-ray-visible soft colloids through incorporation of iodine-containing hydrophobic components into polymer nanoparticles prepared by aqueous polymerization-induced self-assembly (PISA).

The PISA approach enables scalable synthesis of colloiddally stable nanoparticles with controlled dimensions and narrow size distributions while maintaining surfactant-free, well-defined interfaces. ² By varying formulation parameters, the iodine loading can be tuned independently of particle size, providing adjustable X-ray attenuation and scattering contrast. Initial studies demonstrate enhanced detectability of the particles in multicomponent systems and improved contrast in scattering-based measurements.

These iodine-loaded nanoparticles constitute a versatile platform for contrast-matched and contrast-enhanced studies of colloidal interactions, transport phenomena, and structural dynamics in complex soft materials. The concept also offers opportunities for characterization of bio-based and hierarchical materials where conventional contrast is insufficient.

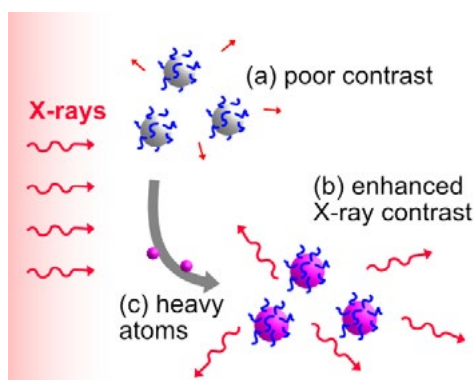


Figure 1. (a) Current colloidal nanoparticles provide poor X-ray contrast. (b) This project will develop a platform of enhanced-contrast nanoparticles by (c) the incorporation of heavy atoms.

References:

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In-Situ Probing of ZIF-8 Colloid Self-Assembly into Photonic Mesocrystals

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Controlling the self-assembly of colloidal particles into superstructures with long-range order is important for the design of photonic crystals (PhCs) ¹. In the last decade, metal-organic framework (MOF)-based PhCs have been of interest because their tuneable structure, porosity, and surface area in turn tune the photonic band gap ^{2,3}. However, control over the morphology and size of the MOF colloidal nanoparticles is essential to the successful fabrication of PhCs. Furthermore, understanding their self-assembly behaviour is key to enabling greater control over PhC formation. This research focused on ZIF-8 synthesis and looked to understand how several synthesis parameters, including zinc node:2-methylimidazole molar ratio, could control morphology and size of ZIF-8 colloidal nanoparticles. It was found that decreasing the zinc to 2-methylimidazole molar ratio resulted in morphological change from truncated rhombic dodecahedra to truncated cubes, as well as a decrease in nanoparticle diameter (Fig.1 (a) to (b)). Optimised ZIF-8 colloids were subsequently self-assembled into monocrystalline superstructures with photonic properties, and as such, exhibited a range of structural colours, that red shifted as the particle size increased (Fig.1 (c) to (f)). Small angle X-ray scattering (SAXS) was then used to resolve the packing structure of these mesocrystals (Fig.1 (g)). Combined with nuclear magnetic resonance (NMR) and dynamic light scattering (DLS) studies, these studies provided insight into why particles of certain sizes prefer packing, differences between crystallised colloids and those remaining in the supernatant, and the formation of mesocrystals via self-assembled colloidal clusters. Additionally, humidity-controlled *in-situ* grazing incidence small angle X-ray scattering (GISAXS) revealed the role of interfacial water in establishing photonic behaviour, where shifts in reflectance peaks indicated a contraction of the lattice parameter of the superstructure upon drying. To our knowledge, this work is the first *in-situ* study of the self-assembly process of ZIF-8 colloidal systems. These results provide a deeper understanding of MOF colloid assembly and potentially provide pathways to more efficient self-assembly of MOF colloids in the future and enabling the fabrication of new photonic structures experimentally.

Keywords:

Metal-Organic Frameworks, Photonic Crystals, Small Angle X-ray Scattering, Self-Assembly

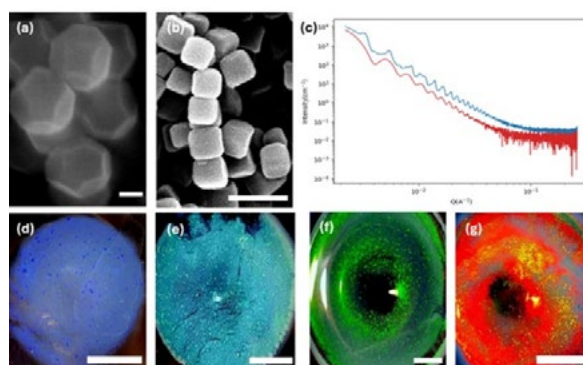


Figure 1. (a-b) SEM images of ZIF-8 synthesised with different morphologies, (c) SAXS data showing the nanoparticles in the mesostructure (blue) compared to in the supernatant (red), (d-g) optical images of the different coloured photonic crystals. Scalebars (a-b) 500 nm, (d-g) 1 cm.

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Solvent Extraction for Metal Recovery: Composition and Distribution of Organic and Ionic Species at the Water/Oil Interface

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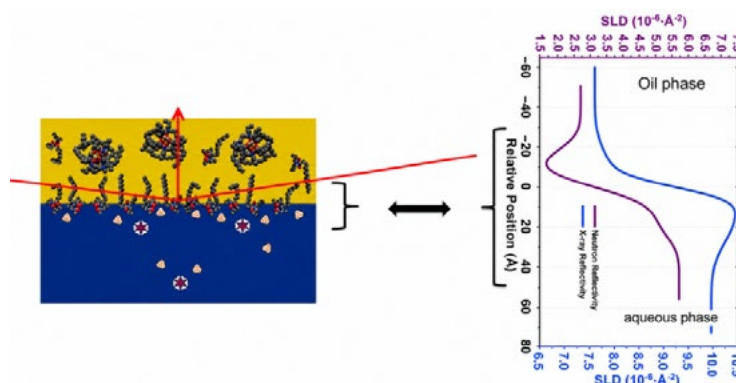
Liquid–liquid extraction of metal ions relies on the difference in affinity of a solute between two immiscible phases and is widely used for the selective recovery of critical and valuable metals from industrial wastes. In this process, an amphiphilic phase-transfer agent (ligand or extractant) is typically added to the organic phase to promote the selective transfer of metal ions.[1]

When the complexation energy between the ligand and the metal ion is weak and the solubilization of the complex in the organic phase depends on ligand aggregation,[2] the structural organization of ligands at the water/oil interface becomes a key factor controlling ion-transfer kinetics.[3] A detailed understanding of the supramolecular structure of these interfaces is therefore essential for rationalizing and predicting extraction mechanisms.[4] However, experimental information at the nanoscale remains scarce due to the difficulty of probing fluctuating buried liquid–liquid interfaces. [3b, 3c, 5] Over the past decade, we have combined neutron and X-ray reflectivity (with nonlinear optical techniques and molecular dynamics simulations) to investigate the structure of ligand-containing liquid–liquid interfaces without imposing prior assumptions on ligand organization. We will present results showing that the extractant system—particularly diamide and monoamide ligands—controls the formation of either a sharp interface or an extended interphase, with direct implications for ion-transfer kinetics.

These findings provide new insights into the interfacial organization governing ion transfer in liquid–liquid extraction systems and perspectives using scattering techniques, non-linear optical technique and molecular dynamics [6] will be also proposed and detailed.

Keywords:

liquid-liquid interfaces, ion transfer, reflectivity



Left: Schematic of a liquid–liquid interface in solvent extraction probed by X-ray or neutron reflectivity. Right: SLD profile normal to the interface for a system with an amide ligand in oil and uranyl nitrate in water. Neutrons probe organics, X-rays probe ions.

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Time-Dependent Structural Evolution of Casein Micelles in Reconstituted Milk Probed by SANS and SAXS

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Small angle neutron scattering (SANS) provides unique sensitivity to hierarchical organization in complex soft-matter systems and is particularly well suited for probing the internal structure of the casein micelle in milk. In this contribution, we present newly obtained SANS data on reconstituted milk samples, focusing on how the internal organization of the casein micelle evolves as a function of reconstitution time and concentration.

First, we investigated the structural development of the casein micelle following reconstitution from milk powder. The SANS data reveal clear and systematic changes in the internal micellar structure over time, with measurable differences persisting for up to 24 hours after reconstitution. These results indicate that the casein micelle does not instantaneously recover its equilibrium internal organization upon rehydration, but instead undergoes a gradual structural reorganization.

Second, we examine the effect of concentration, and concomitantly mineral concentration, on the micellar structure. Variations in concentration lead to pronounced changes in the scattering profiles, highlighting the strong coupling between casein organization and mineral-mediated interactions within the micelle.

Initial modelling of the SANS data is presented, capturing the main structural features and trends observed experimentally. Ongoing work aims to apply our comprehensive structural model, previously developed for small angle X-ray scattering (SAXS) data on casein micelles, to the SANS measurements. This modelling approach is expected to provide a holistic and quantitative description of the internal organization of the casein micelle, bridging neutron and X-ray scattering insights and advancing our understanding of milk as a dynamic, multiscale colloidal system.

Keywords:

Casein micelle

Milk

Small angle X-ray scattering

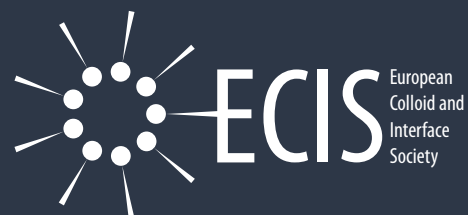
Small angle neutron scattering
structure

milk powder reconstitution

Topic 1

Colloid and Interface Science
for Biomedical Applications
and Biomaterials

! POSTER



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Bicontinuous Microemulsions for Co-Delivery of Phycocyanin and Curcumin in Dermal Applications

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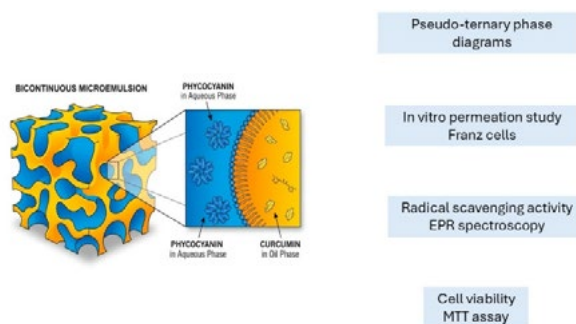
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This study focuses on the co-solubilization of two antioxidant bioactive compounds, namely phycocyanin - a hydrophilic pigment - and curcumin - a hydrophobic polyphenol - within a bicontinuous microemulsion (bi-ME) (1). Guided by pseudo-ternary phase diagrams, stable and transparent bi-MEs were developed to solubilize both hydrophilic and hydrophobic compounds (2). The radical-scavenging activity of curcumin and phycocyanin was assessed via EPR spectroscopy with galvinoxyl radicals, exhibiting % inhibition of approximately 75% and 60%, respectively, after 32 minutes. A further increase in % inhibition was observed upon co-loading both compounds in the bi-MEs, suggesting interaction between the two compounds. An *in-vitro* permeation study was performed using Franz-type diffusion cells equipped with a synthetic polycarbonate membrane to evaluate the ability of the bi-MEs to function as topical delivery systems. Curcumin displayed zero-order permeation, with ~5% total cumulative release over 6 h, whereas phycocyanin remained surface-bound. These findings highlight differing permeation behaviors relevant to topical delivery systems. To assess the potential toxicity of such systems and to determine the maximum safe concentration for administration, MTT assays in WM164 and Caco-2 cell lines were performed indicating the non-cytotoxic nature of the bi-MEs (3). Overall, these findings demonstrate the potential of bi-MEs as dual antioxidant delivery systems in topical and transdermal applications.

Keywords:

bicontinuous microemulsions, dual-drug delivery, antioxidant, radical-scavenging activity, EPR, in vitro release, MTT



Co-solubilization of phycocyanin and curcumin within a bicontinuous microemulsion. Phase behavior and biological performance.

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Protein corona of *Hevea brasiliensis* field latex

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Hevea brasiliensis field latex are known to be stabilized by a complex interfacial layer composed mainly of proteins and lipids, forming a so-called protein corona surrounding the rubber particles. This surface layer plays a key role in determining the surface charge and colloidal stability of latex dispersions [1, 2, 3]. However, the nature, distribution, and role of these corona proteins in stabilizing the latex particles remain incompletely understood. In this work, we investigate the electrokinetic properties of field latex and the behavior of its protein corona in order to better understand the mechanisms governing latex stability. First, the electrokinetic behavior of *Hevea brasiliensis* field latex were investigated by examining the effects of ionic strength and pH on electrophoretic mobility. Fitting the mobility data using Ohshima's soft particle model yielded a charge density Z_N of approximately -373 mM and an ionic permeability layer thickness of $\sim 2 \text{ nm}$, confirming the presence of a permeable polymer corona at the particle surface [4]. The effect of pH (2–12) revealed an isoelectric point around pH 3.5–4.0, consistent with the fact that the surface charge of field latex is imposed by the amphoteric properties of proteins on the latex external corona [2]. Then, we looked at the nature and distribution of these proteins. Adsorption of a cationic surfactant, sodium dodecyl sulfate (SDS), led to an increased negative electrophoretic mobility and more importantly to displacement of proteins from the latex corona to the serum [5]. An analysis of the total amount of the displaced proteins and of their nature by proteonomics is currently underway. The ultimate goal is to get a more precise description of the proteins stabilizing field hevea latex. Current work also aims to elucidate the interaction between SDS and the protein corona, by determining whether SDS primarily adsorbs onto the latex particle surface, partially replaces surface proteins, or whether both mechanisms occur simultaneously, through comparative analysis of protein distribution in the cream and serum phases.

Keywords:

Hevea brasiliensis field latex, Colloidal stability, Protein corona

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Acknowledgements:

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Influence of Mixing Strategy and Surfactant Presence on the Ouzo Boundary-Stability Limit in Polymeric Nanoparticle Nanoprecipitation

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Control over the characteristics of polymeric nanoparticles, particularly size, formed via nanoprecipitation is critical for their application in biomedicine[1]. Although nanoparticle formation by nanoprecipitation has been extensively studied, the influence of mixing strategy and surfactant presence on governing the Ouzo boundary and stability limits is not well understood. In this study, we systematically examine how batch and semi-batch mixing, with and without surfactants, affect the Ouzo boundary and the resulting nanoparticle characteristics.

Ouzo region and stability boundary/limit (onset of formation of gels and flakes along with the nano/micro particles often described as the system enters spinodal decomposition[2]) were mapped by varying solvent mass fraction (f_s) and polymer mass fraction (f_{PLGA}), indicating distinct compositional regimes with specific physico-chemical properties of particles formed.

At low solvent mass fraction ($f_s \approx 0.2$), these boundaries are dependent on both mixing conditions and surfactant presence in batch and semi-batch processes. A similar trend is observed for surfactant effects: pronounced influence at low f_s , followed by convergence of boundary locations up to $f_s \approx 0.5$. From a polymer concentration perspective, above a threshold ($f_{PLGA} \sim 0.01$), neither mixing nor surfactant plays a dominant role in determining the stability boundary. Dynamic light scattering (DLS) measurements show that increasing f_{PLGA} leads to increased polydispersity with volume – based hydrodynamic sizes (H_d) transitioning from monomodal to proximate and distant bimodal, marked by the appearance and growth of a secondary peak. H_d increases with f_{PLGA} only in the absence of surfactants and within the Ouzo region (reported from the literature) particles are formed across a wide size range (48-191 nm). At the stability limit, two types of populations (nanoparticles and gels/flakes) can be found which highlight the role of mixing kinetics.

These results indicate how composition, mixing strategy, and interfacial stabilization collectively shape nanoparticle formation within metastable regions, offering mechanistic insight for the design and the control of nanoprecipitation processes.

Keywords:

Polymeric nanoparticles, Ouzo effect, Stability limit, Mixing strategy, Surfactant

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Dual critical micelle concentration and temperature-driven structural transitions in escin aqueous solutions

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Escin, a natural saponin with a complex amphiphilic structure, exhibits rich self-assembly behavior in aqueous solution that remains only partially understood. In this work, we present a comprehensive multi-technique study of escin across a broad concentration and temperature range, combining surface tension, isothermal titration calorimetry (ITC), proton nuclear magnetic resonance (¹H NMR), dynamic light scattering (DLS), differential scanning calorimetry (DSC), density, and speed of sound measurements.

ITC measurements clearly identify a first critical micelle concentration (CMC₁), while the presence of a second aggregation threshold is less evident due to the low concentration regime [1]. However, surface tension measurements reveal two distinct inflection points, located at approximately 0.3 mM and 1 mM, suggesting the existence of two critical micelle concentrations (CMC₁ and CMC₂). These findings are independently supported by ¹H NMR chemical shift analysis, where selected proton signals exhibit concentration-dependent shifts that define distinct aggregation regimes consistent with the CMC values obtained from surface tension.

Further insight into the nature of these aggregates is obtained from DLS, DSC, density, and acoustic measurements. These techniques reveal clear differences in the thermodynamic and structural behavior of aggregates formed above CMC₁ and CMC₂. Notably, a temperature-dependent transition is observed in the range of 25–30 °C for systems above CMC₂, indicating a possible conformational or organizational rearrangement within higher-order self-assembled structures.

Altogether, our results provide strong evidence for a hierarchical self-assembly process in escin solutions, characterized by multiple aggregation thresholds and temperature-sensitive structural transitions. This work highlights the importance of combining complementary techniques to unravel the complex phase behavior of natural surfactants.

Keywords:

Escin, Saponins, Critical concentration, Self-assembly, Thermal transitions, Hierarchical aggregation

References:

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Acknowledgements:

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Harnessing Bacterial Lipid Coatings on Gold Nanoparticles for Enhanced Cell Adhesion Applications

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Introduction: Antimicrobial resistance (AMR) is a public health threat, causing millions of deaths annually. The misuse and overuse of antibiotic drugs have led to the rise of drug-resistant pathogens. Without novel treatments for AMR, current antibiotics can decline in efficiency. Nanoparticles (NPs), particularly when coated with bacterial membranes, can offer an alternative platform to potentiate existing antibiotics. The homotypic properties of cell membrane coating on NPs are hypothesised to increase nanoparticle-cell adhesion. In this study, we have isolated the lipid of *Escherichia coli* and used the harvested lipids as a coating for inorganic material such as gold nanoparticles (AuNPs) and re-exposed to host cells to test for enhancements in drug delivery.

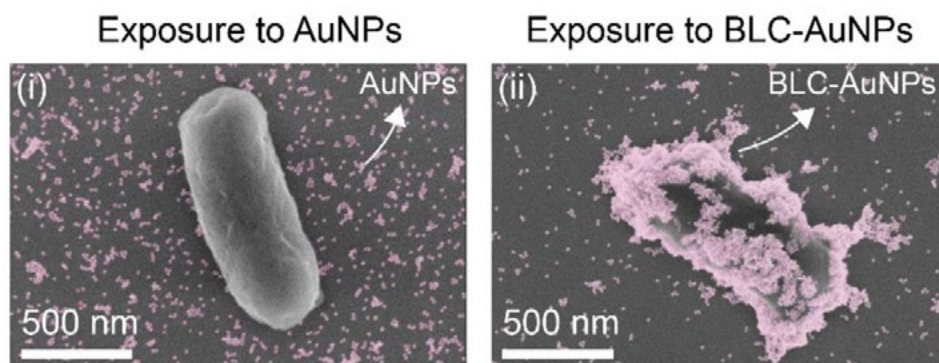
Aim: Testing the drug delivery potential of bacterial membrane lipids as NP coatings. This study aims to reduce the burden of AMR using biomimetic bacterial lipid coated gold nanoparticles (BLC-AuNPs).

Methods: Bacterial lipids were isolated using Folch method. Liposomes were prepared through extrusion. BLC-AuNPs synthesized through vesicle fusion (sonication). Various microscopic and spectroscopic techniques were utilised to characterize BLC-NPs and their interaction with their host cells (*E. coli*).

Conclusion: BLC-AuNPs were able to adhere to *E. coli* at a much higher frequency than bare AuNPs, showing that the addition of a bacterial lipid coating can increase the affinity of NPs to their respective host cells upon re-exposure and therefore may enhance drug delivery to pathogenic bacteria. Factors such as the NP coating, lipid composition, ionic strength and surface charge can greatly impact the observed interaction between NPs and bacteria.

Keywords:

Bacterial membrane, gold nanoparticle, biomimetic coating, lipid coated particles, cell adhesion, uptake



Differences in coating pattern between *E. coli* cells exposed to Bare AuNP (i) and BLC-AuNP (ii).

Disrupting the Deadly Fungus: How Amphotericin B Targets and Destabilizes the *Candida auris* Membrane

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Candida auris (CA) is an emerging fungal pathogen responsible for increasing numbers of fatal infections worldwide. Currently, only a limited number of antifungal agents are effective against this microorganism, among which Amphotericin B (AmB) remains one of the most important. AmB is an amphipathic macrolide polyene antibiotic whose antifungal activity primarily involves interactions with fungal cell membrane components, particularly ergosterol. In this study, the interactions between AmB and a model membrane mimicking the lipid composition of CA were investigated using Langmuir monolayers as simplified biological membrane models. Thermodynamic analysis and atomic force microscope (AFM) topographical imaging were employed to characterize the molecular interactions and their effects on membrane morphology. The results demonstrated a strong affinity of AmB for the model CA membrane, leading to significant structural degradation and fluidization of the lipid film. Detailed analysis confirmed a particularly strong interaction between AmB and ergosterol, which occurred effectively only when the AmB molecule adopted a horizontal orientation within the monolayer. Additionally, very strong interactions were observed between AmB and phosphatidylinositol (PI), a lipid present in both fungal and mammalian membranes. These findings suggest that PI may serve as an additional molecular target of AmB, potentially contributing to its known toxicity toward mammalian cells. Overall, the study highlights the importance of both specific lipid–drug interactions and the spatial orientation of AmB molecules in determining its antifungal efficacy and selectivity.

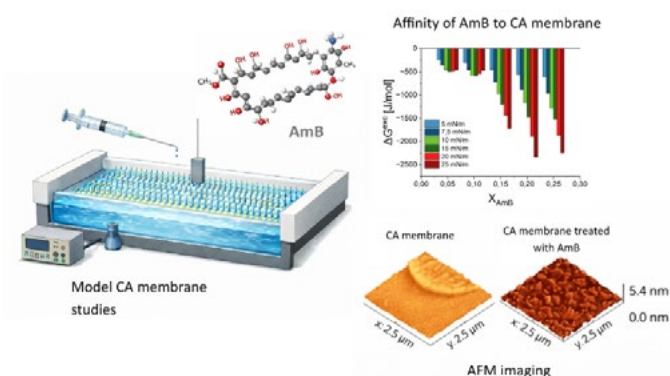


Fig. 1 Influence of AmB on *Candida Auris* membrane modeled with Langmuir monolayer

Unraveling the molecular mechanisms of cholesterol structural effects through Langmuir experiments and atomistic Molecular Dynamics simulations

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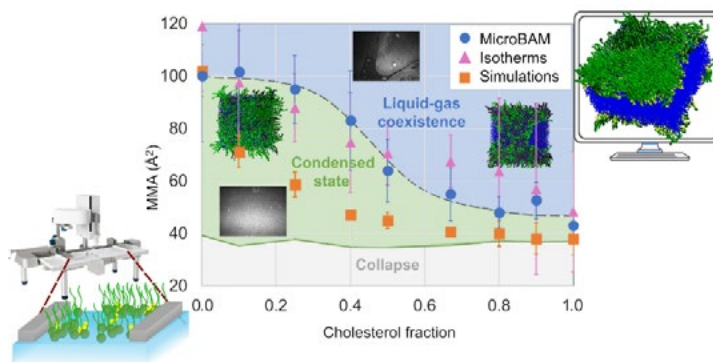
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Cholesterol is the main modulating agent of the structure, rigidity, and stability of animal cell plasma membranes. This study analyzes the influence of Chol on model membrane organization and phase separation through a multi-scale analysis of DPPC-cholesterol Langmuir monolayers, to uncover the microscopic mechanisms behind cholesterol's effect. By integrating experimental surface pressure-molecular area isotherms and Micro-Brewster Angle Microscopy (MicroBAM) with atomistic Molecular Dynamics (MD) simulations, we provide an atomic-level characterization of lipid-cholesterol interactions. Our results demonstrate a strong attraction between DPPC fatty acyl chains and cholesterol, which increases the monolayer stiffness and packing density. This interaction drives lipid chains into a more perpendicular orientation relative to the water surface, thereby minimizing their projected area and restricting chain entanglement. This reduced molecular flexibility leads to a distinct phase separation at low areas per lipid, characterized by the emergence of low-density voids and high-density domains, a phenomenon captured by both MicroBAM imaging and MD trajectories. These findings clarify the biophysical mechanisms by which cholesterol regulates biological membrane organization and validate the integration of atomistic simulations with microscopy as a robust framework for exploring complex lipid environments.

Keywords:

Cholesterol, DPPC, Langmuir monolayers, atomistic Molecular Dynamics simulations



Phase diagram denoting different states of a cholesterol-DPPC monolayer in terms of mean molecular area (MMA) and cholesterol mole fraction, integrating data from both experimental methods (MicroBAM images and surface pressure-area isotherms) and Molecular Dynamics simulations.

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From Monolayers to Liposomes: Physicochemical Insights into Lipid-Surfactant Interactions in Viral Envelope Models

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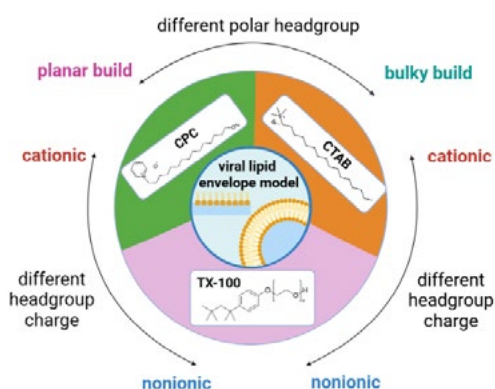
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The high genetic variability of viruses is a major challenge in the effective treatment of viral infections, as it hinders the development of efficient long-term antiviral therapies^{1,2}. In this context, surfactants capable of altering the physicochemical properties of viral envelopes that are independent of genomic mutations, represent a promising alternative strategy^{3,4}.

The aim of this study was to compare the ability of surfactants of different structures and charges, used at concentrations below their critical micelle concentration (CMC), to affect model lipid envelopes of selected viruses under various environmental conditions. Models of the SARS-CoV-2 lipid envelope (DOPC:DMPS:PI, 50:35:15 molar ratio) and the Influenza virus lipid envelope (DOPE:DMPS:SM, 50:35:15 molar ratio) were prepared as Langmuir monolayers (2D structures) and liposomes (3D structures). First, we compared the effect of two cationic surfactants - cetylpyridinium chloride (CPC) build of a planar polar headgroup and cetyltrimethylammonium bromide (CTAB) with a bulky polar headgroup, on SARS-CoV-2 lipid envelope model. The combination of Langmuir technique and surface potential measurements for planar systems along with dynamic light scattering (DLS) and fluorescence microscopy for spherical bilayer structures revealed a stronger impact of CPC on examined models due to its enhanced ability to penetrate lipid layers. Also, we examined how ionic strength affects this process, showing that higher ionic strength enhances the effectiveness of the surfactants. To gain deeper insight into lipid-surfactant interactions of CPC and CTAB, we applied Langmuir technique and DLS supplemented with spectrofluorimetry in mixed lipid-surfactant systems (i.a. DOPC:DMPS:SM:CPC) with varying molar ratios using SARS-CoV-2 and Influenza viral lipid envelope models. Obtained results allowed us to choose the optimal lipid-surfactant ratio to obtain stable structures. Additionally we compared the efficiency of cationic surfactants (CPC, LAE) and nonionic surfactants (Triton X-100, C₁₀EO₈) on a model Influenza virus envelope and a simplified model of a human cell membrane (DMPC:Chol 7:3) in PBS buffer. The results indicate distinct mechanisms of action between cationic and nonionic surfactants, with nonionic surfactants exhibiting a stronger disruptive effect on lipid layers. The obtained results show the importance of the environment, surfactant charge, polar headgroup structure, and concentration in interactions between surfactant and phospholipid membrane models.

Keywords:

viral lipid envelopes, surfactants, Langmuir, liposomes



Structures of the surfactants used to investigate the physicochemical alterations in the model viral lipid envelopes

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Density oscillations and confinement-induced forces in particulate fluids

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Understanding how particulate fluids organize near surfaces is essential for interpreting the behavior of colloidal and other confined soft matter systems. Under confinement, particles form condensed phases that support layering and crystal-like ordering of particulate systems that generate osmotic stresses on the confining surfaces. When in contact with a reservoir, the particulate fluid in the confinement can further support attractive depletion forces between the confining boundaries. A substantial body of literature describes the behavior of particulate fluids comprising uniformly sized particles. However, for multicomponent particulate fluids with size asymmetry—such as blood, blood plasma, and commercial particulate fillers in polymer melts—predicting the particulate structure under confinement and the stresses therein remains a challenge.

In this work, we employ Fundamental Measure Theory and free-energy minimization to investigate how particle size distribution, density, and confinement influence the structure and stress in confined particulate fluids (see illustration in the figure). We compute equilibrium density profiles under confinement and characterize density oscillations and particle segregation. Altogether, this study provides microscopic insight into how structural correlations and confinement jointly determine interfacial forces across complex fluids.

Keywords:

Complex fluid, Density functional theory, Fundamental measure theory, Osmotic stresses, Interfacial layering

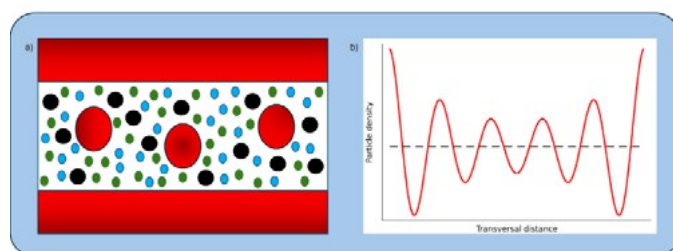


Figure: (a) Schematic of a confined particulate fluid between planar walls. (b) Density profile across the confinement, showing layering near the walls and a damped oscillatory structure around the bulk density (dashed line) in the interior.

BIOCOMPATIBLE LIPOSOMES CO-ENCAPSULATING TRIPLE ANTIRETROVIRAL COMBINATIONS AND TLR AGONISTS AS NANOPLATFORMS TO TARGET HIV RESERVOIRS

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Persistent cellular and anatomical HIV-1 reservoirs prevent durable remission after antiretroviral therapy (ART) interruption. We developed biocompatible phosphatidylcholine/cholesterol (PC:CHO) liposomes, with or without a cationic Ru(II)-based metallolipid (RuC19C19), to co-deliver triple antiretroviral combinations and Toll-like receptor (TLR) agonists as a dual pharmacological and immunomodulatory strategy.

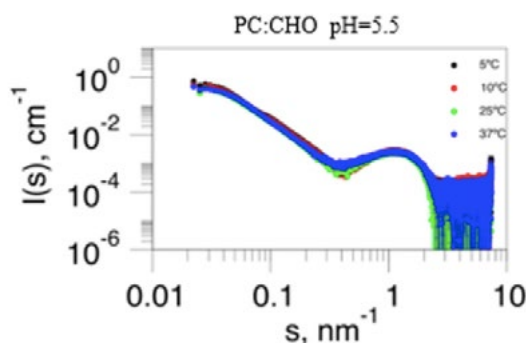
Two regimens (tenofovir/emtricitabine/nevirapine and tenofovir/emtricitabine/bictegravir) together with the TLR9 agonist (CpG ODN 2216) were encapsulated in the aqueous core, while TLR4 (LPS) and TLR7 (GS-9620) agonists were incorporated in the lipid bilayer. Liposomes were prepared by thin-film method to obtain unilamellar nanostructures that were characterised by dynamic light scattering, ζ -potential and small-angle X-ray scattering measurements. Particle sizes do not shown changes neither the temperature nor the pH. High antiretroviral encapsulation efficiencies were obtained in all the working conditions studied. Drug release at 310 K followed apparent first-order kinetics, with slower release from Ru-based liposomes and faster release for nevirapine- versus bictegravir-based antiretroviral combinations.

In vitro assays in several immunological cell lines and primary human Peripheral Blood Mononuclear Cells (PBMCs) indicated low cytotoxicity for PC:CHO liposomes over the tested concentration range. However, Ru-liposomes required low-to-intermediate concentrations to maintain cell viability. PC:CHO liposomes were non-haemolytic ($\leq 5\%$), while Ru-liposomes showed increased haemolysis only at the highest doses. Ru-liposome uptake by PBMCs reached $\sim 75\%$ after 6 h at 37°C .

Ongoing studies quantify TLR-driven dendritic and monocyte activation by multiparametric flow cytometry. Results support PC:CHO (with and without RUC19C19) liposomes are promising nanocarriers to enhance long-acting ART delivery while enabling innate immune activation, warranting further *ex vivo* evaluation in reservoir-relevant models.

Keywords:

Nanocarriers, biocompatible liposomes, metalloliposomes, HIV reservoirs, antiretrovirals, TLR agonists.



Small-Angle Scattering Intensity versus wave vector (SAXS data) collected for PC:CHO liposomes at pH 7.4 at different temperatures.

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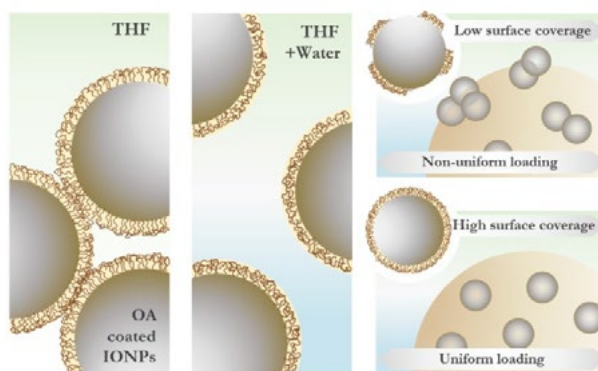
Insights into competing colloidal interactions in polymer encapsulation of iron oxide nanoparticles via flash nanoprecipitation

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The control over synthesis conditions is necessary to ensure high loading in polymer encapsulated iron oxide nanoparticles (P-IONPs) to enable magnetic-field-guided localization for biomedical applications. While flash nanoprecipitation (FNP) is a robust method to fabricate P-IONPs, very little is known regarding the response of hydrophobic IONPs to the change in solvent quality upon water addition and its effect on the nature of encapsulation. In this work, we first probe the cluster sizes of oleic acid (OA) coated IONPs at varying composition of water in THF(tetrahydrofuran)-water mixture through kinetic measurements using dynamic light scattering (DLS). It was found that the OA-IONPs exist as large micron sized clusters in THF, which broke into smaller clusters as water composition increased. A free energy model of clustering is presented and fitted to qualitatively describe the competing repulsive and attractive interparticle interactions driving the equilibrium cluster sizes (d^*) as a function of water composition. This effect was further pronounced when an aqueous Tween80 solution was added to the dispersion, resulting in individually dispersed IONPs at high . These interpretations from DLS measurements were confirmed using cryo-electron-microscopy. The d^* showed direct co-relation with the nature of P-IONPs produced using FNP at aqueous to organic flow rate ratio, resulting in complete encapsulation when IONPs were individually dispersed, and corona like assemblies around polymer particle surface at slightly larger d^* . Finally, a systematic study was performed to investigate the effects of concentration of polymer and IONPs on the extent and nature of encapsulation of IONPs with varying OA surface coverage. The IONPs with low surface coverage and high IONP concentration resulted in maximum encapsulation with non-uniform distribution of IONPs in the polymer particle matrix. Although, IONPs of similar sizes with higher surface coverage resulted in moderate encapsulation, the distribution inside polymer matrix was found to be highly uniform. These understandings on competing interactions during the course of encapsulation would enable rational design of P-IONPS using FNP, with high and uniform loading.



Schematic of IONP clustering and surface coverage driving encapsulation of IONPs

Engineering Biocompatible and Bioactive Stents for Improved Endothelial Integration in Cardiovascular Applications

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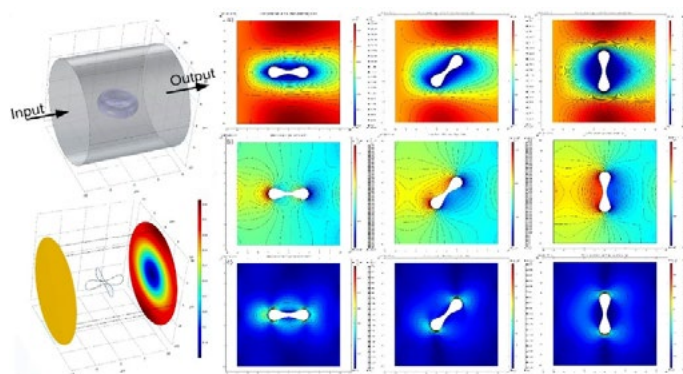
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Cardiovascular disease, particularly coronary artery disease (CAD), remains a leading cause of mortality worldwide. The project's aim is to fabricate and evaluate novel biomaterials (a combination of natural and synthetic polymers) for stents by combining casting and 3D bioprinting to develop stents that are slowly biodegradable, mechanically stable, reproducible, and compatible, and that enhance endothelial cell adhesion and promote endothelialisation. The innovative approaches address key challenges in stent biomaterial and design, thus reducing complications such as thrombosis and restenosis while enhancing vascular healing. A key part of the project is to predict the influence of stent shape, rheological, and material properties on blood flow parameters using Computational Fluid Dynamics (CFD) methods.

Keywords:

biomaterials for stents, enhancement of vascular healing, blood flow, computational fluid dynamics



Fluid dynamics around a red blood cell. Model (left): cylindrical tube (marked input and output surfaces), red blood cell shape placed centrally; input velocity is constant. On the right side are 2D maps of a) velocity; b) pressure; c) shear stress for cells rotated by 0°, 45°, and 90°

Acknowledgements:

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Synthesis Of Si/Si-BMNP Janus Particles For Drug Co-Administration

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Janus particles (JPs) are colloids that break spatial symmetry by featuring two or more domains with distinct physicochemical properties. This asymmetry grants them unique versatility in biomedicine, particularly in their potential to co-administer incompatible drugs, thereby overcoming the limitations of conventional vectors.

The central objective of this work is the synthesis of hybrid JPs combining silica spheres with magnetic components. Specifically, biomimetic magnetic nanoparticles (BMNPs) are employed, consisting of magnetite (Fe_3O_4) crystals synthesized in vitro to mimic bacterial magnetosomes [1]. The synthesis is carried out via the Pickering emulsion method, allowing for the selective functionalization of a single hemisphere of the silica particle. This results in a Janus structure (Si/Si-BMNP) with one bare silica face and another coated with magnetite [2]. The inclusion of these magnetic domains is critical, as it enables remote manipulation and heat generation via magnetic hyperthermia under alternating magnetic fields. In this regard, the magneto-thermal response, assembly dynamics, and the formation of chain-like structures of the Si/Si-BMNP have been exhaustively characterized, comparing their behavior against fully coated and half-coated particles.

Finally, their application potential is studied through the simultaneous immobilization of doxorubicin and tetracycline. This design allows for the targeted and localized administration of combination therapies in damaged tissues via magnetic guidance, minimizing adverse effects in healthy areas.

Keywords:

Janus particles, Pickering emulsion, Biomimetic magnetite, Magnetic hyperthermia, Drug co-administration

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Acknowledgements:

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Tuning structure and morphology of lipidic cubosomes by encapsulation of novel porphyrin-derivatives

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The encapsulation of biologically relevant molecules into non-lamellar lipid nanoparticles represents an effective strategy for drug delivery applications [1]. Cubosomes are suitable candidates as drug carriers, due to their intrinsic colloidal stability and higher loading capacity compared to vesicular systems [2]. However, the coexistence of different bicontinuous cubic phases induced by steric stabilizers, e.g., Pluronics, or the concurrent formation of vesicles during preparation can hinder a clear correlation between the physico-chemical properties of these nanostructures and their biological performance [1,2]. In this context, three novel porphyrin derivatives were synthesized and encapsulated into cubosomes composed of monoolein as the lipid building block and triblock copolymer Pluronic F108 as the steric stabilizer [3,4]: two target molecules were functionalized with bile acid moieties (cholic and deoxycholic) and one with a tetrapeptide, with the aim of developing advanced theranostic materials. Firstly, the effect of the cargo concentration was evaluated on the structure of the cubosomes, showing that the bile acid derivatives did not affect the lipid self-assembly, providing only the native cubic phase (Pn3m) of monoolein at the investigated concentrations. In contrast, increasing concentrations of the tetrapeptide derivative induced the formation of a mixed Pn3m + Im3m phase similarly to the behavior of the empty formulation, but also accompanied by a subsequent loss in crystallinity. The apparent hydrodynamic size or the polydispersity of the cubosomes after encapsulation was then studied at two different temperatures (25 and 37°C). Formulations containing 0.50 mg/mL of cargo exhibited higher colloidal stability over time, with no significant variations in size or ζ -potential for more than one month. Interestingly, formulations containing bile acid derivatives displayed the characteristic cubosome morphology and a reduced number of vesicles (approximately a 60:40 cubosomes-to-vesicles ratio), whereas the sample containing the tetrapeptide-linked porphyrin led to a cubosomes-to-vesicles ratio close to 26:74, comparable to that of the empty formulation. Experiments conducted at physiological temperature (37°C) highlighted that the structural features of the formulations remained largely unchanged, with retention of the phases observed at room temperature. Overall, the promising physicochemical properties, particularly at body temperature, highlight the potential of these systems as effective nanoplateforms for drug delivery applications.

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Self-Assembled Cubosomes as Colloidal Platforms for Antimicrobial Peptide Delivery

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Antimicrobial peptides (AMPs) represent promising alternatives to conventional antibiotics due to their broad-spectrum activity. In parallel, lipid nanoparticles have emerged as versatile colloidal carriers for targeted drug delivery; however, most clinically approved systems remain limited to lamellar liposomes.

Here, we propose non-lamellar lipid nanoparticles, cubosomes, as advanced carriers for peptide antibiotics. Cubosomes are self-assembled colloidal structures composed of a curved lipid bilayer enclosing an interconnected network of aqueous nanochannels, providing exceptionally high internal surface area and drug-loading capacity. To enhance interactions with bacterial membranes, the nanoparticles were functionalised to promote targeted binding.

The interactions of AMP-loaded cubosomes were investigated using both model lipid membranes and biological systems. The results indicate improved membrane affinity and suggest enhanced delivery efficiency of encapsulated peptides. These findings highlight cubosomes as promising, tunable colloidal platforms for antimicrobial delivery and support their potential in the development of next-generation nanomedicine strategies against antibiotic resistance.

Keywords:

lipid nanoparticles, cubosomes, antimicrobial peptide

Acknowledgements:

This study was supported by the Polish National Science Centre (Project No. 2025/57/B/ST4/04289).

Repurposing Amyloid beta as drug delivery carrier through controlled nano-assembly

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Amyloid beta is an intrinsically disordered protein capable of self-assembling into highly ordered cross beta sheet fibrils implicated in neurodegenerative diseases. Due to their structural polymorphism, inherent biocompatibility and excellent self-assembly properties they are ideal for repurposing into therapeutic materials with minimal immunogenic risk. Protein nanoparticles have gained attention as next generation drug delivery vehicles for cancer treatment due to their multiple advantages such as biocompatibility, versatile functionalisation, biodegradability. However, the design of carriers often rely on complex, energy-intensive synthesis routes involving toxic solvents. In addition, the challenges in suitability of proteins to withstand carrier synthesis conditions limit their clinical translation. In this work, we demonstrate the repurposing of amyloid beta ($A\beta$) - as proof of concept, into a non-pathogenic and biocompatible nanocarrier for drug delivery application. Factors such as solvent environment, pH, and biopolymer interactions were identified as integral in redirecting the protein's aggregation pathway toward stable, amorphous nanostructures rather than toxic fibrils. These findings were integrated with the development of drying-induced self-assembly method which is a solvent-free, energy-efficient, and highly scalable production workflow for nanoparticle synthesis. $A\beta$ was successfully repurposed into stable, drug loaded amyloid beta nanoparticles in the size range of 130-200 nm, with high encapsulation efficiency which demonstrated the feasibility of the developed synthesis technique. The $A\beta$ NPs exhibit a slow diffusion-mediated drug release. In vitro studies on MCF-7 breast cancer cell lines demonstrated enhanced cytotoxicity and ex-ovo CAM assay revealed significant inhibition of tumour-induced angiogenesis and downregulation of pro-angiogenic markers VEGFA, FGF2, and ANG1. Through this research, we aim to demonstrate repurposed protein based therapeutic systems with promising translational potential.

Keywords:

Amyloid beta, cancer therapeutics, drug delivery

A statistical approach to early-stage interactions between *B. subtilis* and ZnO-based surfaces through fluorescence tracking

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Understanding the mechanisms underlying the bioactivity of antimicrobial surfaces is essential for designing safer and more sustainable materials, while minimizing the risk of antimicrobial resistance through precise control of dose–response relationships. In this work, we investigate the early-stage interaction between ZnO-based bioactive coatings and *Bacillus subtilis*, focusing on bacterial motility as a sensitive indicator of antimicrobial activity.

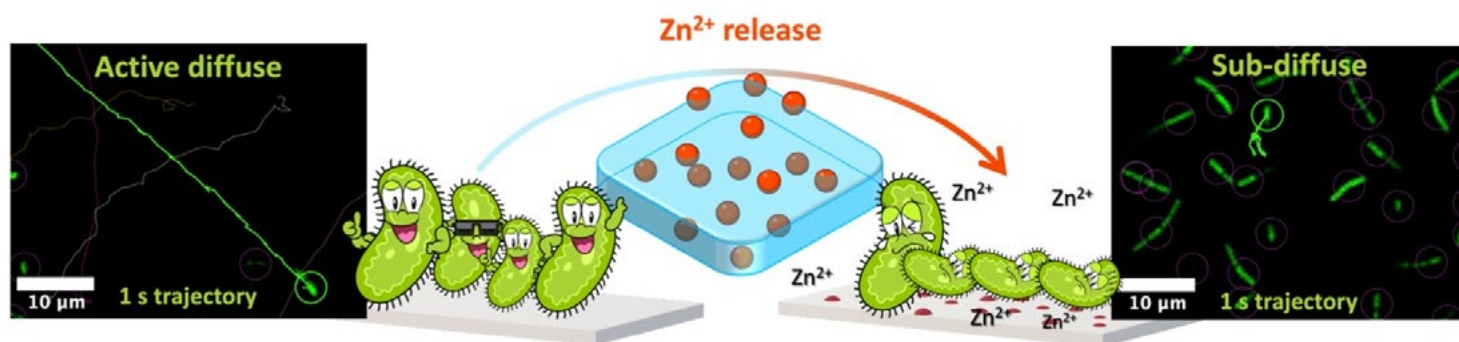
ZnO nanostructures (NSs) were synthesized via a scalable electrochemical method in aqueous phase[1], involving Sodium Dodecyl Sulfate (SDS) and Poly-Diallyl-Dimethyl-Ammonium chloride (PDDA) as stabilizing agents to tailor morphology. The resulting inorganic antimicrobials were incorporated into different polymeric matrices (polyethylene oxide, polylactic acid, and poly-vinyl-methyl-ketone), resulting in nanocomposite coatings with a controllable release of Zn^{2+} ions and, consequently, with controllable bioactivity. A comprehensive surface characterization was carried out using UV-Vis spectroscopy, Fourier-transform infrared (FTIR) spectroscopy, X-ray photoelectron spectroscopy (XPS), and both scanning and transmission electron microscopy (SEM/TEM).

The impact of Zn^{2+} ion release on the motility of *Bacillus subtilis* was monitored at short times using laser scanning confocal microscopy (LSCM)[2], coupled with particle tracking analysis. Mean squared displacement (MSD) analysis revealed a transition from typical run-and-tumble dynamics to sub-diffusive behavior upon exposure to Zn^{2+} ions. By integrating fluorescence-based live/dead assays with single-cell tracking, we established a robust statistical approach correlating ion release, bacterial motility, and viability.

This combined analytical approach provides a powerful methodology to distinguish between bacteriostatic and bactericidal effects at early interaction stages. Moreover, it highlights the potential of motility-based statistical analysis as a sensitive tool for probing microorganism–material interactions, supporting the rational design of antimicrobial coatings with spatially and temporally controlled activity[3].

Keywords:

Antimicrobial surface, Zinc oxide, Bacteria motility, Confocal microscopy, *Bacillus subtilis*



*Zn²⁺ release from ZnO-based surfaces induces a shift in *B. subtilis* from active diffusion to sub-diffusive motion. Fluorescence tracking of single-cell trajectories enables statistical correlation between motility changes and antimicrobial activity.*

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Doxorubicin and alginate interact synergistically to form nanoparticles

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Doxorubicin hydrochloride (DX) is a drug widely employed in cancer treatment, although its clinical use is limited by serious side effects, mainly cardiotoxicity and bone marrow suppression. One strategy to control its systemic toxicity is through the encapsulation in polymeric or lipid matrices to achieve targeted delivery into tumour tissues. DX has a distinctive chemical structure, characterized by the presence of a planar anthraquinone moiety, several chiral centres and a unique spatial organization of hydrogen bond donor/acceptor groups, responsible for its ability to intercalate into DNA, for its fluorescent properties and Circular Dichroism (CD) activity. Moreover, DX contains several ionizable groups, and by appropriately adjusting the pH, the molecule can exist in a cationic (pH < 7), neutral (pH ≈ 8) or anionic form (pH > 9). Such a characteristic can be exploited to trigger the DX interactions with other molecules [1].

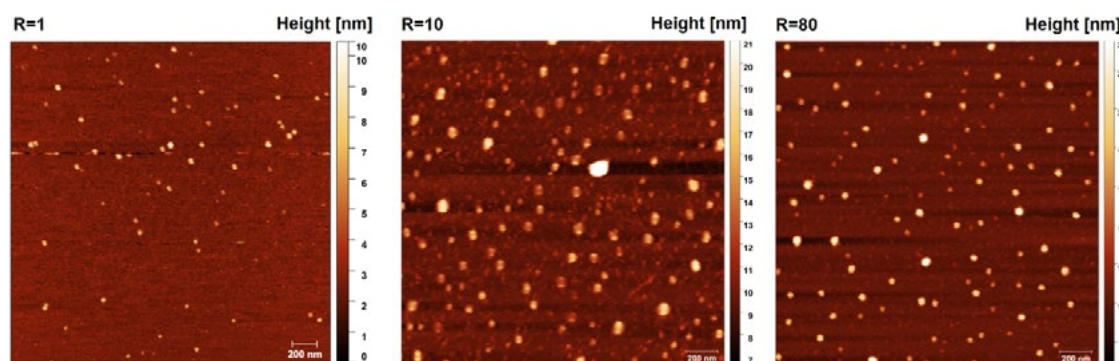
One of its distinctive features is its ability to self-assemble into dimers and, under certain conditions of drug concentration (≈ 10 mM) and ionic strength (>200 mM NaCl), to further aggregate into self-assembled supramolecular cylindrical polymeric aggregates, the entanglement of which leads to an increase in the macroscopic viscosity, resulting in the formation of a non-covalent gel phase (DX_{gel}) not observed with other anthracyclines [2-4]. However, DX_{gel} easily disrupts upon dilution, necessary to reach the drug therapeutic concentration.

Sodium alginate (ALG) is a natural polymer known to act as a gelator when in the presence of divalent cation, such as calcium. Both DX and ALG alone do not aggregate to form discrete nanoparticles (NP). However, when mixed at the right pH (between 4 and 6) and in the proper molar ratio (R), they do self-assemble into stable and monodisperse NPs (DX@ALG).

Here we present the full spectroscopic and structural characterization of DX@ALG NP for different values of R as well as the first in-vitro tests on selected cell lines.

Keywords:

Doxorubicin, sodium alginate, nanoparticles; biomaterials



AFM images in wet of DX@ALG at different values of R (R= moles ALG/moles DX).

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Stimuli-responsive polymersomes encrusted with biocompatible surfactants for rapid luminescence lifetime imaging through encapsulation of UCNPs

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The design of stimuli-responsive delivery systems, particularly those tailored to the acidic tumour microenvironment, has attracted considerable scientific interest. ¹ Among different colloidal vehicles, polymer-based nanocarriers with modern supramolecular architectures – polymersomes (PS), stand out. These are vesicular structures composed of amphiphilic copolymers that offer several advantages, including improved colloidal stability, enhanced loading capacity, biodegradability, ease of modification, and high versatility in surface functionalization. ^{2,3} For instance, PS can be used to encapsulate lanthanide-doped up-converting nanoparticles (UCNPs), which, with appropriately selected doping, will exhibit luminescent properties in the short-wave IR spectral region. This enables the development of desired NIR-emissive nanoplatforms with potential applications in biosensing and bioimaging. Furthermore, the application of appropriate surface-active agents, PS application features like long-term stability and the way they respond to stimulus can be regulated and improved.

In the presented contribution, biocompatible copolymers of poly (ethylene glycol)-block-poly(L-lactide-co-glycolide) (PEG-PLGA) were applied for the self-assembly of PS, which were carefully optimized and co-stabilized with coco-betaine, a mild amphoteric surfactant, along with non-ionic polymeric amphiphilic agent from the Pluronic group (F-127). After that, polymersomes were loaded with core@shell UCNPs – NaErF₄@CaF₂, which enabled the creation of luminescent stimuli-responsive nanoplatforms with pH-sensitivity owing to the PLGA building blocks, and the use of high dopant of Er³⁺ ions with recently reported high sensitivity towards water molecules. ⁴

Our results show that the presence of the selected surfactants improves the colloidal stability of supramolecular vesicles, while the use of PEG-PLGA enables the pH-responsiveness of designed nanoplatforms. Moreover, we conclude that the surfactant choice remains a key factor in designing such nanosystems, as we observed different trends in the UCNPs NIR-lifetime kinetics within the pH-induced degradation of UCNPs-polymersome structure for amphoteric and non-ionic surfactants. Presented intense emission and long luminescence lifetimes within the NIR region after excitation with the 980 nm laser show great potential of the proposed colloidal nanoplatforms in sensing and detection of the local microenvironment changes within biological tissues with decreased scattering and lack of autofluorescence.

Keywords:

polymersomes, lanthanide-doped UCNPs, long luminescence lifetime, stimuli-responsive colloidal biomaterials, NIR-emissive nanoplatforms

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Drug loading and release in stimuli-responsive microgels: insights from coarse-grained simulations

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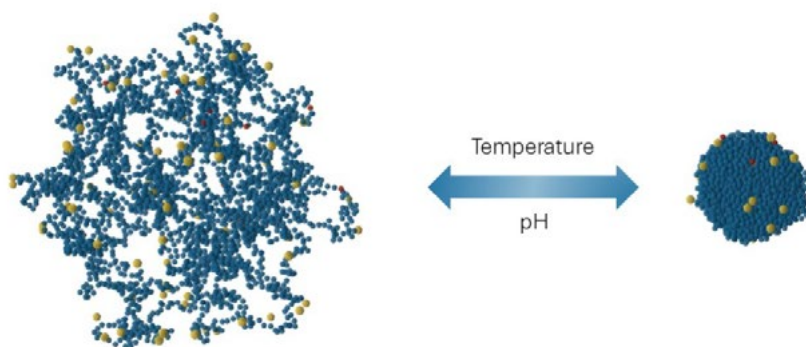
Stimuli-responsive microgels are promising platforms for controlled drug delivery, combining structural tunability with sensitivity to external stimuli such as temperature and pH. In this work, coarse-grained simulations were used to investigate the physicochemical parameters governing drug loading and release in temperature- and pH-responsive microgels. Thermoresponsiveness is modelled using a monomer–monomer hydrophobic interaction potential, while pH-sensitivity is introduced by incorporating charged monomers into the polymer network, mimicking the ionization of chemical groups at different pH conditions.

First, we characterized the structural and electrostatic properties of the microgels in the absence of drug molecules, analysing how particle size, net charge, and surface potential change depending on both the number of charged monomers and the hydrophobic interaction strength. Then, drug loading and temperature-triggered release were studied by modelling drug molecules as nanoparticles with tunable hydrophobicity, varied through a monomer–nanoparticle interaction potential. The effects of drug concentration, drug–polymer affinity, and the degree of microgel collapse on drug loading and release are explored.

These findings contribute to the understanding of the key parameters governing drug uptake and release in stimuli-responsive microgels, providing guidelines for the rational design of microgels as drug delivery systems.

Keywords:

Microgels, coarse-grained, simulations, drug delivery, stimuli-responsiveness



Snapshots of a drug-loaded microgel in the swollen (left) and collapsed (right) states, illustrating the structural response to temperature and pH. Blue and orange spheres represent neutral and charged monomers, respectively; yellow spheres represent drug nanoparticles.

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Nanovesicular formulations of estrogenic soft drugs as components of nanohybrid hydrogel for advanced wound care

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Estrogens are steroid hormones with well-documented roles in wound healing, but their systemic administration causes significant side effects. To overcome this drawback, active molecules can be converted into Soft Drugs, thus confining their action to the application site. In a previous study, two estrogenic soft drugs with a hydrolysable ester group, **1** and **2**, were identified as the most promising candidates for topical application [1,2].

In this work, compounds **1** and **2** were formulated in nanovesicular carriers, namely liposomes and transfersomes, and then loaded in hydrogel in order to obtain hybrid nanosystems, potential suitable for direct topical application (Figure 1). Nanovesicular formulations [3] were prepared using a phosphocholine (dipalmitoylphosphatidylcholine, DPPC, or dimyristoylphosphatidylcholine, DMPC) as the main component, in mixture with the estrogen derivative (**1** or **2**) and/or sodium cholate as edge activator. Formulations were physicochemically characterized by DLS and DELS analysis. The entrapment efficiency of **1** and **2** was assed by UV-Vis measurements. In addition, the leakage of estrogenic compounds was monitored over 24h.

Finally, the nanovesicular systems were adsorbed into gel matrices properly selected for their ability to maintain moisture, mimic the extracellular matrix, and support tissue regeneration, with the final goal to obtain suitable wound dressing. To this aim, a protein-polysaccharide hydrogel blend based on gelatin type A (GEL) and gellan gum (GG), respectively, was firstly developed. Afterwards, an interconnected porous membrane was prepared by a controlled freeze-drying process. Neat and loaded GEL/GG dressings were characterized in terms of morphological, physicochemical and biological properties by using human dermal fibroblasts.

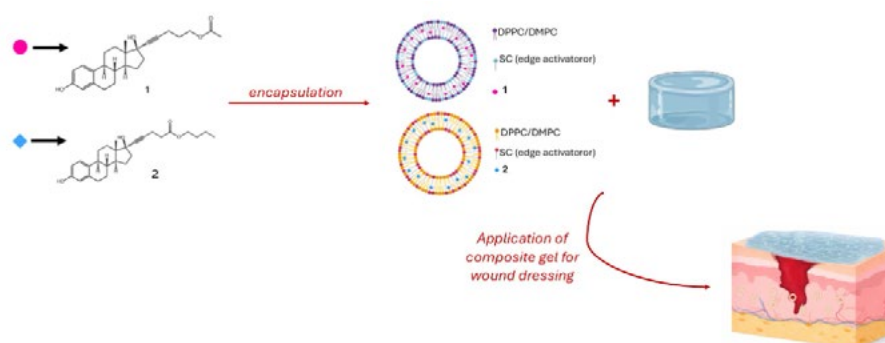


Figure 1: Transdermal nanocomposite drug delivery systems

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Control of PLGA Nanoparticle Size in Flash Nanoprecipitation: Understanding the Roles of Solvent, Concentration, Flow Rate, and Mixing Kinetics

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The success of Lipid nanoparticles (LNPs) in COVID-19 mRNA vaccines, have highlighted the potential of nucleic acid therapeutics. (1) However, their high cost and reliance on specialized lipids limit broader application. This motivates the development of scalable manufacturing approaches and delivery systems based on inexpensive, readily available materials. In this work, flash nanoprecipitation is explored as a scalable process, and poly (lactic-co-glycolic acid) as a cost-effective alternative material. (2)

To achieve predictive control over particle size, the effects of polymer concentration, solvent selection, and flow rate on PLGA nanoparticle formation are systematically studied under well-mixed FNP conditions. A strong solvent-dependent size trend is observed (DMSO < acetone < acetonitrile < THF), with particle diameters varying by more than a factor of three. This trend is independent of macroscopic mixing, indicating that nanoparticle size is governed by molecular-level solvent–antisolvent interactions.

An empirical scaling law is developed to quantitatively describe nanoparticle size as a function of polymer concentration and flow rate, yielding power-law exponents of 0.43 and 0.10, respectively, with excellent predictive accuracy ($R^2 = 0.99$). Solvent effects are captured through a dimensionless factor, which is subsequently reformulated using principal component analysis of solvent physicochemical descriptors, including dielectric constant and interaction parameters.

Keywords:

Flash nanoprecipitation,

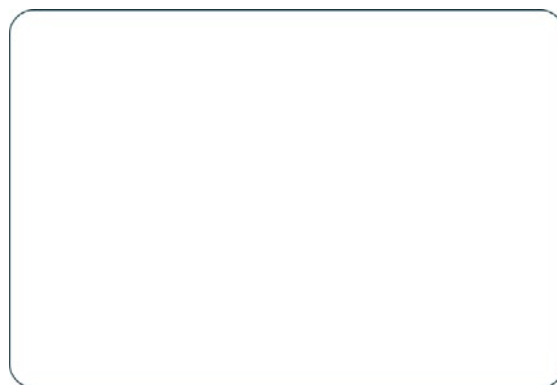
PLGA nanoparticles

Solvent effects

Phase separation

Flory–Huggins interaction parameter

Solvent–water



a) FNP setup. (b) Particle size vs solvent and concentration (5–30 mg/mL). (c–f) Particle number vs f (PLGA) for DMSO, acetone, acetonitrile, and THF..

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Preparation of biocompatible polymer-based drug delivery systems by continuous flow technique

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Nowadays, the polymer-based nanostructured drug carriers play a key role in the field of nanomedicine [1]. By using them, we can prolong and increase the efficacy of the drugs. Due to the excellent biocompatibility and good material properties, the poly(lactide-co-glycolide) (PLGA), poly(lactide) (PLA), or polycaprolactone (PCL) polymers are some of the most popularly used biopolymers in the development of new types of colloidal drug delivery systems. The importance of these polymers are also shown by the fact that many types of batch-based techniques were developed for the formation of the drug delivery systems, such as nanoprecipitation, double emulsion, etc., where the properties of the particles can be tuned by the preparation conditions. However, these methods are mainly applicable to the production of smaller sample volumes, and they can only be used in stages to produce a higher amount of particles. Various microfluidic devices are ideally suited for eliminating these issues, where more controllable preparation processes can be feasible in contrast to the batch-based methods [2]. With these techniques, the properties of the particles can be controlled by the flow conditions (flow rate, relative flow rate, type of the mixer cells (active or passive), etc.); thus, we can optimize the carrier systems for the drugs. Taking these into account, our aim is to prepare PCI-based drug-containing nanoparticles (NPs) by microfluidic systems and to determine the effect of the synthesis parameters (e.g., flow conditions, concentration, quality of stabilizing agents) on the size, polydispersity, encapsulation efficiency, and structure of the NPs. In order to fully characterize the particles, DSC, FT-IR spectroscopy, DLS, TEM, and UV-Vis measurements were used. During the synthesis of the PCI NPs, it has been proved that the hydrodynamic diameter and the size distribution of the particles can be controlled with the changing of flow rate, where, depending on the flow parameters, 210–300 nm particle size can be achieved. Based on the UV-Vis and DSC studies, 50–60% encapsulation efficiency (EE) and 18–25% drug loading (DL) can be achieved using vitamin D3 as a model drug. Dissolution properties of D3 were also determined in physiological conditions (pH = 7.4) and model gastric juice medium (pH = 1.5), where the results pointed out that release processes are greatly controlled by the type of stabilizers. The dissolution curves were fitted by different kinetic models, and the diffusion-controlled features of the encapsulated model drug were obtained at the 0–360 min interval.

Keywords:

colloidal carriers, biocompatible polymers, polycaprolactone, continuous flow system, drug formulation

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Encapsulation of nutraceuticals in biocompatible oligo(ethylene glycol) (OEG)-based microgels

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Stimuli-responsive microgels based on oligo(ethylene glycol) (OEG) represent an emerging class of smart materials with strong potential for biomedical applications, particularly in the encapsulation and controlled delivery of nutraceuticals. These microgels undergo reversible swelling or collapse in response to external stimuli, such as including temperature and pH [1].

Combination of colloidal techniques (hydrodynamic diameter and electrokinetic) was used to probe the physicochemical properties of the system. Nutraceutical encapsulation performance was evaluated through UV-Vis spectroscopy, quantifying both encapsulation efficiency and loading capacity to advance the understanding of OEG-based microgels as nutraceutical delivery platforms.

The swelling behavior and electrokinetic response of the microgels were systematically investigated as a function of pH and temperature, enabling determination of the volumetric phase transition temperature (VPTT) across a range of pH conditions and following nutraceutical occlusion. Various ratios of nutraceuticals to OEG microgels were analysed. Surprisingly, increasing nutraceutical concentration did not yield improvements in encapsulation efficiency or loading capacity. Continued research into these promising systems is needed to fully elucidate the underlying mechanisms governing their encapsulation behavior.

Keywords:

Oligo(ethylene glycol), Nutraceutical, Microgels

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Investigating phase behaviour of lipid-water-ethanol systems in lipid nanoparticle (LNP) formation

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Lipid nanoparticles (LNPs) are used as drug delivery systems, attracting much attention after their successful application in nucleic acid therapeutics including mRNA vaccines¹. LNPs are manufactured through mixing of ethanolic lipid solutions and aqueous solutions containing nucleic acid therapeutic payloads, typically using microfluidic mixers due to their controllable and reproducible mixing conditions. Molecular self-assembly of LNPs results from the complex interplay of constituent material properties and process parameters related to solution composition, temperature, and mixing². However, the process of self-assembly during mixing remains a “black-box” model requiring further research and understanding of this interplay to enable rational process development to enhance scalability and therapeutic advancements.

The aim of this project is to gain insight into the phase behaviour of LNPs by developing phase diagrams for the self-assembly process using a frequently used constituents: SM102, DSPC, Cholesterol, and DMG-PEG2000. Firstly, by establishing lipid constituent solubility in ethanol and binary water-ethanol miscible environments, we map out suitable concentration ranges LNP manufacturing. Secondly, we investigate their phase behaviour as the environment changes (e.g., water-ethanol ratio, pH, and ionic strength) and its impact on self-assembly. Lastly, we develop a phase diagram that identifies environments for stable LNP formation using widely used lipid constituents.

These findings will aid further development of process models for controlling the manufacturing process to tailor manufacturing to desired outcomes enabling faster production, reduced waste, and better control and scalability. This can be applied to enhance development of LNPs as drug delivery systems in therapeutics.

Keywords:

Lipid Nanoparticles, Phase Diagram, Pharmaceuticals, Drug Delivery

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Diffusion coefficients of fluoro-alcohols in fluorocarbons used in liquid ventilation

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The development of fluorocarbon-based microemulsions for biomedical applications has been a topic of interest in recent years [1]. Of particular relevance are water-in-fluorocarbon inverse emulsions, used for the transport and controlled release of drugs in the context of liquid ventilation [2].

The stability of these emulsions is fundamental to their successful use. This depends on a set of thermodynamic and thermophysical properties that must be known, such as the molar volume of water, the solubility of water in the continuous phase, the water/fluorocarbon interfacial tension, and the diffusion coefficient of water in the continuous phase. The mobility in the continuous phase of the surfactant used to stabilise the emulsion is also particularly relevant. Knowledge of these properties allows the stability of this type of emulsion to be predicted, which is a fundamental criterion for their use.

Among the surfactants to be used in this type of two-phase system, fluorinated surfactants stand out for their potential, of which fluorinated alcohols can serve as a simple model.

In this study, diffusion coefficients of a series of fluorinated alcohols (1H,1H-perfluoro-1-butanol, 1H,1H-perfluoro-1-pentanol, 1H,1H-perfluoro-1-hexanol, 1H,1H-perfluoro-1-heptanol and 1H,1H-perfluoro-1-octanol) in fluorocarbons used in blood substitute formulations and liquid ventilation (perfluoro-octyl bromide, perfluoro-decaline, pefluoro-octane) were determined as a function of composition and temperature, using the spin-echo NMR technique.

The results were interpreted in the light of knowledge accumulated in recent years regarding mixtures involving fluorinated and hydrogenated alcohols, water, alkanes and perfluoro-alcohols [3,4].

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Investigating Protein Interactions with Clay Nanoparticles: Molecular and Supramolecular Insights

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Clay nanoparticles have emerged as promising platforms for biomedical applications due to their unique physicochemical properties, high surface area, diverse ion-exchange capacity, tunable surface chemistry, and excellent biocompatibility. [1] Understanding their interactions with proteins is essential for both fundamental biophysical insights and the design of biofunctional nanostructures. Protein adsorption onto clay surfaces involves diverse mechanisms, including surface adsorption, partial intercalation, and conformational adaptation, yet the molecular details of these processes remain incompletely understood. [2]

In this study, we investigate the interactions between two structurally distinct proteins—myoglobin and carbonic anhydrase which differ in their secondary structure—and synthetic clay nanoparticles, including imogolite nanotubes of two aspect ratios, [3] as well as beidellite and laponite. We aim to elucidate how nanoparticle structure and surface properties influence protein adsorption, conformational stability, and supramolecular organization.

We combine spectroscopic and scattering techniques to investigate protein–clay nanoparticle interactions at both molecular and supramolecular levels. At the molecular level, UV-Vis, fluorescence, and circular dichroism spectroscopy are used to quantify protein binding and monitor conformational changes, while small-angle X-ray and neutron scattering probe the structural organization of protein-nanoparticle assemblies at the nanoscale.

Preliminary results, suggest that protein adsorption and conformational changes are strongly influenced by the nanoparticle aspect ratio and surface properties, highlighting the importance of nanoscale design in biomedical applications.

Keywords:

clay nanoparticles; proteins; self-assembly;

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Hydrophobic Cohesion Overrides Charge Reversal in RNA–Cationic Surfactant Condensates

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The rational design of nucleic acid delivery systems requires a precise understanding of the driving forces behind polyelectrolyte–surfactant condensation. While these interactions are often attributed to simple electrostatic neutralization, this model fails to explain why condensates remain stable beyond the point of charge equivalence. In this study, we investigated the interactions between polyuridylic acid (PolyU) and a series of cationic alkyltrimethylammonium bromide surfactants using dynamic light scattering (DLS), zeta potential measurements, UV–Vis turbidimetry, and isothermal titration calorimetry (ITC). DLS and zeta potential data show a progressive increase in hydrodynamic diameter alongside the systematic neutralization of the PolyU backbone. Notably, charge reversal occurred beyond stoichiometric equivalence, yet UV–Vis turbidimetry confirmed that the condensates persisted deep into this overcharged regime. Resolubilization was only observed at significantly higher surfactant concentrations, suggesting that a non-Coulombic force maintains the integrity of the complex.

To quantify this behavior, ITC was conducted at 20, 30, and 37.5 °C. Fitting the calorimetric profiles to a multi-step binding model revealed two distinct regimes: an initial enthalpically-driven electrostatic phase and a subsequent cooperative, entropy-driven phase. This second phase is governed by hydrophobic tail aggregation along the RNA backbone. The extracted parameters (ΔG , ΔH , $T\Delta S$) indicate that entropic contributions, resulting from counterion release and alkyl chain dehydration, become increasingly dominant as chain length and temperature increase. These results show that hydrophobic cohesion, rather than electrostatic complementarity, is the primary force sustaining these complexes after charge reversal. This work provides a quantitative thermodynamic results for optimizing the stability of non-viral gene delivery vectors.

Keywords:

Isothermal titration calorimetry, titration, calorimetry, surfactant-polymer interactions, thermodynamics

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Layered Magnetic Hydrogels for Cell Placement via Time-dependent Field Self-Assembly

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The design of hydrogel-based artificial tissues capable of reversible, programmed, and complex motions requires both stimuli-responsiveness and structural anisotropy. In this work, we achieve non-unidirectional anisotropies by structuring biocompatible hydrogels into lamellar architectures using particle suspensions. The method involves the application of an unsteady magnetic field to a static sample [1]. In this approach, magnetic particles undergo directed self-assembly within a polymer matrix that subsequently gels over time, effectively "freezing" the formed structures. We analyze the aggregation kinetics, characterize the resulting lamellar patterns, and construct phase diagrams for the available microstructure [2]. Crucially, we demonstrate that the resulting layered structures are capable of confining human fibroblast cells between adjacent particle-rich layers, highlighting the potential of these architectures for guiding cell positioning. The morphology and periodicity of the lamellae are shown to depend sensitively on particle concentration and geometric confinement. These findings pave the way for the development of advanced anisotropic hydrogels with programmable internal architectures, enabling applications in soft robotics, bioactuation, and tissue engineering.

Keywords:

Anisotropic hydrogel, magnetic hydrogel, magnetorheological fluid, lamella, layer, pattern, tissue engineering.

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Design of Metal Organic Frameworks and their application in anti-cancer drugs by machine learning

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This study explores metal–organic frameworks (MOFs) as advanced carriers for anticancer drug delivery, leveraging their high porosity, stability, and biocompatibility. By integrating machine learning (ML) with experimental and computational analyses, a predictive framework was developed to optimize MOF design and accurately model drug-release behavior. Various ML algorithms were evaluated to predict MOF functionality and guide the rational design of customized delivery systems. The results demonstrate that ML-assisted MOF engineering enables precise control over drug release, supporting optimized dosing strategies and personalized cancer treatment. Overall, this work highlights the strong synergy between materials science and machine learning in advancing next-generation drug delivery technologies.

Keywords:

Metal-Organic Frameworks (MOFs), Drug delivery Systems, Machine learning(ML)

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Controlling Crystallization for Improved Cryopreservation

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Cryopreservation has had huge benefits for the world at large, including preservation of blood and stem cells, along with assisted reproductive technologies.¹ However, there are many cell types that cannot be stored using current cryopreservation methods, and no organs.²⁻⁴ In fact, 60% of all donated hearts and lungs in the USA are discarded due to inadequate storage methods, and this waste could be overcome with cryopreservation.⁵

The main challenge in improving cryopreservation outcomes is the sheer number of variables that influence success such as cooling rate, vessel volume, crystal seeding, and the ongoing reliance on predominantly just two cryoprotective agents, both of which are toxic: dimethylsulfoxide (DMSO) and glycerol.^{6,7}

We have developed high-throughput methods of evaluating each of these variables to optimize cryopreservation protocols for specific cell types, especially those with previous poor cryopreservation outcomes. This includes designing new cryoprotectants and building novel methods of seeding ice crystals to control the freezing process.

Methods including cryomicroscopy, differential scanning calorimetry, and cell assays provide fundamental information which feeds into the optimised protocols.

These results provide new avenues of cryopreservation for cell types which cannot be preserved with existing methods. This in turn has wide-ranging benefits, especially in the biomedical field.

Keywords:

Cryopreservation, Crystallization, Freezing, Deep Eutectic Solvent

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Transforming Waste into Biomaterials: Ion-Engineered Calcium Phosphate for Dental and Toothpaste Applications

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The increase in human life expectancy has created new challenges for modern medicine, particularly in the field of regenerative medicine. According to the World Health Organization (WHO), dental and oral diseases are among the most significant public health problems worldwide, affecting approximately 3.5 billion people globally. It is estimated that complete tooth loss affects about 7% of adults worldwide and approximately 23% of people over the age of 60. In this context, the development of advanced biomaterials capable of supporting dental tissue regeneration and improving oral health is of great importance [1].

Calcium phosphate based materials play a key role in these applications due to their excellent bioactivity, biocompatibility, and chemical similarity to the inorganic components of human hard tissues, such as tooth enamel and bone. As a result, they are widely investigated for implant surface modifications, bone and dental tissue regeneration, as well as functional additives in toothpaste formulations aimed at enhancing enamel remineralization. At the same time increasing attention is being paid to sustainable approaches to biomaterials synthesis, particularly those that utilize industrial waste liquid as raw materials [2], [3].

The aim of this study was to synthesize calcium phosphate materials via the wet precipitation method using a model wastewater from ammonia recovery in the industrial Solvay process, containing: 1.1 M CaCl₂ and 0.95 M NaCl, as a sustainable source of calcium.

As a result of the synthesis brushite powder with an irregular lamellar morphology was obtained. Furthermore, selected ions with well-documented benefits for dental applications were incorporated via ion substitution. During the synthesis process, part of the calcium ions was replaced with 1% and 2.5% molar percentage of silver and zinc ions, as well as 0.1 molar % of fluoride ions.

The incorporation of these ions into calcium phosphate materials enhance their antibacterial properties, potentially reducing bacterial colonization in the oral cavity. These features make the materials particularly promising for dental applications, including implant coatings and remineralizing toothpaste formulations. Overall, this study demonstrates that calcium phosphate materials derived from industrial waste can serve as sustainable and functional biomaterials, combining waste valorization with potential benefits for oral health.

Keywords:

calcium phosphate; ion substitution, biomaterials, antibacterial activity, dentistry

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Raft polymerization provides better antifouling coatings on inorganic nanoparticles than grafting through polymerization

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Precise control of particle stability and the nanobiointerface is crucial for bioapplications. Nanoparticle properties are often altered after adsorption of a protein corona in a biological environment. Many applications become complicated due to non-specific binding of nanoparticles to proteins or cells. To avoid these inconveniences, inorganic nanoparticles need to be coated with polymers with antifouling properties, which create an intact surface and stabilize nanoparticles by steric hindrance. ¹ These hydrophilic polymers typically require further modification with functional molecules with defined orientation, and appropriate flexibility to meet specific application needs.

Various hydrophilic polymers have been used for this purpose such as polyethyleneglycol, polyoxazolines, polysaccharides, polyglycerol or poly(N-(2-hydroxypropyl) methacrylamide). ² There are various ways to attach polymers to nanoparticles such as “grafting to”, “grafting from” and “grafting through” methods. The last two approaches offer thicker and denser brushes, since the polymer grows from the particle surface.³

We present methods for coating inorganic nanoparticles with a dense polymeric shell composed of two distinct polymers. The inner layer consists of polyglycerol, synthesized via ring-opening polymerization, followed by an outer layer of poly(N-(2-hydroxypropyl) methacrylamide) (pHPMA). The pHPMA shell is formed using either conventional free radical polymerization or RAFT polymerization. The size and density of the resulting polymer layers are characterized and compared using dynamic light scattering (DLS), nanoparticle tracking analysis (NTA), transmission electron microscopy (TEM), and thermogravimetric analysis (TGA). To enable post-synthetic functionalization, two different functional monomers were incorporated into the polymer shell, propargyl methacrylamide or azidopropyl methacrylamide. The efficiency of their integration is evaluated by NMR and infrared spectroscopy. Their accessibility for subsequent “click” chemistry is assessed by conjugation with small molecules (e.g., dyes) and larger biomolecules (e.g., proteins). Finally, the reduction in non-specific binding of the polymer-coated nanoparticles to biomolecular structures is evaluated via surface plasmon resonance (SPR), confocal microscopy and flow cytometry.

As inorganic nanoparticles, we use fluorescent nanodiamonds (FNDs), which are a promising material for the preparation of near-infrared fluorescent probes and sensors for bioimaging due to their unique properties such as exceptionally stable fluorescence, sensitivity to magnetic and electric fields and broad biocompatibility. Unlike many other fluorophores, nanodiamonds do not photobleach and have a long fluorescence lifetime.⁴

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Surfactant-Based Polyelectrolyte Multicore Nanocarriers for Hydrophobic Cargo Delivery

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The delivery of hydrophobic compounds remains a fundamental challenge in colloid and interface science due to their poor solubility and limited stability in aqueous environments. Here, we report the design of polyelectrolyte multicore nanocarriers fabricated via a layer-by-layer (LbL) assembly approach, exploiting electrostatic interactions between micellar templates and oppositely charged polyelectrolytes [1]. The proposed system is based on the complexation of surfactant micelles with oppositely charged polyelectrolytes, followed by the deposition of functional multilayers, leading to the formation of stable multicore colloidal systems. This architecture enables the incorporation of hydrophobic cargo within micellar domains distributed throughout the polyelectrolyte matrix. The resulting nanocarriers exhibit sizes in the nanometer range (~200 nm), controlled surface charge, and high colloidal stability governed by electrostatic interactions. Moreover, the outer layer of the multilayer shell can be further functionalized (e.g., by PEGylation) to introduce steric stabilization and enhance their potential as drug delivery systems based on the enhanced permeability and retention (EPR) effect. To evaluate encapsulation efficiency and functionality, two model hydrophobic compounds were employed: coumarin 6 as a fluorescent probe and paclitaxel as a model anticancer drug. The micelle-assisted loading strategy enables efficient incorporation of hydrophobic molecules, while the multilayer shell provides structural integrity and modulates interactions with the surrounding medium. Biological studies confirm that the encapsulated cargo retains its activity, while the nanocarrier itself remains non-toxic. These findings highlight the potential of multicore micelle–polyelectrolyte assemblies as a versatile platform in colloid and interface science for designing tunable delivery systems based on self-organization, interfacial interactions, and multilayer structuring.

Keywords:

nanocapsules, nanocarriers, micelles, taxanes, EPR effect

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Engineering Light-Responsive Liposomal Complexes: Gold Nanorods as Photothermal Triggers for Targeted Drug Release

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The rational design of nanoparticle-based drug delivery systems requires a mechanistic understanding of how nanoparticle geometry and surface chemistry modulate lipid membrane behavior. As the structural and functional backbone of liposomal nanocarriers, lipid bilayers are highly sensitive to incorporated nanomaterials, and characterizing these interactions is essential for predicting therapeutic performance and biocompatibility. Here, we investigate the thermodynamic and photothermal effects of PEG-coated gold nanorods (AuNRs) on SOPC-based liposomal bilayers, with the aim of establishing their potential as controllable agents in light-responsive nanomedical systems.

PEG-AuNRs, used in the study, exhibit a rod-like morphology with an average length of 55 ± 18 nm and width of 15 ± 5 nm (aspect ratio ~ 4.1), consistent with a pronounced longitudinal surface plasmon resonance in the visible range. Dynamic light scattering confirmed a hydrodynamic diameter of 60-90 nm and a zeta potential of -26 mV, indicating moderate colloidal stability. A multitechnique approach combining ATR-FTIR spectroscopy, differential scanning calorimetry (DSC), and laser irradiation at 343, 515, and 1030 nm was employed to assess AuNR-membrane interactions across thermodynamic and optical dimensions.

DSC measurements reveal that AuNR incorporation at 0.5%, 1%, and 2.5% produces a non-monotonic, concentration-dependent perturbation of bilayer thermodynamics, with heating enthalpies of 0.269, 0.371, and 0.326 J/g respectively, indicative of a complex membrane interaction distinct from simple fluidization. Photothermal characterization in physiological medium demonstrates efficient light-to-heat conversion with strong wavelength and power density dependence: 515 nm irradiation at 0.2 W cm^{-2} yielded a maximum temperature increase of $\sim 38.9^\circ\text{C}$ within 10 minutes, while 1030 nm excitation produced only modest heating ($\sim 7.2^\circ\text{C}$), identifying the visible range as the optimal spectral window for AuNR-mediated thermal actuation. To summarize, these findings support AuNRs as high-performance photothermal agents capable of controllably modulating lipid membrane properties, with promising implications for thermosensitive liposomal drug delivery platforms.

Keywords:

nanoparticle membrane interactions; gold nanorods; photothermal therapy; light-to-heat conversion; laser irradiation

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Chitosan-coated mesoporous silica nanoparticles for controlled delivery of indomethacin

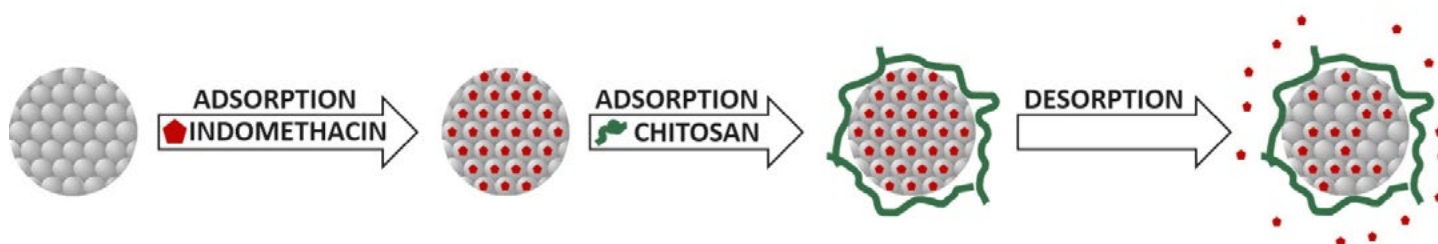
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Indomethacin (IDM) is a nonsteroidal anti-inflammatory drug with very effective antipyretic, analgesic, and anti-inflammatory activity. [1] Despite its therapeutic efficacy, its poor water solubility leads to limited oral bioavailability, [2] and its use is associated with irritation of the gastrointestinal mucosa. [3] A nanocarrier drug delivery system could be used to address both of these issues. A possible nanocarrier system to be used are mesoporous silica nanoparticles (MSN). MSN are a very attractive candidate for drug delivery due to their favorable properties, such as an ordered porous network with uniform pore size, large pore volume, and high specific surface area. [4] Preventing premature drug release is an important consideration in the design of nanocarrier drug delivery systems. One commonly employed strategy involves the incorporation of polymer layers onto nanoparticles via covalent linkage or adsorption. [5] A suitable candidate for this role is chitosan, a biocompatible and biodegradable polymer obtained by alkaline partial deacetylation of chitin. [6]

In this research, adsorption of IDM on MSN was studied under varying concentrations of indomethacin using UV-Vis spectrophotometry to determine optimal conditions for loading IDM on MSN. Subsequently, IDM-loaded MSN were prepared and further coated with chitosan with different molecular weights as well as some functionalized chitosans. Coated and uncoated IDM-loaded MSN were characterized by means of solid-state UV-Vis spectrophotometry, thermogravimetric analysis, differential scanning calorimetry, powder X-ray diffraction and scanning electron microscopy. Release of IDM from coated and uncoated particles was monitored using UV-Vis spectrophotometry to determine whether the chitosan coating slows down the release of IDM.



Graphical abstract

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PEI/Cy5-functionalized Carbonated Apatite nanoparticles for efficient luminescent gene delivery

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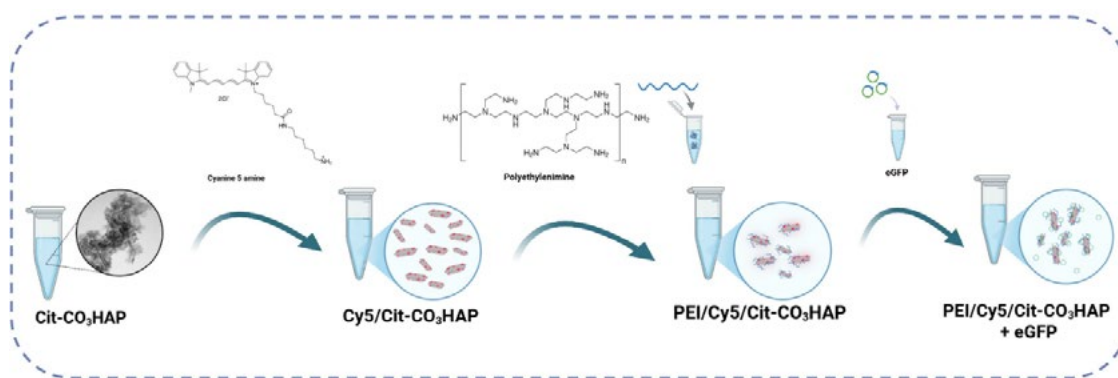
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Among nanomaterials designed for directed delivery and controlled release of therapeutic biomolecules, hydroxyapatite-based nanoparticles (HAPs) have gained attention in nanomedicine due to their excellent biocompatibility, structural similarity to bone mineral, and ease of functionalization. Here, we have developed matured citrate-coated carbonated HAP nanoparticles (Cit-CO₃ HAP), surface-functionalized with cyanine 5 (Cy5) and polyethyleneimine (PEI), as fluorescent gene delivery vectors both *in vitro* and *in vivo*. Plasmid DNA is loaded via isothermal adsorption onto the synthesized core-shell nanocarriers following the schema shown in figure.

The physico-chemical characterization of the nanosystem confirms its successful functionalization with Cy5 and PEI and the subsequent surface immobilization by physical adsorption of the negatively charged plasmid DNA (pDNA). The particle size based on the volume distribution for this functionalized nanosystem show a colloidal situation suitable for an adequate biodistribution in physiological fluids. Confocal microscopy experiments show an efficient cellular uptake and high transfection efficiency in breast and cervical cancer cell lines. Additional biocompatibility assays in cancerous and non-cancerous cells support the safety and versatility of these nanocarriers. The results highlight the broad potential of PEI/Cy5/Cit-CO₃ HAP nanoparticles as safe, efficient, and multifunctional luminescent gene delivery vectors.

Keywords:

hydroxyapatite nanoparticles, citrate functionalization, polyethyleneimine (PEI), fluorescent gene delivery, nanomedicine applications



Process for the synthesis of functionalized PEI/Cy5/Cit-CO₃HAP nanoparticles

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Comprehensive in vitro analyses of phosphorylated glucan chains originating from various starch granule surfaces

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Starch is the most important energy and carbon store, enabling plants to survive periods when photosynthesis is impaired. To survive these periods, proper starch degradation is crucial; this begins with the formation of phosphoesters on glucosyl units within the amylopectin molecules on the starch granule surface, carried out by two starch-associated dikinases (α -glucan water dikinase (GWD) and phosphoglucan water dikinase (PWD)). The phosphoesterification is currently the only naturally occurring covalent modification of starch and is closely linked to significant changes in the properties of the granule surface. GWD phosphorylates exclusively the OH-group at the C6 position, whilst PWD phosphorylates only the OH-group at the C3 position [1]. Moreover, it has been demonstrated that the action of the dikinases lead to the formation of mono-, di- and tri-phosphorylated α -glucans; nevertheless, the position within the glucan chain at which the phosphate group is incorporated remains uncertain [2].

Using ³³P labelling and MALDI-TOF-MS and MS/MS analyses, it has been demonstrated that the phosphate groups within the α -glucans are not always esterified at the same position relative to the reducing ends. However, GWD penetrates the surface of the starch granule and phosphorylates the glucosyl units near branching points, thereby converting the highly ordered glucan chains into a less ordered state and making them accessible to the downstream hydrolases [3]. In contrast, PWD phosphorylation shows a shift towards a greater distance from the reducing end or branching position, averaging approximately three glucosyl units further away. Neither the origin of the two enzymes (GWD and PWD) nor the associated sequence differences, nor the different types of starch, influence these positions.

Industry has a keen interest in starch, as phosphorylated starches are a promising biomaterial for various biomedical applications. A detailed understanding of the mechanisms of starch phosphorylation on the granule surface and their targeted modification could therefore represent a significant step forward in optimising protein and drug delivery, as well as the properties of orthopaedic implants, to name just a few possible applications and areas.

Keywords:

Phosphorylation, starch granule surface

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Nile red lipophilic anions interactions at organic aqueous interface - a way to visualize water and ion transport in ion selective membranes

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Nile red dye exhibits peculiar optical properties at organic-aqueous interfaces [3,4]. In such environments, its emission is changing due to protonation especially if formed cations can be stabilized by lipophilic anions present in either phase. This is observed as decrease of the emission intensity at ca 620 nm and formation of another emission maximum at ca 675 nm, visually this is observed as a change of the color of sample from red to blue.

These effects have been reported for interfaces of aqueous and organic media, especially in the presence of acids and surfactants in aqueous phase. However, interface of organic liquid (plasticizers) and aqueous phase is also formed within the receptor layers in sensors, especially in ion-selective membranes containing plasticized PVC, together with ion-exchangers and ionophores. In case of cation selective sensors typically used ion-exchanger are: sodium tetrakis[3,5-bis(trifluoromethyl) phenyl]borate or potassium tetrakis(4-chlorophenyl)borate, i.e. lipophilic anions are present in the system. Adding Nile red to classical composition of the receptor is not affecting analytical performance (selectivity, sensitivity, linear response range), however, it offers a unique opportunity to observe gradual hydration of the receptor, in course of necessary pre-treatment.

Gradual partition of aqueous phase into receptor results in formation of protonated Nile red (where aqueous phase in the presence of excess of organic one – plasticizer is a source of H⁺ ions). Formed cations are stabilized with ion-exchanger anions, resulting in a change of the membrane colour from red to blue. Thus, the process can be easily visually or fluorimetrically monitored.

Interestingly, for fully hydrated membrane upon contact with ions to which the membrane is selective, due to their preferential binding by neutral ionophore present in the receptor layer, hydrogen ions are expelled from the receptor (ion-exchanger anions are compensating ionophore – primary cations charges) resulting in deprotonation of Nile red. This can be observed visually or in emission mode as change of the colour of the membrane from blue to red or strong increase of emission at ca 620 nm.

Thus, introduction of Nile red dye to the ion-selective membrane composition enables colorimetric/ fluorimetric insight into process of ion-selective membrane preparation for sensing.

Keywords:

Nile red, ion selective membranes, ion transport, water transport, interfacial phenomena

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Highly-ordered microgel monolayers for precise and localized biomolecule capture: towards diagnostic and biosensing platforms

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Thermoresponsive microgels composed of poly(N-isopropylacrylamide) (pNIPAM) and poly(N-vinylcaprolactam) (pVCL) are self-assembled into ordered monolayers at liquid interfaces and transferred onto glass substrates via Langmuir-Blodgett deposition. Their colloidal stability and morphological changes under different liquid media, including phosphate-buffered saline (PBS), Dulbecco's Modified Eagle Medium (DMEM), supplemented DMEM (cDMEM), and HEK-293 cell culture, are evaluated via in-situ fluid-cell atomic force microscopy (AFM). Although both microgels show biocompatibility, only the softer pVCL ones remain structurally stable after incubation and cell removal, enabling reproducible microscopic characterization. Irreversible protein adsorption and exosome capture by pVCL microgels are confirmed by fluorescence microscopy, AFM and FTIR spectroscopy, and quantitatively estimated through AFM-based volumetric analysis and UV-vis microplate reader measurements. These findings establish that soft, low-crosslinked pVCL microgels are promising candidates for bioactive surfaces with high molecular uptake capacity for biosensing, diagnostics, and biomedical applications.

Keywords:

Thermoresponsive microgel, pNIPAM, pVCL, Fluid atomic force microscopy, Biointeractions, Biomolecules

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Encapsulation of (PT–Lap)/PAAm Hydrogels for Reliable Electrochemical Measurements for Wearable Electronics

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(PT–Lap)/PAAm physical hydrogels are used due to their unique combination of electrochemical conductivity, mechanical flexibility, and structural stability, while closely mimicking biological tissues, making them highly suitable for bioelectronic and flexible electronic devices [1], [2]. Their composite structure where the PAAm chains are linked by the (PT–Lap) cubosomes enables high stretchability, robustness, and ionic conductivity, while providing a relevant platform to study electrochemical interactions and environmental effects [3], [8], [9].

However these hydrogels exhibit strong dependence on environmental conditions. Their high water content makes them prone to evaporation, leading to conductivity instability and poor reproducibility of measurements [4], [5]. In addition, their non-ohmic electrochemical behavior and mechanical aging further complicate their characterization [5].

In this context, encapsulation becomes essential to stabilize their properties by limiting deshydration and improving measurement reliability [5]. A Kapton based encapsulation is well suited for experimental characterization due to its chemical stability and electrical compatibility [6]. However its limited flexibility restricts its use in real-world applications. Alternatively, elastomers such as PDMS (polydimethylsiloxane) provide a more flexible and stretchable encapsulation, better suited for bioelectronic systems while maintaining effective environmental protection [3], [7].

Electrical characterization will include time-dependent conductivity measurements, and charge–discharge experiments to evaluate stability, ionic transport, and electrochemical performance [9].

Work is in progress in order to gather more data and help in understanding the conditions in forming such complex and interesting smart assemblies for suitable electronic devices.

Keywords:

hydrogels, bioelectronics, flexible electronic devices, sensors, soft conductive materials

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Towards therapeutically relevant nanoparticle formulations: Influence of mRNA length

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To develop more efficient vaccines, immunotherapies and gene therapies, major efforts are being put into optimizing delivery systems for mRNA therapeutics. However, standard reporter mRNAs encoding for fluorescent proteins are rarely representative of their therapeutic counterparts. In fact, such therapeutic mRNAs, including the spike protein mRNA used in the COVID-19 vaccines, are often more than twice as long as common reporters used during development, directly influencing delivery efficiency. These issues stem from degradation, translation inefficiency, as well as encapsulation efficiency, meaning that to develop more predictable delivery vehicles and increase their clinical translation, better reporter mRNAs need to be developed.

Here, we have designed a set of mCherry-encoding constructs of varying lengths with retained protein encoding functionality when transfecting Jurkat T-cells. Using these constructs, we investigated the impact of mRNA length on both physicochemical and biofunctional properties of polymer-based nanotherapeutic delivery systems. The mRNA molecules were synthesised by in vitro transcription and purified using affinity-based chromatography. Their translational functionality into protein was confirmed in Jurkat T-cells using lab-grade, commercially available transfection reagent and flow cytometry analysis. For drug delivery purposes, the mRNAs were complexed with polymer-based nanoparticle systems, where physicochemical properties and influence of mRNA length was assessed, including size, zeta potential, encapsulation efficiency and morphology.

Our results demonstrate that increasing the length of the mRNA constructs results in translational functionality, although with lower transfection efficiencies compared to the native optimized transcript when using transfection standard JetMessenger (Figure 1). Following complexation with cationic polymers, the hydrodynamic diameter increased proportionally to both RNA length and concentration, with a minimum size of 100nm. In conclusion, our designed mRNA constructs offer a biologically relevant and quantifiable in vitro readout for delivery system development.

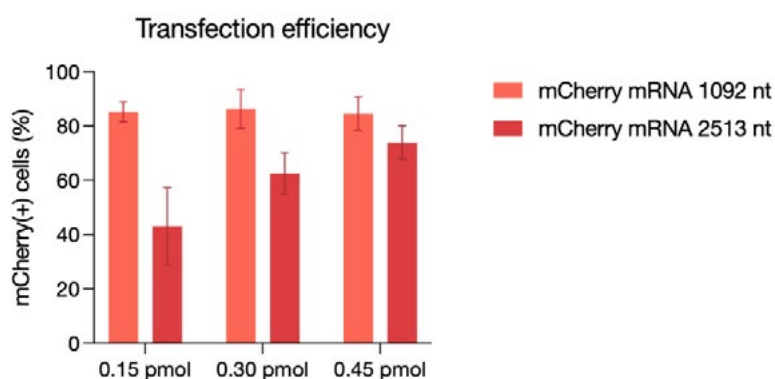


Figure 1: Transfection efficiency reported as percentage of fluorescence positive cells expressing 1092 nt and 2513 nt mCherry encoding mRNA. The mRNA was delivered to Jurkat T-cell line using JetMessenger transfection reagent and was evaluated by flow cytometry.

Magnetic Lymphocytes as Cellular Carriers for Nanoparticle Delivery Across the Blood–Brain Barrier in Glioblastoma

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Glioblastoma (GBM) is the most aggressive primary tumor of the central nervous system (CNS), with a 5-year survival rate below 5%. Its treatment is strongly limited by the blood–brain barrier (BBB), which restricts the entry of most therapeutic agents into the brain, including temozolomide, which reaches only ~20% CNS penetration [1].

In this context, magnetic nanoparticles (MNPs) have been explored as multifunctional platforms for drug delivery, imaging, and magnetic hyperthermia. However, their clinical application is hindered by rapid immune clearance and poor ability to cross biological barriers. To address these limitations, CD4⁺ T lymphocytes have been investigated as cellular carriers due to their intrinsic capacity to traverse the BBB and migrate toward inflamed neural tissue [2].

In this work, CD4⁺ T cells were functionalized with magnetic nanoparticles to generate magnetic lymphocytes. These cells retained key biological properties relevant for CNS delivery, including viability and migratory potential. The resulting hybrid system combines the natural BBB-crossing ability of T cells with the magnetic responsiveness of nanoparticles, enabling external magnetic guidance and improved targeting potential.

Overall, these results support the feasibility of using T cell–based magnetic nanoparticle carriers as a promising strategy to enhance delivery systems across the BBB for GBM applications.

Keywords:

Glioblastoma, magnetic nanoparticles, lymphocytes, blood-brain barrier

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Engineering Alloy Nanoclusters in a Cellulose Matrix for Enhanced Type-I Photodynamic Theranostics

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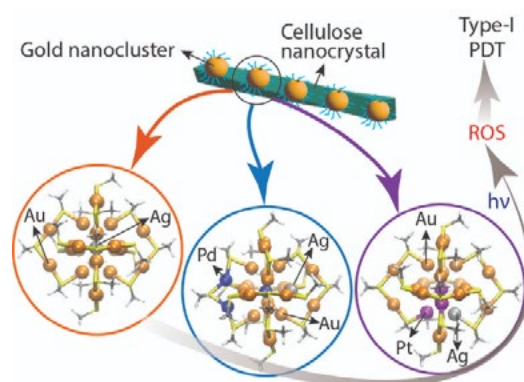
Photodynamic therapy (PDT) has emerged as a minimally invasive strategy for cancer treatment. However, its clinical translation is limited by oxygen dependence, poor selectivity, and suboptimal photosensitizer performance. ¹ In particular, conventional organic photosensitizers suffer from low solubility, limited tissue penetration, and phototoxic side effects, while many inorganic alternatives raise concerns regarding long-term toxicity and biocompatibility. ¹

Atomically precise gold nanoclusters (AuNCs) have emerged as an active area of great interest due to their ultra-small size (usually < 2 nm), discrete energy levels and most importantly their intrinsic biocompatibility. ² They are behaving in between the atoms and metal nanoparticles. Unlike plasmonic gold nanoparticles, structural control of the Au-cores in AuNCs generates specific bandgaps. As a result, AuNCs exhibit tunable optical properties that make them promising candidates for light-driven biomedical applications, particularly in the realm of imaging, sensing and theranostics. ³

Herin, we report a versatile theranostic platform based on bioderived cellulose nanocrystal-supported AuNCs (CNC–AuNCs) with selective mono- and multi-heteroatom (Ag, Pd, and Pt) substitution as Type-I photosensitizers. Heteroatom incorporation modulates photoluminescence and excited-state relaxation kinetics while maintaining high biocompatibility. Under light irradiation, nanocluster excited-state pathways enable efficient reactive oxygen species (ROS) generation, leading to effective Type-I photodynamic cell destruction. This approach doesn't rely on external oxygenation and may potentially be effective on hypoxia-responsive imaging and photodynamic therapy.

Keywords:

Gold nanoclusters, Cellulose nanocrystals, Photosensitizer, ROS, Theranostics



Trace heteroatom doping in CNC-supported gold nanoclusters enable efficient Type-I photodynamic theranostics.

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Investigating Gold Nanoclusters as Multimodal MRI and CT Contrast Agents

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Diagnostic imaging relies heavily on contrast agents to enhance signal-to-noise ratios and image clarity. While gadolinium-based contrast agents (GBCAs) are the current clinical standard for Magnetic Resonance Imaging (MRI), evidence regarding their long-term accumulation in brain and bone tissues has raised significant safety concerns.[1] Despite extensive research to find commercial alternatives, a gap remains for agents that offer both high performance and enhanced safety. Furthermore, the development of multimodal agents capable of providing contrast for both MRI and Computed Tomography (CT) would optimize medical costs and clinical time by eliminating the need for multiple contrast administrations.

This study explores the potential of gold nanoclusters (AuNCs) as highly tunable, multimodal contrast agents. AuNCs are composed of several to tens of atoms and possess diameters of only a few nanometers, resulting in unique physicochemical properties, including strong photoluminescence and high biocompatibility. In particular, the biological inertness, renal clearance, combined with the ability to control their properties at the atomic level, make AuNC very promising candidate for biomedical applications.[2] A series of AuNCs doped with various transition metals were synthesized, characterized and systematically tested for their dual-mode performance. Our findings demonstrate that AuNCs are suitable agents for integrated MRI and CT imaging, offering a safe and practical option for clinical use .

Keywords:

Gold nanoclusters, metal doping, contrast agents, MRI, CT

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Noble metal nanoclusters surface-modified with amino acid derivatives

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Nowadays, various noble metal nanostructures are the focus of numerous research projects. Thanks to their unique optical and structural properties, they can be used in wide range of application, including electronics, (bio)catalysis, (bio)sensorics and biomedical science.

Our research group has been investigating the synthesis of noble metal nanoparticles and nanoclusters for 12 years. One of the main directions is the production of gold and silver-containing nanoclusters stabilized and surface-modified with small molecules, as well as the characterization of their structure and the exploration of their sensor applications. We have previously proven the applicability of various amino acids, such as phenylalanine [1] and tyrosine [2], for the formation of blue-emitting nanoclusters. As a continuation of this research, we set out to investigate modified versions of the amino acids that had proven successful, with the aim of determining whether it is possible to tune or alter the structural and optical properties of the resulting clusters. The modification involved the incorporation of an electron-rich hydroxamic acid group with chelating properties in the case of the aforementioned phenylalanine and tyrosine ligands.

In my work, I investigated whether stable gold and silver nanoclusters with good optical properties can be prepared using hydroxamic acid derivatives of the amino acids tyrosine and phenylalanine. I primarily determined the experimental conditions governing the formation of the products, such as the ratio of the metal ion and the stabilizing ligand used, and the metal concentration, but I also examined the effects of temperature, pH, and reaction time. After the products were prepared, I also developed a protocol for their purification.

We determined the detection limit and, through temperature-dependent fluorescence quenching experiments, also determined the thermodynamic parameters of the quenching.

Keywords:

nanoclusters, hydroxamic acid, fluorescence quenching, noble metal

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Surface-engineered silica nanoparticles as versatile platforms for bioconjugation of MAGE and other bioactive molecules

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Cancer progression is strongly influenced by the biochemical complexity of the tumor microenvironment, where advanced glycation end-products (AGEs), including the recently identified melibiose-derived AGE (MAGE), are emerging as important modulators of cellular responses. However, the biological role of MAGE is still not fully understood, and its endogenous origin in tissues remains unknown, clearly indicating the need for further research [1-3]. To enable systematic investigation of MAGE-related processes, there is also a growing need for well-defined, multifunctional, surface-engineered nanomaterial platforms capable of controlled bioconjugation and delivery of MAGE.

In this study, we report the development and preliminary evaluation of silica-based nanoparticle systems functionalized using organosilane chemistry to introduce reactive surface groups enabling controlled bioconjugation. A set of functional silanes, including amino-, aldehyde-, and N-hydroxysuccinimide-terminated precursors, was employed to modulate surface reactivity and provide anchoring sites to attach MAGE, fluorescent probes, as well as model therapeutic agents (doxorubicin). The resulting nanosystems were characterized using SEM, TEM, XPS, FTIR, and EDS to get detailed picture of their morphology, surface functionalization, and chemical composition, while DLS and zeta potential data provided valuable insights into colloidal properties of the obtained systems.

Overall, these preliminary results demonstrate the feasibility of constructing stable, chemically versatile nanoplateforms for MAGE bioconjugation, where both, porosity and surface chemistry affects the bioconjugation efficiency. The developed systems provide a robust foundation for future studies on MAGE-loaded nanoparticles as the potential carriers of drugs targeting different cells within the tumor microenvironment and thus their potential application in bioanalytical and therapeutic contexts.

Keywords:

Silica nanoparticles, Surface functionalization, Organosilane chemistry, Biomolecule immobilization, Bioactive surface design, Nanocarriers, MAGE

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Laser-Induced Graphene substrates: electrical, structural and biological characterization for biomedical applications

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Laser-Induced Graphene (LIG) has emerged as a promising two-dimensional material for biomedical applications due to its high electrical conductivity, tunable surface properties, and biocompatibility. In this work, LIG substrates were fabricated from commercial polyimide (PI) via laser photoablation, systematically varying key processing parameters such as laser power, scan speed, and pattern design to achieve controlled physicochemical and structural properties ¹.

A comprehensive characterization of the resulting substrates was carried out, including electrical measurements, surface morphology and roughness analysis, as well as wettability assessment through contact angle measurements. In addition, *in vitro* biological assays were performed to evaluate cell-substrate interactions ^{2,3}.

The results demonstrate that LIG substrates can be reproducibly fabricated with tailored surface morphologies and suitable electrical performance. Importantly, these substrates exhibited good biocompatibility, supporting cellular adhesion and guiding cell growth, with surface topography playing a key role in modulating cellular behavior ⁴.

Overall, these findings highlight the potential of LIG as a versatile and tunable platform for the development of advanced biointerfaces, paving the way for future applications in bioelectronics, tissue engineering, and biomedical devices.

Keywords:

Laser-Induced Graphene (LIG); biointerfaces; wettability; contact angle hysteresis; surface roughness; graphene-based materials; cell–substrate interaction

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Chimeric bio-hybrid liposomes for targeted therapy against Triple-Negative Breast Cancer

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Triple-negative breast cancer (TNBC) is an aggressive carcinoma driven by chemoresistant cancer stem cells (CSCs) responsible for relapse and metastasis. While cell membrane-coated nanoparticles offer a promising biomimetic strategy, their clinical translation is often hindered by low membrane yields and batch variability. To address these limitations, we developed Hybrid-MASLiN, a scalable core-shell nanoplatfrom featuring a bioactive solid lipid nanoparticle core composed of maslinic acid (MA). This core encapsulates the hydrophobic drug docetaxel (DTX) to enable a synergistic dual-therapy. This core serves as a versatile carrier that can encapsulate hydrophobic drugs such as docetaxel (DTX) to enable a synergistic dual-therapy (MASLiN). The MASLiN core is cloaked with a chimeric hybrid liposomal shell that co-assembles synthetic lipids with biological membrane fragments derived from CSCs and T-lymphocytes. This modular coating exploits homotypic recognition for precision targeting of aggressive tumor cells, while providing an immunomodulatory interface designed to counteract the immunosuppressive tumor microenvironment.

Successful assembly was validated via Dynamic Light Scattering (DLS) and TEM-EDX, which confirmed the presence of a phosphorus-rich lipid bilayer surrounding the electron-dense MASLiN core. Functional assays highlighted the selective profile on the nanoparticles. Hybrid-MASLiN increased cellular internalization and cytotoxicity in TNBC cells and CSCs compared to bare formulations, while exhibiting minimal uptake and no toxicity in healthy fibroblasts and T-lymphocytes. Furthermore, acute systemic toxicity studies in immunocompetent mice showed no adverse effects at high doses, supporting overall biocompatibility. By integrating the biophysical robustness of synthetic liposomes with the homing precision of biological membranes, this chimeric interface presents a promising, scalable approach to overcoming the translational barriers of biomimetic nanomedicine in refractory tumors.

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Biomechanical alterations in breast cancer cells

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Understanding how the tumour microenvironment shapes cellular biomechanics is key to explaining cancer progression [1]. Using AFM, we examined how cell–cell contact, culture time and dimensionality (2D vs. 3D) influence the mechanics of breast cancer cells.

Cell–cell contact produced no major differences, though small sample sizes may limit preliminary conclusions. Time showed a crucial role causing a reduction in the young's modulus of the cells when cultured longer periods of time. Dimensionality was assessed comparing the cells in monolayers to the cells in the upper stratum of the spheroid, Spheroids displayed a reduction in the young's modulus compared to the cells in monolayers.

Overall, cellular biomechanics are highly context-dependent and strongly shaped by microenvironmental cues, underscoring the importance of physiologically relevant models.

Keywords:

Breast cancer, 2D, 3D, Cell mechanics

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Soluplus® Micellar Systems as Nanocarriers for Leishmaniasis Therapy

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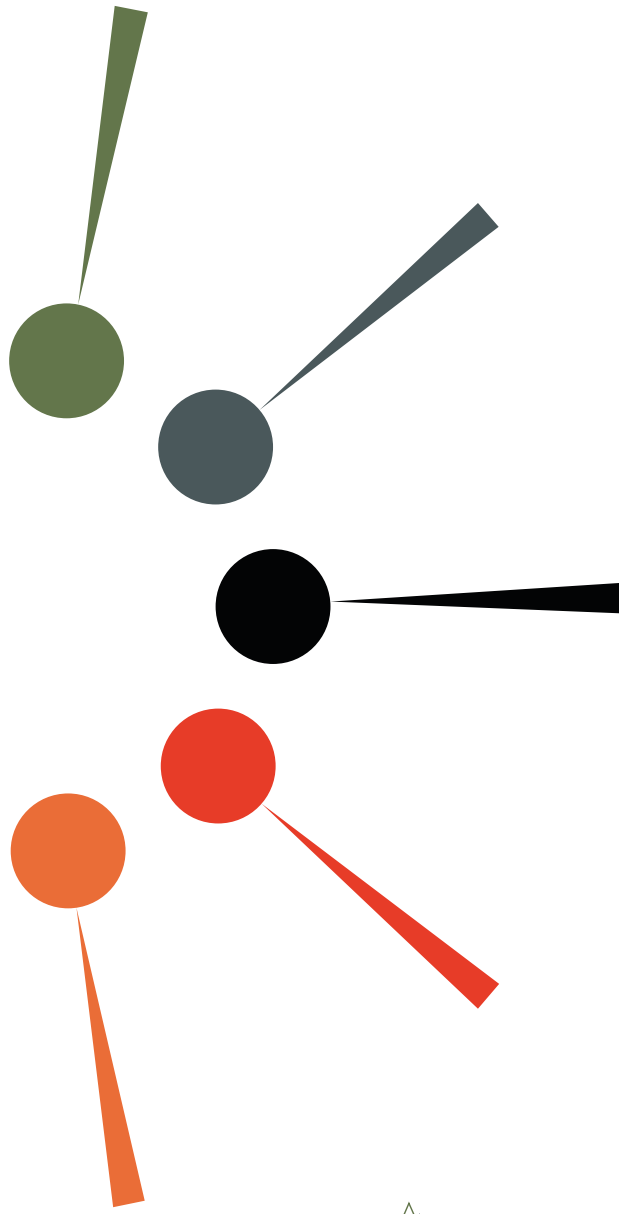
The development of advanced colloidal carriers for localized treatment of Cutaneous Leishmaniasis (CL) offers a superior alternative to conventional systemic therapies, which are often limited by toxicity and drug solubility. This study explores the development of a tunable colloidal platform based on Soluplus® (SLP), an amphiphilic triblock copolymer, focusing on the fundamental interactions that drive drug encapsulation and biological efficacy. Using Dynamic Light Scattering (DLS), Nuclear Magnetic Resonance (NMR), and Small-Angle Neutron Scattering (SANS), we analyzed the structural transitions from the pristine polymer to binary and ternary systems. We found that drug partitioning is strictly dependent on the component ratios: while PTM consistently interacts with the hydrophilic PEG shell, the role of MF is adaptive. In MF-dominant regimes, SLP acts as an interfacial stabilizer for MF-rich micelles. Conversely, in SLP-dominant systems, MF is incorporated into the micellar shell. The ternary system (SLP/PTM/MF) exhibits a complex colloidal hierarchy influenced by temperature: the system reorganizes into stable SLP micelles with MF:PTM complexes in the shell, coexisting with highly dispersed drug-polymer complexes. *In vitro* biological assays demonstrated that binary (SLP-drug) and ternary (SLP/PTM/MF) systems maintain potent antileishmanial activity against *Leishmania major* promastigotes and intracellular amastigotes, and reduce cytotoxicity in macrophages compared to pure drugs. The ternary system reveals a significant therapeutic synergy, enhancing antiparasitic action. Overall, these results highlight the potential of SLP-based colloidal formulations to provide a safer and more efficient localized treatment for cutaneous infections.

Keywords:

Soluplus, Leishmaniasis, Pentamidine, Miltefosine, DLS, NMR, SANS

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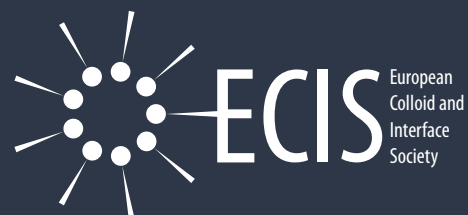
This research was funded by the Ministerio de Ciencia, Innovación y Universidades from Spain (MICIU/AEI/10.13039/501100011033, PID2023-147765OB-C21,-C22), and Fundación Roviralta (Chair “Maria Francisca de Roviralta of Molecular Parasitology, Leishmaniasis and One Health”). N.G.-M. thanks the Ministerio de Ciencia, Innovación y Universidades from Spain for her doctoral grant (FPU22/01186). We also acknowledge COST actions CA21105 (OneHealthBlastocystis) and CA21111 (OneHealthdrugs).



Topic 2

Colloid and Interface Science
in Industry, Environment,
Sustainability, Cosmetics and Food

! POSTER



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Ruthenium Single-Atom Sites Stabilized on Functionalized Al-MOF for Electrochemical Hydrogenation

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The development of efficient catalysts for electrochemical hydrogenation (ECH) requires precise control over active site dispersion and substrate–catalyst interactions. Herein, we report a post-synthetic modification strategy to engineer Al-MOF-303 for stabilizing atomically dispersed ruthenium sites for ECH applications. The parent Al-MOF-303 was functionalized with aniline to introduce nitrogen-rich coordination environments, enabling the anchoring of isolated Ru atoms within the framework.

Structural integrity of the modified material was confirmed by X-ray diffraction (XRD), Fourier-transform infrared spectroscopy (FTIR), and solid-state ^{13}C NMR. Aberration-corrected HAADF-STEM and X-ray absorption spectroscopy (XAS) analyses verify the atomic dispersion of Ru and reveal a well-defined Ru–N_x coordination environment. X-ray photoelectron spectroscopy indicates a Ru oxidation state close to +3, suggesting strong metal–ligand interactions that stabilize the active sites.

Electrochemical hydrogenation studies demonstrate that the Ru single-atom catalyst exhibits enhanced activity and selectivity compared to the pristine and modified MOF counterparts. The improved performance is attributed to the synergistic interplay between isolated Ru sites and nitrogen coordination, which promotes efficient adsorption and activation of reactant molecules while modulating hydrogen adsorption behavior. Furthermore, the tailored coordination environment suppresses competing hydrogen evolution, enabling improved hydrogen utilization efficiency.

This work highlights that functionalization of MOFs provides a versatile platform for stabilizing single-atom catalysts and tuning their catalytic properties for electrochemical hydrogenation. The findings offer insights into the rational design of MOF-based single-atom electrocatalysts for selective hydrogenation reactions.

Keywords:

Single-atom catalyst, Metal–organic framework (MOF), Functionalization, Electrochemical hydrogenation, Ru–N coordination

Role of Particle Size and Surface Wettability in the Mineralization of Decorative Polystyrene Microplastics with Calcium Carbonate

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Decorative polystyrene (PS) microplastics, widely used as additives in paints, are increasingly recognized as a source of environmental contamination, as they can readily enter aquatic and terrestrial ecosystems during use and degradation. Due to their small size and persistence, these particles are easily transported and ingested by living organisms, raising concerns about their accumulation and potential ecological impact. In natural systems, mineralization processes, particularly calcium carbonate (CaCO_3) formation, are often associated with living organisms, where they play a fundamental role in biomineralization (e.g., shell and skeleton formation). However, similar processes may also occur on abiotic substrates such as microplastics, altering their surface properties, environmental behavior, and interactions with biota.

This study investigates the mineralization of decorative PS microplastic particles with sizes of 0.07 mm, 0.1 mm, and 0.4 mm. The main objective was to evaluate the influence of particle size and surface wettability on the efficiency of calcium carbonate formation. Mineralization was carried out using two approaches: CO_2 diffusion and direct precipitation from calcium chloride and sodium carbonate solutions at concentrations of 0.05 M, enabling controlled CaCO_3 deposition on hydrophobic polymer surfaces. To enhance surface wettability, an anionic surfactant, sodium dodecyl sulfate (SDS), commonly found in cosmetic and household products was applied.

The results demonstrate that calcium carbonate effectively nucleates and grows on the surface of microplastic particles, with preferential deposition at high energy sites such as edges and surface irregularities. Improved wettability leads to more uniform and extensive mineral coverage. A clear particle size effect was observed.

These findings confirm that controlled mineralization of decorative microplastics can be achieved through appropriate surface and chemical conditions, providing insight into their transformation in the environment and suggesting a potential pathway to limit their mobility and impact in ecosystems.

Quantum Dots for automotive lighting systems

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Semiconductor quantum dots (QDs) have emerged as promising materials for advanced automotive lighting technologies due to their tunable optical properties, narrow emission bandwidth, and high photoluminescence efficiency. In this work, we present the experimental design and fabrication of photoluminescent QD-based composite films for automotive optoelectronic applications. The study focuses on the synthesis of environmentally compliant core-shell QDs and their integration into transparent polymeric matrices to develop efficient light-conversion layers suitable for next-generation vehicle lighting systems.

Colloidal synthesis methods were employed to produce InP/ZnS core-shell QDs as cadmium-free alternatives compatible with current environmental regulations. ZnS shell growth was used to enhance surface passivation, improving photoluminescence quantum yield (PLQY) and chemical stability. The purified QDs were subsequently dispersed into transparent polymeric matrices, including PMMA and epoxy resins, to fabricate luminescent thin films. Controlled curing processes were optimized to preserve the optical performance of the QDs while ensuring homogeneous film formation. The resulting QD-films will be evaluated under conditions relevant to the automotive industry, including luminance uniformity mapping, accelerated thermal cycling, UV exposure, and humidity stability tests to assess thermal quenching and environmental degradation effects.

The developed materials demonstrate the potential of QD-polymer composites as efficient spectral conversion layers capable of transforming blue LED emission into high-purity white or customized colored light for automotive applications. This work contributes to the development of energy-efficient and durable optoelectronic materials within the framework of the UGR-Valeo Chair.

Keywords:

Quantum Dots, Lightning, Automotion

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Hydrogen bond driven association of cationic polysaccharides and non-ionic sugar-based surfactants

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Understanding non-electrostatic coacervation is critical for advancing sustainable formulations [1]. Here, hydrogen bond-mediated association between cationic polysaccharides (CP) and alkyl polyglucoside (APG), a bio-based nonionic surfactant, is investigated under varying ionic strength conditions. In contrast to conventional polyelectrolyte-surfactant systems governed primarily by electrostatic interactions, the CP-APG association arises exclusively from nonionic, hydrogen bond-driven mechanisms.

A combination of UV-visible spectroscopy, phase diagram analysis, and quartz crystal microbalance with dissipation monitoring (QCM-D) was employed to characterize both bulk phase behavior and the adsorption of CP-APG complexes onto negatively charged surfaces. The results demonstrate that APG concentration controls the onset of coacervation: intermediate surfactant concentrations induce phase separation, whereas increasing ionic strength promotes coacervate formation by enhancing hydrogen bonding interactions.

This process results in the formation of micron-scale coacervate droplets with a core-shell morphology, consisting of a hydrophobic APG-rich core surrounded by a hydrated CP shell, as supported by zeta potential measurements. Coacervation significantly enhances the deposition of CP-APG complexes on solid substrates, highlighting their potential for controlled release, targeted delivery, and surface functionalization applications.

Overall, these findings advance the understanding of non-electrostatic, hydrogen bond-driven coacervation in polymer-surfactant systems and demonstrate that ionic strength serves as a key tunable parameter for modulating structure, deposition, and performance. This work provides valuable insights for the design of sustainable formulations in cosmetics, biomedical coatings, food technology, and enhanced oil recovery. Future studies should further explore the effects of salinity, salt type, surfactant concentration, and dilution under conditions representative of real-world applications.

Keywords:

Alkyl polyglucosides, Hydrogen-bond-driven coacervation, Ionic-strength modulation, Quaternized hydroxyethylcellulose;

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Protein Nanofibers as Pickering Emulsion Stabilizers

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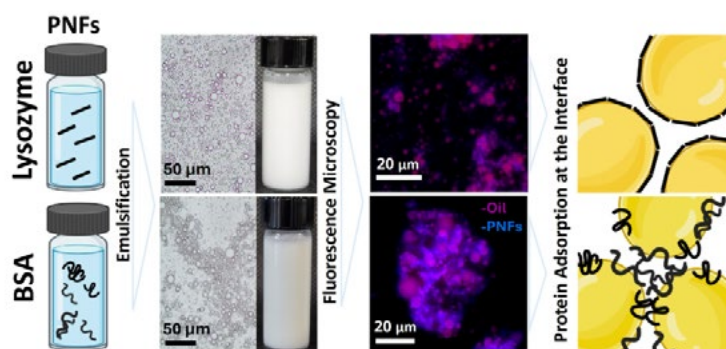
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Pickering emulsions are systems in which solid particles rather than conventional surfactants stabilize the interface between immiscible phases. ¹ Although traditional surfactants are highly effective, many are derived from petroleum sources and in addition may pose risks to human health and the environment. ² Protein-based materials are attractive due to their abundance, relatively low cost, surface activity, and the presence of diverse amino acid functional groups. However, native proteins are prone to degradation, whereas emulsion-based products typically require extended shelf lives. Proteins can self-assemble into highly organized fibrillar aggregates, also known as protein nanofibers (PNFs). ³ High-purity proteins obtained as byproducts of agricultural processes and food processing, such as bovine serum albumin from beef production and lysozyme from chicken eggs, have emerged as promising candidates for PNF formation. ^{4,5}

In this work, protein nanofibers derived from bovine serum albumin and lysozyme were evaluated as stabilizers for oil-in-water Pickering emulsions. Stable emulsions with discrete, well-dispersed droplets and monomodal size distributions were obtained at oil contents of up to 50 wt.% and remained stable for up to six months, demonstrating highly competitive long-term stabilization relative to previously reported bio-based nanoparticles. The effects of protein concentration, pH, ionic strength, and suspension conditions on emulsion stability were systematically investigated. Overall, lysozyme nanofibers provided superior stabilization compared to BSA nanofibers. This difference is attributed to the higher surface charge of lysozyme PNFs, which promotes stronger electrostatic repulsion between droplets, as well as more effective interfacial coverage compared with the more flexible BSA PNFs. These results demonstrate the potential of protein nanofibers as bio-based Pickering stabilizers for formulations in food, cosmetics, and pharmaceutical applications.

Keywords:

Protein nanofibers, Pickering emulsion, BSA, Lysozyme



Schematic of protein nanofiber emulsions and proposed mechanism of adsorption at the interface

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Rational design of lyotropic liquid crystal based carriers for Resveratrol transdermal administration

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Introduction : Lyotropic liquid crystals (LLCs), soft nanostructured systems combining anisotropic order with a gels' mechanical stability, have become promising alternatives towards improving biodisponibility, pharmacological effectiveness, and patient compliance for transdermal delivery of active principles [1]. Because of their unique properties and structure, LLCs show potential use as drug delivery systems for both hydrophilic and hydrophobic active principles, especially for transdermic administration [2]. Resveratrol, 3,4,5-trihydroxy-trans-stilbene, a natural phenolic compound, has shown interest due to having a variety of beneficial health effects, such as anti-inflammatory, antioxidant, and antimicrobial activities [3].

The aim of this work is developing lyotropic liquid crystal based DDS, suitable for Resveratrol delivery, a cosmetic antioxidant, and study the influence of the active ingredient encapsulation on the morphology of the self-assembled surfactant mesophases.

Materials and methods : LLCs obtained at various concentrations of Pluronic P123 in water were characterized using SAXS, polarized optical microscopy (POM) and rheology and used for the encapsulation of the hydrophobic active ingredient.

Results : The systems with minimum content of surfactant and various lyotropic liquid crystal morphologies were selected as carriers for the hydrophobic active principle. The presence of cosmetic oily phase Bakuchiol in the formulation modify the hydrophobicity of the surfactant and results in changes of LLC morphology , depending on the oil concentration. Encapsulation efficiency and Resveratrol release studies were performed and showed promising results.

Conclusions : LLCs were prepared, using Pluronic P123 and water. The obtained systems show a high drug loading efficiency and exhibit prolonged release profile of Resveratrol, proving their use as transdermal drug delivery systems.

Keywords:

drug delivery, surfactants, self-assembly.

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Coalescence in soy protein-stabilized emulsion drops during drying

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During drying, sessile drops of colloidal suspensions, including emulsions, often develop a solid-like shell as evaporation progresses. The drying Péclet number captures the balance between the diffusion and evaporation time scales. It predicts the occurrence of instabilities, such as the formation of a skin due to particle accumulation near the interface [1]. In an evaporating emulsion drop, in consequence of water loss, dispersed oil droplets are compressed and the increasing oil volume fraction promotes destabilization processes such as coalescence due to film rupture [2]. We study the development of those instabilities in emulsions formed using commercial soy protein (whole and fractions thereof), under specific temperature and physico-chemical conditions, in real time. These are not only rich colloidal questions, but also relevant in the context of the shift toward more sustainable food ingredients (e.g plant based milk powder).

Controlled sessile drop drying experiments, used as a model for industrial spray-drying [3], combined with image analysis, allow us to characterize in real time the emergence and evolution of coalescence in plant-protein-stabilized emulsions. Adjusting the air flow, temperature, and humidity allows us to tune the drying Péclet number and the formation of the shell. The dynamics of coalescence are being analyzed to quantify how formulation parameters (protein concentration, oil fraction, ionic strength) and drying conditions (temperature, airflow, relative humidity) influence this process. We capture the dynamics of droplet-droplet coalescence, as well as oil leakage occurring during the slow drying of an emulsion drop on a hydrophobic surface (Figure 1).

Keywords:

Emulsion, Drying, Plant protein, Coalescence, Food

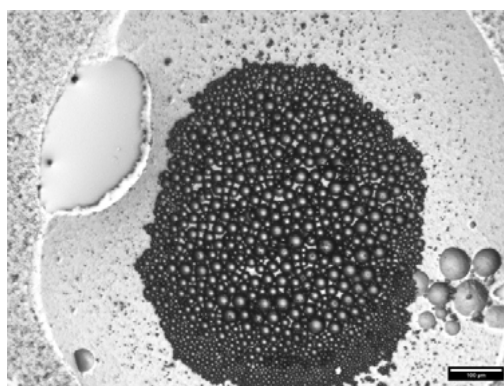


Figure 1: Bottom view of an evaporating emulsion drop (slow drying) on a hydrophobic surface

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Extraction of Metal Ions Using Quaternary-Ammonium-Salt-Type Amphiphilic Gemini Ionic Liquids with O- and N-Containing Spacer

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It is known that amphiphilic ionic liquids containing long alkyl chains show surface activities similar to surfactants. Gemini surfactants, in which two conventional monomeric surfactants are connected by a spacer, exhibit unique behaviors, such as lower critical micelle concentration (CMC), enhanced ability to reduce surface tension compared with monomeric surfactants, and spontaneous formation of premicelles and vesicles at low concentrations. We previously developed various quaternary-ammonium-salt-type amphiphilic ionic liquids containing oxygen or nitrogen in the spacer, and their physicochemical properties, adsorption behavior at the air/water and air/ionic liquid interfaces and layer structure formation in bulk were revealed by using various measurements [1-4]. Although many studies on the extraction of metal ions using ionic liquids have been reported in recent years, no report has focused on extraction using gemini ionic liquids and their spacer structures. In this study, extraction of metal ions such as Li^+ , Cu^{2+} , and Au^{3+} was examined using the quaternary-ammonium-salt-type amphiphilic gemini ionic liquids with different spacer structures containing oxygen and nitrogen ($2\text{C}_{12}(\text{Spacer})\text{NTf}_2$, where (Spacer) = (2-O-2), (2-O-2-O-2), (2-N-2), (2/2-N-2), (3), (5), and (6)), and the effects of the length and structure of the spacers on the extraction behavior were investigated.

Fig. 1 shows the extraction ratio E of metal ions from aqueous phase into $2\text{C}_{12}(\text{Spacer})\text{NTf}_2$. The extraction ratio of Cu^{2+} in the amphiphilic gemini ionic liquids containing oxygen and nitrogen in spacer was higher than that in $2\text{C}_{12}\text{-s-NTf}_2$ with alkylene spacer, indicating that the structure of the spacer significantly influenced the extraction ratio of Cu^{2+} . The extraction ratio of Cu^{2+} was higher for the 2-O-2-O-2 spacer, which has two oxygen atoms, and lower for the 2/2-N-2 spacer, which has a rigid ring structure. This suggests that the extraction ratio was improved by using a flexible spacer. On the other hand, $2\text{C}_{12}(\text{Spacer})\text{NTf}_2$ exhibited excellent extraction capacity for Au^{3+} regardless of the spacer structure.

Keywords:

Amphiphilic ionic liquids, Gemini ionic liquids, Extraction, Metal ion, Bulk property

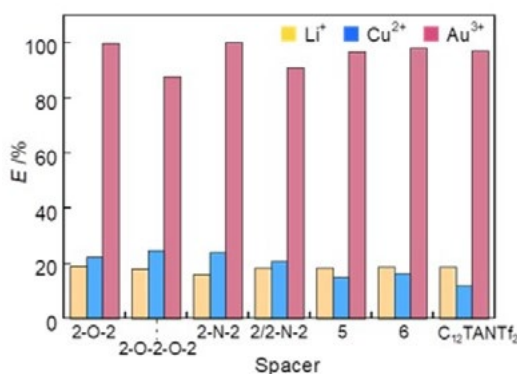


Fig. 1 The extraction ratio E of metal ions from aqueous phase into $2\text{C}_{12}(\text{Spacer})\text{NTf}_2$ at 25 °C.

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Impact of Low-Sodium and Table Salt on Creep–Recovery and Oscillatory Rheological Properties of Wheat Flour Dough, a Colloidal System

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Wheat dough is a complex colloidal system of gluten network embedded with starch granules and other dispersed particles which exhibits nonlinear viscoelastic behavior under stress. Sodium chloride is one of the raw materials used in dough making with a major impact on its rheological properties and, therefore on its processability, being closely correlated with the final products quality. Since bakery products are one of the main contributors to daily sodium intake, reducing their sodium content is important for public health. However, a significant reduction of sodium chloride in bakery products formulation, without affecting dough processability and bakery products quality remains a major challenge for the bakery industry. This study evaluates the impact of conventional table salt (NaCl) and a low-sodium sea salt (a mix of 82.5-87.5% KCl, 12.5-17.5% NaCl, 1% SiO₂) with a less than 85% sodium content (SS) than table salt on rheological properties of wheat-flour dough, a colloidal system. The effects of the SS were compared with those obtained by NaCl for an addition levels in wheat flour up to 1.6%. For this purpose, a HAAKE MARS 40 rheometer had been used where creep-recovery and oscillatory test were performed. For oscillatory frequency sweeps tests storage (G') and loss (G'') moduli were fitted using a power-law model. The power law exponents (n' , n'') were slightly lower for SS, indicating reduced frequency dependence of viscoelastic behavior. For NaCl dough, G' and G'' initially decreased at 0.4% compared to the control sample, then increased at 0.8–1.2%, before decreasing again at 1.6%, showing the concentration-dependent reinforcement of the viscoelastic dough network. SS addition presented higher values for G' , G'' compared to dough samples with NaCl indicating a stronger and more uniform dough network with more stable colloidal interactions. Loss tangent was lower than 1 for all the dough samples which indicates their solid-like behavior. On creep and recover tests, SS and NaCl had similar effects, but dough with NaCl was slightly weaker with a $J_{\max}$ values higher than those for SS and a recovery ratio lower than dough samples with SS. These results indicate that NaCl substitution with SS lead to dough samples with good viscoelasticity, offering a promising approach for obtaining bakery products with a less sodium content without affecting dough technological behaviour.

Keywords:

wheat flour dough, rheological behaviour, low sodium salt, creep–recovery tests, oscillatory measurements

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Substrate-Selective Catalytic System Based on a Clay/Surfactant Hybrid

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Development of substrate-selective catalysts is a key topic in science. In many cases, highly developed synthetic skill and high experimental cost are required to develop conventional substrate-selective catalysts. In this study, we propose a concept for constructing substrate-selective catalysts with easy preparation method using clay/surfactant hybrids as a similar role with polypeptide in enzyme.

Anionic layered clay minerals intercalate various cationic surfactants into their interlayers. The clay/surfactant hybrids are widely utilized as adsorbents for removal of hazardous materials, and the adsorption properties are largely affected by interactions between the intercalated cationic surfactant and the adsorbed species [1,2]. In other words, the clay/surfactant hybrids exhibit substrate selectivity governed by differences in affinity between the intercalated cationic surfactant and the adsorbates.

In this study, we develop a catalytic system by incorporating catalytic molecules into a clay/surfactant hybrid, which can be prepared by simple mixing. We propose that substrate size and miscibility with the intercalated surfactants regulate access to the catalytic centers, in a manner analogous to a lock-and-key mechanism in enzymes.

The catalyst was prepared by assembling an anionic clay (saponite: SP), a cationic surfactant (cetyltrimethylammonium bromide: CTAB), and Mn (II) tetrakis(1-methyl-4-pyridyl) porphyrin (MnP) as a catalytic center. The diffraction peaks around 5 thetas of SP/CTAB and SP/MnP-CTAB hybrids shifted to lower angles compared to pristine SP, indicating that intercalations resulted in an expansion of the basal spacing between layers (Figure). The prepared hybrid powders were observed to be green, indicating the incorporation of MnP in the SP/CTAB hybrids.

Using the developed catalyst, we are investigating the catalytic epoxidation of various alkenes to explore its substrate selectivity. The detailed results will be discussed in the presentation.

Keywords:

Clay minerals, Intercalation, Substrate selectivity, Porphyrin, Epoxidation

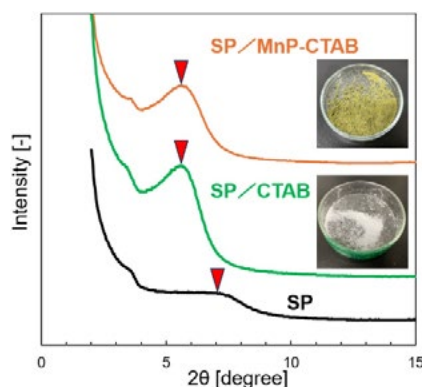


Fig. XRD patterns and observation of the hybrids

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Interfacial rheology of Acacia gums at fluid interfaces studied by interfacial shear rheometer and drop tensiometer

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Acacia gum is a naturally occurring, heterogeneous mixture of arabinogalactan-proteins, valued for its surface activity in industrial applications. We investigated the rheological properties of two Acacia gum dispersions (species *A. senegal* and *A. seyal* gum) in bulk and especially at fluid interfaces.

Using bulk rheology with a shear rheometer and two different geometries (cone-plate and concentric cylinder), the Acacia gum dispersions (5 wt%) displayed viscoelastic behaviors that intensified with time. The addition of a minor amount of a non-ionic surfactant (Tween 80) in Acacia gum dispersions eliminated the viscoelastic behavior. Hence, the observed viscoelastic behaviors at low Acacia gum concentrations and low strain can be primarily attributed to the interfacial effects of Acacia gum macromolecules adsorbed at the air-water interface, and not only to the bulk response.

Considering the previous bulk rheology results, and using interfacial rheology with an interfacial shear rheometer, both gums adsorbed onto air-water and hydrophobic phase-water interfaces and formed interfacial networks (interfacial shear moduli $G_i' > G_i''$). For the three investigated hydrophobic phases with different hydrophobicity (*n*-Hexadecane, MCT, Undecanol), *A. senegal* gum exhibited much faster interfacial network formation and higher viscoelasticity than *A. seyal* gum. Additionally, *A. senegal* gum exhibited increased adsorption kinetics and interfacial viscoelasticity with increasing hydrophobicity. Both G_i' and G_i'' increased slightly with time and never reached a plateau even after days, which is believed to result from increased lateral interactions, dehydration and/or multilayer formation at the interfaces. This point was also supported by the results of dynamic interfacial tension using drop tensiometer. However, for interfacial dilatational moduli ($E' > E''$) determined by drop tensiometer, both E' and E'' increased to a maximum and then slowly decreased with aging. No significant differences in E_{max} were observed for the two gums. The contrasting differences between the shear and dilatational properties may be due to the inappropriacy of the drop tensiometer for determining complex interfaces that cannot be described by the Young-Laplace equation. Furthermore, the presence of interfacial shear resistance further complicates the interpretation of the dilatational moduli.

Keywords:

Interfacial rheology, drop tensiometer, Acacia gum, viscoelastic, shear, dilatational properties

Acknowledgements:

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Single-Step Thermoresponsive Hydrogels for Marine Biofouling Control: A Sustainable Colloidal Strategy for the Offshore Industry

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The invasion of sun corals (*Tubastraea* spp.) poses a severe threat to marine biodiversity. Current control strategies rely primarily on manual mechanical removal, which is costly, hazardous, and often inefficient due to the risk of fragment dispersion. While biocidal hydrogels have been proposed as an alternative, existing formulations depend on external crosslinking agents to increase viscosity and ensure proper coverage, adding operational and compositional complexity.

This work presents the development of a novel, crosslinker-free thermoresponsive hydrogel composed of water-soluble biopolymers (kappa-carrageenan and xanthan gum) as a viscosity modifier and sodium hydroxide (NaOH) as an alkaline biocide, which triggers rapid tissue degradation by inducing a localized high-pH environment. Prepared at elevated temperatures (50-70 °C), the formulation exhibits low viscosity, allowing for easy pumping and localized application. Upon contact with seawater, the hydrogel undergoes a rapid sol-gel transition solely driven by thermal equilibrium. This phase transition increases the storage modulus (G') and provides sufficient mechanical strength to allow the material to adhere to submerged coral colonies and withstand underwater shear forces without additional cross-linking steps.

Field trials at TRL 7 in Arraial do Cabo (Brazil) validated the technology's industrial readiness. Figure (a) illustrates the localized application of the hydrogel using an integrated Remotely Operated Vehicle (ROV) system, demonstrating its viability for diverless operations. The environmental efficacy is confirmed in Figure (b), where colonies encapsulated by the gel showed lethality rates between 95% and 100% after 7 days. This versatile, eco-friendly approach significantly simplifies subaquatic biofouling management while offering a high-performance, sustainable solution for large-scale biodiversity protection and industrial maintenance.

Keywords:

Thermoresponsive hydrogels, Sol-gel transition; *Tubastraea* spp.; Diverless technology; Sustainable remediation

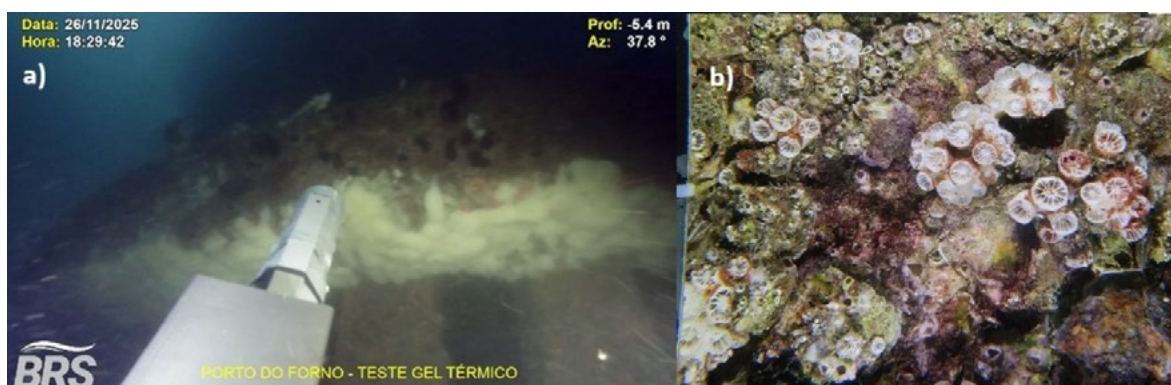


Figure 1. ROV deployment and biocidal efficacy of the thermoresponsive hydrogel. (a) Localized subaquatic application of the formulation onto colonies via a custom ROV nozzle. (b) Photograph taken 7 days post-application showing tissue degradation (whitening) mediated by the NaOH biocide.

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Layer-by-layer Assembled Polyelectrolyte-based Bead Bio-composites: Advanced Materials for Enhanced Adsorption

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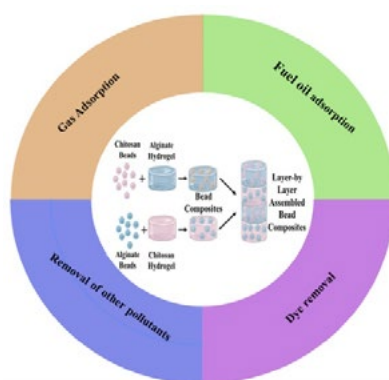
While traditional wastewater treatments like ion exchange and chemical precipitation are effective, they are often costly and risk secondary pollution. Biopolymeric hydrogels offer a greener alternative but lack the necessary porosity and mechanical strength. [1] These limitations can be overcome by utilizing **polyelectrolyte-based composites**. [2] These charged polymer structures leverage specific intermolecular forces to significantly enhance pollutant adsorption. Beyond water treatment, their high porosity makes them versatile for applications like **fuel-oil recovery** and **gas adsorption**.

In this study, two different polyelectrolytes, chitosan and alginate, were used to prepare composites to increase the suitability of the materials for a broad range of applications. As positively and negatively charged polyelectrolytes, chitosan and alginate can be used for the adsorption of negatively and positively charged pollutants based on electrostatic attractions. Furthermore, hydrogen bonding also plays a vital role in adsorption. Chitosan, which is hydrophobic (depending on its acetylation degree), also contributes to the adsorption of hydrophobic pollutants. Polymeric beads were introduced into the system to induce porosity in the hydrogel. The composites were prepared using a combination of two types of materials: polymeric beads and hydrogels. Chitosan-based polymeric beads were prepared by cross-linking chitosan with sodium tripolyphosphate, and alginate-based beads were prepared by cross-linking alginate with calcium chloride. The chitosan beads were then added to the alginate solution and then frozen followed by cross-linking with calcium chloride to prepare the composite A. In a similar way, the alginate beads were added to the chitosan solution and then frozen followed by cross-linking with sodium tripolyphosphate to prepare the composite B. The layer-by-layer assembled composite was prepared by first preparing composite A then, adding the solution of composite B followed by freezing and cross-linking it to prepare the final material. Furthermore, this material showed promising results for gas adsorption and fuel oil adsorption.

With 98% efficiency for both anionic and cationic dyes, these multilayered composites leverage diverse intermolecular forces for superior performance. Their extended lifespan stems from **reversible ionic cross-linking**: bonds break during desorption and reform during adsorption. Ultimately, this high-porosity "universal material" offers a robust, reusable solution for broad pollutant removal.

Keywords:

Adsorption, Alginate, Chitosan, hydrogel



Composite for diverse pollutant removal

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Electrochemical method for CO₂ Capture by Electrical Double Layers by means of capacitive deionization

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The climate crisis affecting our planet, and its relationship with the accumulation of greenhouse gases in the atmosphere, particularly CO₂, has led to a growing interest in methods for removing carbon dioxide from the atmosphere. Here we highlight the use of electrochemical methods [1] based on the properties of electrical double layers, in particular those generally known as Capacitive Deionisation (CDI) technologies. These are characterised by the capture of ions from solution and their incorporation into the electrical double layers of capacitive electrodes (activated carbon is mostly used) or intercalated in battery electrodes. The use of ion-exchange membranes bonded to the electrodes is also common (membrane CDI or MCDI). Although the method can be used for direct gas capture [2], it is easier to perform a prior dissolution of the CO₂/carrier gas mixture in water or a solution and perform indirect CO₂ removal by adsorption of HCO₃⁻ [3]. In this communication, we present data on the adsorption of CO₂ in aqueous solutions using polyelectrolyte-coated carbon electrodes, which is known as soft electrode capacitive deionisation (Soft-CDI) method [4]. Additionally, the interposition of ion exchange membranes (SE-MCDI) is shown to increase significantly the removal of dissolved carbon dioxide. Figure 1 shows some results in the form of electrical conductivity differences (outlet minus inlet conductivities) as a function of time for alternate positive and negative cell potentials. It should be noted that the application of positive current (favourable to the uptake of HCO₃⁻ anions by the cationic polyelectrolyte (PDADMAC)-coated electrode and of H⁺ cations by the PSS (anionic)-coated electrode) reduces the conductivity, indicating the removal of ions from the solution. The opposite is observed when the current is reversed. These data make it possible to evaluate the amount of CO₂ captured and the efficiency of the process.

Keywords:

Capacitive deionization, Carbon dioxide capture, Electrical double layer

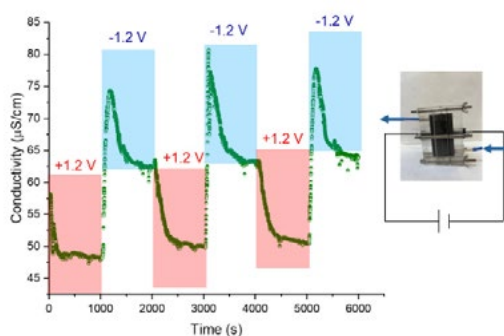


Figure 1. Conductivity of the exit solution (CO₂-saturated water) as a function of time for the indicated cell voltages of a soft-electrode CDI system.

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Self-Assembling Squaramide-Based Amphiphiles for Fragrance Encapsulation

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This research focuses on the synthesis and study of novel self-assembled materials, which may form structures such as vesicles, nanoparticles or gels, for fragrance encapsulation and release. The self-assembly process provides unique opportunities for designing materials for advanced applications, in this case, the controlled release of volatile molecules.

Fragrance delivery systems are of commercial interest as volatile scent molecules are used in variety of products, e.g. fabrics, cosmetics, perfumes and personal care products. By enabling precise control over release kinetics, improving physicochemical stability, and prolonging sensory perception, these systems can enhance the overall product performance and reliability. This drives the formulation innovations while addressing increasing consumer demand for prolonged efficacy and consistent, high quality sensory performance.

Recently, squaramides have been found interesting as versatile motifs in supramolecular self-assembly. These have provided a useful approach to developing nanoscale soft materials due to their structural versatility and the variety of potential self-assembled structures, such as micelles and vesicles.

In this research, squaramide-based amphiphiles are engineered to unlock long-lasting, controlled fragrance release. In this work, a versatile library of amino-acid-derived squaramide-based amphiphiles is explored to reveal how molecular design drives self-assembly, gelation and high-performance fragrance nanocarriers. We report studies DLS, UV, fluorescence, and surface tension measurements while the encapsulation and release of fragrance molecules is monitored by GC and HPLC.

Keywords:

Self-Assembly, nanoparticles, squaramide, amphiphiles, fragrance, encapsulation.

A comparative evaluation of preparation protocols, physicochemical properties, and delivery efficiency of albumin nanoparticles as biocompatible nanocarriers

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Protein-based nanoparticles (NPs) represent a versatile platform for delivery applications in various fields, from pharmaceuticals to dermocosmetics, thanks to their ability to enhance penetration through biological barriers, modulate release profiles, and optimise the bioavailability and precision targeting of active ingredients [1,2]. Moreover, they are characterised by high biocompatibility and biodegradability, as well as high encapsulation efficiency.

Among proteins, serum albumins are particularly promising for these purposes, as they are non-toxic, scarcely immunogenic, highly available and inexpensive. Their multiple functional groups enable interactions with a diverse array of molecules through both hydrophobic and hydrophilic domains [3]. Among the numerous experimental approaches to produce albumin NPs, the desolvation method is likely the best known and most widely used. It is based on reducing protein solubility by adding a desolvating agent, which induces controlled precipitation and particle formation. NP stabilisation is then achieved by adding a suitable cross-linker, such as glutaraldehyde. This approach enables high drug loading and tunable particle size; however, the use of organic solvents and potentially toxic cross-linking agents may raise concerns regarding biocompatibility and residual toxicity. To address these limitations, non-toxic cross-linking agents such as glucose have recently been proposed [4]. Moreover, alternative strategies based on albumin self-assembly can be exploited.

We will present the optimisation and thorough characterisation of highly biocompatible albumin-NPs, which are prepared by either desolvation or metal-induced self-assembly methods and cross-linked by glucose, as carriers of *Populus nigra* (L.) root metabolites with antimicrobial and prebiotic potential for skin microbiota [5].

The properties of the NPs are investigated using light scattering techniques, while the structure and conformation of the albumin are assessed using spectroscopic techniques. Finally, the loading capacity and release profiles are monitored using UV spectroscopy.

Keywords:

Albumin nanoparticles, drug delivery, desolvation, metal-induced protein self-assembly, physico-chemical characterization, structural properties

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Interfacial Structure and Thermal Transport in Polymer-Grafted Nanoparticle Nanofluids: A Molecular Dynamics Study

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Nanofluids, composed of nanoparticles dispersed in a base liquid, have attracted considerable attention as advanced heat transfer media due to their enhanced thermal conductivity. However, their practical application is hindered by nanoparticle agglomeration and sedimentation, which compromise long-term dispersion stability. To overcome this limitation, nanofluids based on polymer-grafted nanoparticles (PGNPs), where polymer chains are tethered to the nanoparticle surface, have been proposed[1]. PGNPs exhibit superior dispersion stability and are also expected to enhance interfacial heat transport[2,3]. Nevertheless, the mechanisms by which the polymer shell structure and the surrounding ordered solvent layer (nanolayer) jointly influence thermal conductivity remain unclear.

In this study, molecular dynamics (MD) simulations were performed to investigate the relationship between interfacial structure and thermal transport properties in PGNP-based nanofluids at the molecular scale. The grafting density of polymer chains and the intermolecular interaction energy were systematically varied to examine their effects on polymer conformations, solvent structuring near the interface, and overall thermal conductivity.

The results indicate that thermal conductivity exhibits a strong dependence on intermolecular interaction energy at high grafting densities: it increases significantly with stronger interactions, whereas it decreases under weaker interactions. Heat-flux decomposition shows that solvent–solvent energy transport dominates at low grafting densities, whereas polymer–polymer and polymer–solvent contributions become increasingly important at higher grafting densities. Additionally, weaker interpolymer interactions enhance the overlap between polymer and solvent density distributions, thereby facilitating interfacial energy transport.

These findings highlight the critical role of interfacial structure in governing heat transport in PGNP nanofluids and provide molecular-level insights for designing high-performance nanofluids.

Keywords:

Nanofluids, Interfacial molecular layer, Molecular dynamics, Thermal conductivity

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A Robotic Soft Matter Scientist: Transforming the Sustainability of Formulated Products

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Formulation of soft matter systems such as emulsions, gels, and suspensions is a core part of a wealth of industries aiming to develop products with desirable functional outcomes. However, product formulation is inherently challenging due to large design space, lots of trial-and-error, and numerous variable optimisations required to achieve ideal compositions. Automation and machine learning can be readily adapted to handling the repetitive processes and variable optimisations involved in materials discovery and product formulation.

Here, we take a ‘frugal automation’ approach to develop an automated system to provide greater flexibility to formulation and particle characterisation in place of standard inflexible, highly optimised and expensive kits. A method is developed to extract particle size distributions (PSD) from laser diffraction data using Mie scattering theory and computer vision (CV). Polystyrene microparticles with known PSD are used as test samples for diffraction analysis, and a compound optical microscope fitted with a complementary metal-oxide semiconductor (CMOS) camera is used to examine basic shape and size of the colloidal particles. This setup is then used to explore an applications-relevant model system. A benchtop experimental platform, comprising a UR5e robotic manipulator and Robotiq Hand-E adaptive gripper, is also under development for workflow automation.

Preliminary results from the CV-diffraction algorithm show that particle size can be predicted by directly comparing measured scattering intensity with theoretical scattering generated from an array of different particle sizes via a Mie theory optical model. Further improvements for the proposed system will focus on fully automating the synthesis, chemical analysis, and laser diffraction workflows. A machine learning model for hypothesis generation will also be considered for future iterations.

Keywords:

Automated formulation, particle characterisation, computer vision, particle size distribution

Structural characterisation of commercially available pasta combining small-angle x-ray and neutron scattering with contrast variation

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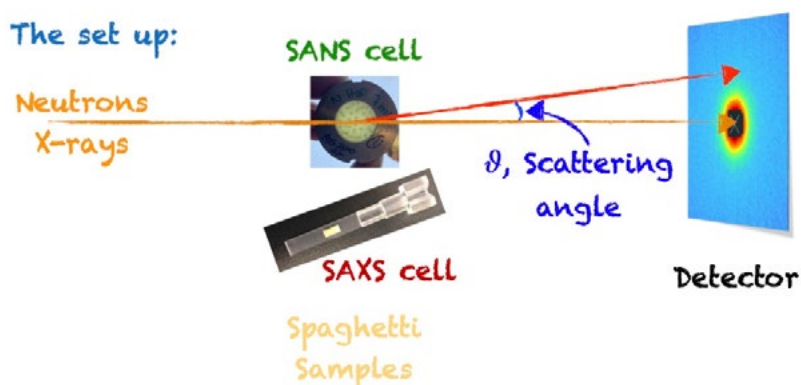
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I will discuss how we performed the structural characterisation of commercially available gluten-free pasta by combining small-angle x-ray and neutron scattering with contrast variation. This will be compared to the analogous regular gluten-containing pasta variety. In particular, the use of neutron and contrast variation allowed us to isolate the information about the gluten matrix and the starch granules. The broad peak that reflects the structure of the starches is lost as a function of cooking.

This effect is more dramatic for the gluten-free pasta, indicating that the absence of gluten strongly promotes the gelation of the starches. Furthermore, the presence of salt in the cooking water is found to preserve the structural properties of the pasta, while at the same time it promotes the degradation of the starch granules. Then I will show how different mechanical processes, needed to obtain different pasta shapes, affect the internal structure of this material. Finally I will compare the internal structure of normal wheat flour with the one of flour obtained from Kernza®, a perennial grain which might in future offer environmental advantages, including carbon sequestration, improved soil structure, reduced nutrient leaching, and lower fertiliser and pesticide inputs compared to annual cereals.

Keywords:

Structural characterisation of food, spaghetti, small-angle scattering, x-rays, neutrons, contrast variation, sustainability



Schematic sketch of a small-angle scattering experiment performed on spaghetti

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Characterization of Tristyrylphenol Ethoxylate Surfactants

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Surfactants are needed in many applications and have different requirements for each use. A significant proportion of surfactant use occurs in industry, where highly specific types of surfactants are employed. [1]

Tristyrylphenol ethoxylates are nonionic surfactants with an extended aromatic part and a variable length of ethoxylated chain. They are primarily used in agricultural applications. [2] Though they are also used or could be useful for other purposes like for dyes and pigments [3], petrochemistry or polymer/materials science. Due to their aromatic part, these surfactants could enhance the solubilization of other aromatic molecules. The structure of those molecules not only causes hydrophobicity, but also π -stacking interactions, which hinder solubilization. For molecules with similar structures to those of the tristyrylphenol ethoxylates, these surfactants could break up stacking interactions, and the hydrophilic part could then solubilize the molecules in water.

Not much is known about these tristyrylphenol ethoxylate surfactants in current literature, so their basic characterization and solubilization mechanisms are being studied. This could improve our understanding of these surfactants and expand their range of applications. Basic characterization includes analytical methods such as UV-Vis, NMR and DLS measurements, foamability and foam stability, surface tension, rheological measurements, colloidal structure determination, and binary and ternary phase diagrams with hydrophobic and aromatic solutes.

Keywords:

surfactant, tristyrylphenol ethoxylate, π -stacking, solubilization

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Acknowledgements:

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Surfactant-free Microemulsions in Surface Cleaning

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Classical microemulsions are transparent, thermodynamically stable liquid systems consisting of two immiscible components stabilized by an amphiphilic substance known as surfactant. Surfactants adsorb at the oil–water interface, reducing the interfacial tension and facilitating the formation of oil-in-water, bicontinuous, or water-in-oil phases [1].

However, nanostructured monophasic solutions can also form in the absence of classical surfactants by using hydrotropes. Unlike surfactants, hydrotropes are smaller molecules with lower amphiphilicity that do not form micelles in aqueous solutions or ordered films at the water-oil interface [2, 3]. In ternary systems, surfactant-free microemulsions (SFMEs) can emerge above the phase boundary within the monophasic region. Depending on the composition, different structural regimes may occur, with oil-in-water-like structures commonly referred to as the pre-Ouzo region [4].

The nanostructuring in SFMEs is characterized by highly dynamic processes and reduced interfacial stabilization. These features result in pronounced mesoscopic fluctuations and increased structural flexibility. This combination of properties makes SFMEs an interesting, eco-friendly alternative for various applications. In particular, in the field of surface cleaning, understanding the role of dynamic structuring is essential to elucidate its potential effects on cleaning performance and mechanisms.

Keywords:

Microemulsion, surfactant-free microemulsion, SFME, nanostructuring, surface cleaning

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Preparation and Size Control of Hollow Silica Nanoparticles with High Dispersibility using Vesicle Template Method

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Hollow silica nanoparticles (HSNPs), having low specific gravity and high specific surface area, demonstrate several unique properties compared to normal solid particles. Recently, these HSNPs have received increased attention in designing new type of low-refractive index materials and low dielectric constant materials. In our previous study, we successfully prepared highly dispersible HSNPs with an average particle size of 20–30 nm using cationic vesicles as soft templates[1]. However, for practical applications, HSNPs with larger particle sizes and higher porosity are required to achieve improved performance. Therefore, in this study, we aimed to synthesize HSNPs with larger particle sizes than those previously reported by using the vesicle template method.

The vesicles were prepared with a mixture of a double-chained cationic surfactant, didodecyldimethylammonium bromide (DDAB), and a single-chained cationic surfactant, dodecyltrimethylammonium bromide (DTAB), with DDAB/DTAB molar ratios of 9/1 or 7/3. The vesicle dispersions were prepared in ammonia basic solutions at pH 11.5 or 11.7 by ultrasonic irradiation treatment. After adding the silica precursor (tetraethyl orthosilicate : TEOS) to this dispersion under stirring for 2 hours, the pH was adjusted from basic to neutral (pH 8.0) condition. Following additional stirring for 16 hours, hydrothermal treatment at 150 °C was carried out to obtain the HSNPs.

When the reaction of TEOS was maintained at pH 11.5 for the first 2 hours and the pH was subsequently decreased to 8.0, highly dispersible HSNPs with particle sizes of 20–30 nm were obtained after hydrothermal treatment when the composition of DDAB/DTAB = 9/1 [1]. When the pH was increased to pH 11.7, the accelerated sol-gel reaction produced HSNPs with a particle size of 40 nm, though particle aggregation was significantly observed. This is likely because increasing the pH accelerates the sol-gel reaction, causing the silica shell to form before the vesicles are destabilized and shrunk under the shear force of stirring. Next, the pH was fixed at 11.7, and the molar ratio of DDAB/DTAB was varied. As a result, well-dispersed HSNPs with a particle size of 46 nm were obtained at a composition of DDAB/DTAB = 7/3. Furthermore, the effect of using tetrapropyl orthosilicate (TPOS) as an alternative silica precursor on the structure and dispersibility was also investigated.

Keywords:

Vesicle Template Method

Hollow Silica Nanoparticles

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Synthesis of Carbon Quantum Dots as a Fluorescent Probe for Trace Detection of 2,4-DNPH

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Nitroaromatic compounds (NACs) are persistent environmental pollutants that pose serious ecological and health risks. Therefore, rapid detection methods with high sensitivity and selectivity toward NACs are urgently required. In this work, a carbon quantum dot (CQD) probe was prepared via a simple, green hydrothermal method using *o*-aminophenol and tartaric acid as low-cost precursors. The prepared CQDs were systematically characterized and then employed as fluorescent probes for targeted detection of NACs; furthermore, the underlying sensing mechanisms were investigated. The results show that the as-prepared CQDs exhibit strong blue fluorescence with a quantum yield of 74.3%. The emission wavelength is centered at 420 nm and is independent of excitation wavelength. The characterization using UV-vis, FTIR, and XPS reveals that there are abundant oxygen- and nitrogen-based functional groups (C=O, C–O, C=C, O–H, N–H) on the CQDs, which also indicates the nitrogen-doped nature of the CQDs. Upon applications of the CQDs for NACs detection, several compounds, including 2,4-dinitrophenylhydrazine (2,4-DNPH), picric acid, 4-nitrobenzyl alcohol, 1,2-/1,3-/1,4-dinitrobenzene, and 2,4-dinitrotoluene, were selected as target analytes. The experiments demonstrate that only 2,4-DNPH induces a pronounced fluorescence-quenching response, indicating its high selectivity for 2,4-DNPH. Mechanistic investigations indicate that the fluorescence quenching arises mainly from the inner filter effect (IFE), along with the dynamic quenching process. For quantitative analysis, the CQD probe achieves a remarkable quenching efficiency of 94% and a low detection limit of 15 nM. Notably, the CQDs exhibit reversible photoluminescence, underscoring their stability, reusability, and suitability for continuous monitoring applications. Overall, these CQDs provide a high-performance, low-cost, and eco-friendly sensing platform for reliable 2,4-DNPH detection, offering significant promise for real-world environmental and analytical applications.

Keywords:

Carbon quantum dots; Nitrogen-doped CQDs; Fluorescent sensing; 2,4-DNPH; Inner filter effect; Environmental monitoring

New solvent-antisolvent nanoprecipitation method for the simple and low-cost production of polyethylene nanoparticles as nanoplastic models

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Nanoplastics (NPs) have a widespread presence as contaminants in aquatic environments and, owing to their nanometric size, can cross biological membranes and penetrate into cells. Consequently, extensive research efforts are focused on understanding the potential impacts of NPs on both human health and ecosystems. Polyethylene (PE) is particularly problematic because its extensive use in commercial plastic bags, becoming the major source of NPs in aquatic environments. For toxicological and environmental studies, well-defined PE nanoparticles are required as reference materials. However, the preparation of small PE nanoparticles with low polydispersity and precisely controlled size using a simple, low-cost, and reproducible method remains a challenge. Here, we present a very simple and easily scalable preparation method based on solvent–antisolvent nanoprecipitation, producing PE nanoparticles (Fig. 1) with smaller particle sizes and lower polydispersity than those obtained by methods based on toluene-in-water emulsions ^[1] or xylene-DMSO nanoprecipitation ^[2]. PE is first dissolved in a medium-chain fatty acid, in the absence of water, and subsequently nanoprecipitated by fast mixing with a highly alkaline aqueous solution. Finally, sample are purified using dialysis membranes. This method can produce PE nanoparticles with controlled sizes below 100 nm, and colloidal stabilization was achieved by adding a surfactant prior to nanoprecipitation, as nanoparticles with sodium octanoate alone were not colloidal stable after dialysis purification, most likely due to desorption of octanoate from particle surface. The formation of small (size < 30 nm) and stable nanoparticles required a molar excess of hydroxide ions relative to initial carboxylic acid (OH^-/RCOOH molar ratio ≈ 3) and the use of Tween 80 (polyoxyethylene (20) sorbitan monooleate) surfactant (Fig. 1a). The largest nanoparticles, obtained in similar conditions, were those prepared in the presence of Brij S100 (polyoxyethylene (100) stearyl ether) surfactant (Fig. 1b). SDS (sodium dodecyl sulfate) and Etocas 200 (polyoxyethylene (200) castor oil) surfactants resulted in intermediate sizes. To the best of our knowledge, this simple and straightforward method has not been reported before.

Keywords:

Polyethylene nanoparticles, solvent-antisolvent nanoprecipitation

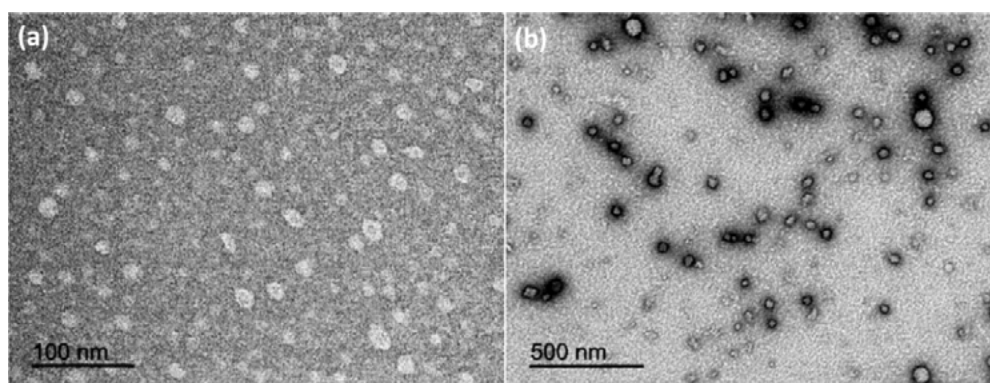


Fig. 1. Examples of TEM images of PE nanoparticles, stabilized by polyoxyethylene (20) sorbitan monooleate (a); and polyoxyethylene (100) stearyl ether (b) surfactants.

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Natural Resins for high mechanical resistant Cosmetic films

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All Day wear is a key expectation for make-up consumers, with only petrochemical solutions available today on the market, especially silicone-based ingredients like MQ resin and/or silicone film-formers. These materials bring to the formula deposit the required adhesion, cohesion, and chemical resistance (towards water, sebum, or olive oil), thus leading to the desired long lastingness.

In the context of a growing need for sustainability, it is crucial to build new Wear Performance Engines with bio-based ingredients for innovative natural makeup products offering long-lasting and comfort throughout the day.

In this study, we explored Natural Resins known for their protection, healing, and adhesion functions in Nature [1] [2] [3] [4], as well as their association with polysaccharides to create new hybrid materials for wear in Make-Up. We characterized the solubility, thermal behavior and mechanical properties of the different systems using Hansen Solubility Parameters measurements, DSC, DMA, rheology, fragmentation and friction tests.

We studied a large set of natural resins alone, such as Candelilla resin, Protium Heptaphyllum resin and Glyceryl Rosinate. Candelilla resin was then associated with Ethylcellulose in different ratio and solubilized in Ethanol/Isododecane mixes. The best associations were formulated with Red-7 pigments to build simplex liquid lipsticks.

A wide range of mechanical behaviors was obtained from highly cohesive and no adhesive deposits to no cohesive and highly adhesive deposits by varying Ethylcellulose/Candelilla Resin ratio from 100/0 to 0/100 (Figure 1). Friction resistance could also be tuned from mid to highly resistant. Optimum ratio of 50/50 was defined to get the right balance between adhesion and cohesion. The best associations were competitive with petrochemical references in terms of global wear results as demonstrated in vitro and in vivo in simplex liquid lipsticks formulas [5][6].

Keywords:

Natural resins, polysaccharides, mechanical resistance, cosmetic films, lipsticks

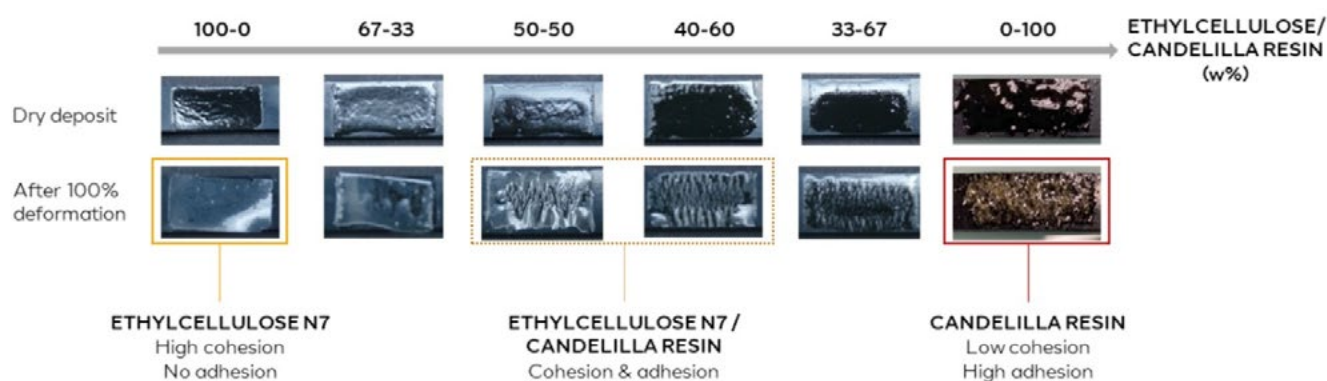


Figure 1 - Adhesion and cohesion balance of Ethylcellulose and Candelilla Resin mixes assessed by fragmentation after 100% deformation on an elastomeric substrate

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Adsorption kinetics of small molecules on FePt metallic electrode by classical molecular dynamics simulation

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This study presents a time-resolved analysis of molecular adsorption at the FePt electrode-electrolyte interface during the methanol oxidation reaction (MOR) by using all-atom classical molecular dynamics simulations. While previous studies have mainly discussed adsorption behavior in terms of adsorption energy or static interfacial structures, the key innovation of this work is the introduction of **adsorption time** as a quantitative kinetic descriptor. This approach makes it possible to evaluate not only whether molecules adsorb on the catalyst surface, but also **how long they remain there**, thereby providing a dynamic perspective that is directly relevant to catalytic reactivity and surface poisoning.

The simulations were performed for FePt surfaces with the (001), (100), and (111) facets in a mixed electrolyte containing methanol, sulfuric acid, and water. By statistically tracking the residence of molecules near the catalyst surface, the adsorption times of each species were quantitatively determined. The results show that methanol has the longest adsorption time, followed by sulfuric acid and then water. This trend reflects their different functional roles in MOR: methanol must remain at the interface long enough to undergo oxidation, sulfuric acid stabilizes the acidic interfacial environment, and water participates more dynamically in transport processes.

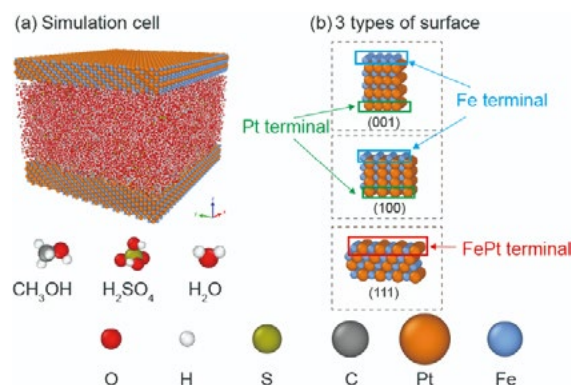
A major finding of this work is that adsorption behavior should be understood not only as a static structural property but also as a **time-dependent interfacial phenomenon**. In particular, the FePt(111) surface exhibits the strongest adsorption capacity for methanol, with an adsorption time about 18 ps longer than that on the FePt(001) surface. This result demonstrates that surface atomic arrangement strongly influences the kinetic residence of reactants, and suggests that adsorption time can serve as an effective descriptor for comparing catalytic interfaces with different facet structures.

In addition to the time-scale analysis, molecular orientation near the surface was examined to clarify how adsorption proceeds at the atomic level. The simulations reveal a two-layer interfacial mechanism. In the outer region, approximately 5 Å from the surface, methanol molecules preferentially approach the surface in a C-down configuration. In the inner region, within about 3 Å of the surface, the molecules tend to reorient into a nearly surface-parallel geometry. These two regions can be interpreted as a guiding layer and a reaction layer, respectively. This finding indicates that adsorption is not a single static event, but a dynamic process involving both residence time and structural reorganization.

The significance of this study lies in establishing a framework that connects **surface structure, adsorption time, and molecular orientation** in a unified manner. In particular, the time-resolved characterization of adsorption provides a new viewpoint beyond conventional energy-based discussions and offers a direct way to evaluate interfacial kinetics in complex electrochemical reactions. This work therefore provides a new design concept for FePt-based electrocatalysts and demonstrates the broader potential of adsorption-time analysis for understanding and optimizing catalytic interfaces.

Keywords:

Methanol oxidation reaction; Adsorption time; FePt; Molecular dynamics simulation; Interfacial adsorption



(a) MD model of the FePt electrode-electrolyte interface: a FePt slab at the bottom contacts a mixed methanol, sulfuric acid, and water electrolyte under periodic boundary conditions. (b) FePt (001), (100), and (111) surfaces show Pt-, Fe-, or mixed Fe-Pt terminations.

Synergistic Interaction of n-Hexane Vapors and Surfactants on Liquid-Gas Interfacial Dynamic

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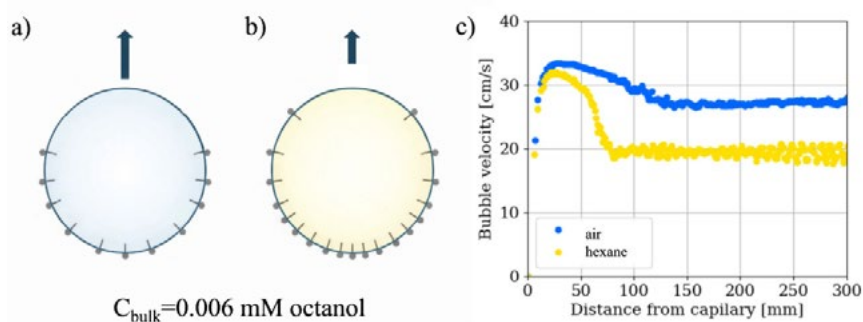
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The motion of a single gas bubble in a liquid strongly depends on the hydrodynamic conditions at the liquid–gas interface. When amphiphilic compounds are present in the liquid, they adsorb at the surface of a rising bubble and form a so-called dynamic adsorption layer (DAL). This layer is not uniform along the bubble surface and therefore partly reduces the mobility of the interface. As a result, the bubble does not rise at a constant speed. Instead, its motion shows characteristic velocity profiles with distinct stages: acceleration after bubble release, reaching a maximum velocity, subsequent deceleration, and finally establishment of a terminal velocity. The shape of these velocity profiles and the time needed to reach the steady state provide an indirect but very sensitive measure of adsorption kinetics and interfacial immobilization. An important and still not well understood problem is the influence of organic vapors present inside the bubble on adsorption processes and interfacial dynamics under non-steady conditions. In this work, we study the effect of n-hexane vapors on the behavior of a rising air bubble in pure water and in aqueous solutions of ionic and non-ionic surfactants. Bubble dynamics were analyzed using local velocity profiles and terminal velocities. In addition, adsorption processes were studied on a stationary buoyant bubble by bubble profile analysis tensiometry, which allowed us to follow adsorption kinetics and changes in surface tension in the presence of n-hexane vapors. The experimental results were supported by molecular dynamics simulations, providing insight into surfactant adsorption energies and the co-adsorption of surfactant molecules and n-hexane at the molecular scale. The results show that in pure water the presence of n-hexane vapors, although they adsorb at a stationary interface, does not significantly affect the motion of a rising bubble. In contrast, a clear synergistic effect is observed in surfactant solutions. The presence of n-hexane vapors strongly accelerates the formation of the dynamic adsorption layer at the bubble surface and leads to faster and stronger immobilization of the liquid–gas interface. This behavior results in lower bubble velocities and a shorter time needed to reach steady-state conditions. Molecular simulations indicate that this effect is caused by limited desorption of surfactant molecules from the interface when n-hexane molecules are also present, which promotes faster buildup of the adsorption layer. These findings improve the understanding of how volatile organic compounds and surfactants interact at the liquid–gas interface under dynamic conditions, especially in relation to the formation and stabilization of the dynamic adsorption layer. The observed synergistic effect suggests that organic vapors can significantly change adsorption kinetics. From an applied perspective, these results may be relevant for industrial processes based on foams, such as flotation or froth separation, where the controlled use of organic vapors could reduce surfactant consumption while preserving the required hydrodynamic behavior of the system.

Keywords:

Bubble, Surfactant solution, Organic vapor, Synergistic effect



a) Diagram of surfactant adsorption on a bubble containing clean air b) Diagram of enhanced surfactant adsorption on a bubble containing hexane vapor c) Comparison of velocity profiles of a bubble with clean air and one with hexane vapor at the same octanol concentration.

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Nanocellulose Aerogel-Supported Zero-Valent Iron Enables Synergistic Adsorption–Degradation of Organic Contaminants

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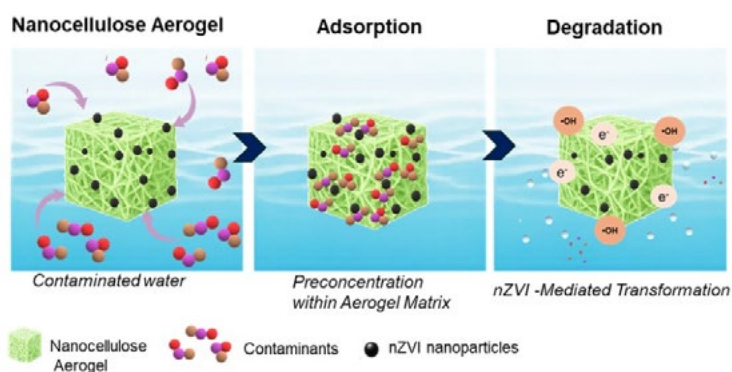
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Persistent organic pollutants in aquatic environments remain extremely challenging to eliminate using conventional treatment techniques, which are primarily driven by adsorption equilibria and often result in secondary waste without complete elimination.[1] This constraint highlights the need for material platforms that integrate interfacial adsorption with localized transformation processes. In this study, we propose a hierarchically porous framework comprising a reactive colloidal phase of nanoscale zero-valent iron (nZVI) within a nanocellulose-based aerogel. The nanocellulose aerogel has a highly porous[2], interconnected three-dimensional structure with extensive surface functions [3], facilitating effective adsorption and preconcentration of organic pollutants from aqueous solutions [4]. This adsorption-driven interfacial enrichment increases the local concentration of pollutants near embedded nZVI, promoting electron-transfer-mediated reactions and Fenton-like reactivity associated with in situ Fe^{2+} generation. [5]

Crucially, the aerogel matrix governs the colloidal behavior of nZVI by suppressing nanoparticle aggregation and promoting uniform spatial dispersion, thereby preserving reactive surface area. The integration of nZVI within the nanocellulose aerogel enhances pollutant removal relative to the pristine matrix through the synergistic coupling between interfacial adsorption and localized redox transformation within the porous framework. This system illustrates how adsorption-induced interfacial concentration gradients, combined with controlled nanoparticle dispersion, influence the efficiency of coupled adsorption–reaction processes. In summary, this study demonstrates that nanocellulose-supported nZVI aerogels are an effective platform for the integration of adsorption and redox transformation within a confined porous architecture. This presents an intelligent strategy for the fabrication of high-efficiency and sustainable water treatment materials.

Keywords:

Nanocellulose aerogel, Zero-valent iron (nZVI) nanoparticles, Water remediation, Adsorption–degradation



Schematic illustration of nanocellulose aerogel-supported nZVI nanoparticles for combined adsorption and degradation of organic pollutants in water.

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Optimized Enzymatic Liquid Detergents: From Interfacial Stability and Colloidal Characterization to Enhanced Food Allergen Removal

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Introduction and Objective:

The development of sustainable detergent formulations increasingly relies on the incorporation of bioactive components (enzymes [1], essential oils [2], biosurfactants) to comply with environmental regulations while enhancing performance in allergen removal [3]. In this context, maintaining enzyme stability within complex colloidal systems remains a critical challenge. This study investigates the stability and compatibility of commercial protease (Blaze® Pro 100L) and α -amylase (Achieve® Alpha 100L) in multicomponent detergent formulations containing anionic surfactants (LAS Linear Alkylbenzene Sulfonate, LES Sodium Lauryl Ether Sulfate), non-ionic surfactants (GLUCOPON 600® Alkyl Polyglucosides, FINDET 1214N23® Fatty Alcohol Ethoxylate, REWOFORM SL-ONE Sophorolipids), and essential oil-derived bioactives (e.g., bioflavonoids, polyphenols). The objective is to elucidate synergistic interactions between surfactants systems and bioactive additives that preserve enzymatic activity while maximizing the efficiency of food allergen removal under realistic cleaning conditions.

Methods:

Accelerated aging tests were conducted at 40-50°C over 14 days to evaluate enzymatic stability under storage-relevant stress conditions. Enzymatic activity was quantified using modified Anson and DNS assays for protease and α -amylase, respectively. Optimal formulations were characterized by Multi-Angle Dynamic Light Scattering (MADLS) using Zetasizer system to determine particle size distribution, zeta potential, and polydispersity index (PDI), providing insight into colloidal stability. Finally, cleaning efficiency was assessed on surfaces contaminated with fish, egg, and gluten allergens, complemented by mechanical soil removal analysis using a Millimanipulator.

Results and Discussion:

Protease exhibited high thermal stability at 40°C, while amylase showed increased sensitivity to anionic surfactants. Among the systems evaluated, FOR1 (LAS/LES/ GLUCOPON 600®/FINDET 1214N23®) and FOR2 (LAS/LES/ REWOFORM SL-ONE/GLUCOPON 600® / FINDET 1214N23®) were identified as the most effective multicomponent formulations. FOR1 showed the highest overall stability, maintaining elevated relative enzymatic activity and a zeta potential $>|30|$ mV, indicative of strong colloidal stability. FOR2 also proved to be a robust alternative, with a measured particle size of 3.6 ± 0.6 nm and a zeta potential of -33.4 ± 5.3 mV, confirming its stability alongside high residual activity. Physicochemical characterization further suggested that enzyme incorporation promotes the formation of stable micellar aggregates in selected formulations. Cleaning assays demonstrated a significant reduction in allergen load (approx. 60-80%) for fish, egg, and gluten residues compared to water controls. In parallel, millimanipulator measurements revealed that enzymatic formulations effectively reduce the elastic modulus (E) of food soils, facilitating their mechanical detachment and overall removal efficiency.

Conclusions:

The synergy between tailored surfactant systems and industrial enzymes not only preserves catalytic activity but also enhances the removal of persistent biological soils. In particular, formulations such as FOR1 and FOR2 demonstrate that the combination of anionic, non-ionic, and biosurfactants components can stabilize enzymes within complex colloidal environments while maintaining high cleaning performance. These systems represent a promising and sustainable approach for advanced industrial cleaning applications, contributing to improved allergen removal and enhanced food safety standards.

Keywords:

Protease, α -amylase, surfactant stability, allergen removal, colloidal characterization

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Mechanistic investigation of synergistic mildness in binary surfactant systems: correlating micellar dynamics of anionic/non-ionic mixtures with 3D-RhE and zein endpoints

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Background and Objective

Surfactants are essential components in cosmetic and detergent formulations, yet their potential to cause skin irritation remains a major concern. Although individual surfactants have been extensively characterized, industrial applications increasingly rely on binary and more complex mixtures to optimize both performance and dermatological compatibility. This study investigates the relationship between irritation potential and the physicochemical properties of mixtures of the anionic surfactants polyethoxylated alkyl ether carboxylic acids (EC), and the non-ionic surfactants alkylpolyglucosides (APG). The aim is to identify possible synergistic effects and provide valuable insights for the rational design of safer, more skin-compatible formulations.

Methodology

A multi-methodological approach was employed to evaluate irritation potential, combining a modified version of the zein method described by Gotte and detailed in [1], together with a Reconstructed Human Epidermis (RhE) model (OECD TG 439) using the 3D in vitro skin model SkinEthic™ from Episkin (Lyon, France). Micellar characterization was carried out using Multi-Angle Dynamic Light Scattering (MADLS) with a Zetasizer Ultra (Malvern Panalytical Ltd., Malvern, UK) to determine hydrodynamic size, translational diffusion coefficient (D), and zeta potential.

Results

Findings on individual surfactants indicated that smaller, highly mobile micelles (high D), typical of anionic species like EC, correlate with higher zein numbers and reduced RhE viability, i.e., increased irritation potential. In contrast, non-ionic APGs form larger, less mobile aggregates, which are associated with milder dermatological profiles [2]. The experimental data from the zein protein solubilization assay and the 3D-reconstructed human epidermis (RhE) model confirm a significant synergistic mildness in the binary mixtures. The irritation potential of the EC/APG systems was notably lower than that of the individual surfactants, indicating a clear mitigation of dermal aggressiveness. These results are being correlated with the micellar physicochemistry of the aggregates. Preliminary analysis suggests that the formation of mixed micelles leads to a reduction in the chemical potential of the monomers and a shift in micellar dynamics. Full characterization of the aggregates, including zeta potential and diffusion coefficients (D), provides the mechanistic basis for this synergy by explaining the reduced mobility and penetration capacity of the mixed systems compared to their pure counterparts.

Conclusion

This study demonstrates that combining ether carboxylic acids (EC) with alkylpolyglucosides (APG) is an effective strategy for developing high-performance, low-irritation surfactant systems. The synergy observed through zein and RhE endpoints is fundamentally linked to the micellar architecture of the mixtures. Integration of micellar dynamics data, including size, surface charge, and diffusivity, facilitates an understanding of how intermolecular interactions improve dermatological compatibility. These physicochemical correlations further validate the use of mechanistic in vitro models to predict the behaviour of complex surfactant blends in topical applications.

Keywords:

Skin irritation, non-ionic surfactants, anionic surfactants, zeta potential, 3D reconstructed human epidermis (RhE)

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Sustainable production and interfacial properties of amphisin biosurfactant for flotation applications

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The growing demand for sustainable and cost-effective biosurfactant production has intensified interest in utilizing industrial waste streams as fermentation substrates. In this study, crude glycerol derived from biodiesel and soap manufacturing was evaluated as a carbon source for amphisin production by *Pseudomonas fluorescens* DSS73. Among the tested substrates, glycerol originating from soap production supported the highest biomass formation and amphisin yield (4.62 g·L⁻¹), highlighting its suitability for biotechnological applications.

To further enhance production efficiency, a Box–Behnken experimental design was applied to optimize key process variables, including glycerol concentration, corn steep liquor (CSL) concentration, and cultivation time. Statistical analysis revealed that all three factors significantly influenced amphisin biosynthesis, with glycerol concentration exerting the strongest effect. The developed quadratic model demonstrated excellent predictive capability ($R^2 = 0.9999$). Under optimized conditions (70.9 g·L⁻¹ glycerol, 29.7 g·L⁻¹ CSL, 5.9 days), amphisin production reached 7.51 g·L⁻¹, closely matching the predicted value.

Comprehensive physicochemical characterization of purified amphisin confirmed its strong surface activity and complex interfacial behavior. The biosurfactant exhibited a low critical micelle concentration (4.7×10^{-6} mol·dm⁻³) and reduced surface tension to 39.2 mN·m⁻¹. Potentiometric titration revealed two dissociation constants ($pK_{a1} = 2.35$ and $pK_{a2} = 5.29$), indicating pH-dependent ionization. Spectroscopic and electrokinetic analyses further confirmed the transition from neutral to anionic forms with increasing pH. Additionally, dynamic and equilibrium surface tension studies, supported by diffusion-based modeling, demonstrated that amphisin adsorption is initially diffusion-controlled but becomes kinetically limited at higher surface coverage. Molecular dynamics simulations revealed the formation of non-spherical, discoidal micelles with complex internal organization.

Overall, this work demonstrates an efficient and sustainable strategy for amphisin production from waste glycerol and provides detailed insight into its interfacial and aggregation properties, supporting its potential in flotation and environmental applications.

Keywords:

amphisin; biosurfactants; crude glycerol; waste valorization; *Pseudomonas fluorescens*; process optimization; Box–Behnken design; surface activity

Acknowledgements:

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Biosurfactant–metallothionein interactions as a basis for advanced environmental systems

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The increasing demand for sustainable environmental protection strategies has intensified interest in biologically derived molecules such as biosurfactants and metallothioneins. Owing to their unique physicochemical properties, these compounds represent promising tools for bioremediation and green technologies. A detailed understanding of their mutual interactions is essential for the rational design of efficient environmental systems. In this study, metallothionein MMT5 was overexpressed in a *Saccharomyces cerevisiae* system, purified, and subsequently investigated in terms of its interactions with selected lipopeptide biosurfactants, namely amphisin, surfactin, and pseudofactin. Surface activity measurements revealed that the presence of MMT5 does not significantly affect the critical micelle concentration (CMC) of the tested biosurfactants, indicating that initial micelle formation remains largely unaltered. However, at higher concentrations, MMT5 markedly influences micellar stability. While biosurfactants alone form stable micellar systems up to approximately $2 \times \text{CMC}$, the addition of MMT5 leads to destabilization and aggregation phenomena. This behavior suggests the presence of competitive or cooperative interactions at the hydrophobic–hydrophilic interface. Fluorescence quenching studies demonstrated that biosurfactants induce structural changes in MMT5, which were further supported by molecular dynamics simulations, providing insight into conformational rearrangements and interaction mechanisms at the molecular level. These findings enhance our understanding of protein–biosurfactant interactions in aqueous environments and provide a foundation for the development of advanced biotechnological systems for environmental applications.

Keywords:

biosurfactants, metallothionein, protein-surfactant interaction, bioremediation

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Toward Sustainable Detergency in Marine Context

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Context: Industrial cleaning and detergency play a crucial role in numerous sectors, including food processing, healthcare, and manufacturing, where high standards of hygiene and surface decontamination are required. However, conventional cleaning formulations still rely heavily on petrochemical-derived surfactants, which are often associated with significant environmental and human health concerns, including poor biodegradability, persistence, and aquatic toxicity. In addition to terrestrial applications, detergency is of critical importance in marine environments, particularly in the context of oil pollution.

Detergency is essential for routine maritime operations, including the cleaning of ship hulls, tanks, and equipment contaminated with hydrocarbon residues. In some cases, these operations may result in the release of cleaning waters into the sea, thereby causing oil slicks to form. Another type of pollution, more dramatic, may be accidental oil spills that represent a major threat to marine ecosystems [1]. These events lead to the formation of persistent oil slicks that can severely impact marine life and coastal habitats [2]. One of the primary response strategies involves the use of chemical dispersants, which are designed to break down oil slicks into fine droplets, thereby enhancing their dilution and promoting microbial biodegradation. However, conventional dispersants are predominantly formulated using petrochemical-derived surfactants and solvents, which may pose risks to aquatic organisms and contribute to secondary pollution. Moreover, their effectiveness can vary depending on environmental conditions, raising further challenges in real-world applications.

The challenge is therefore twofold: to ensure efficient removal and dispersion of hydrophobic pollutants in saline conditions, while minimizing the ecological footprint of the cleaning agents themselves. In this context, the development of bio-based alternatives derived from renewable resources represents a promising and more sustainable alternative. Developing efficient, safe, economically and ecologically viable detergency systems is therefore essential to reconcile performance requirements with environmental protection, particularly in the sensitive context of marine pollution.

Materials and Methods: In the detergent and dispersant industry, commonly used surfactants include anionic and non-ionic compounds such as dioctyl sulfosuccinate (DOSS), as well as sorbitan esters (Span) and ethoxylated sorbitan esters (Tween)[3]. In this study, several model formulations were developed and investigated with the use of both petroleum and bio-based alternatives. A comprehensive physicochemical characterization was conducted including pH and ionic strength monitoring, surface tension measurements and CMC determination through the Du Noüy ring method to document stability under different aqueous conditions and ability to reduce interfacial tension. The dispersion efficiency of the formulations was further evaluated using the Baffled Flask Test (BFT), a standardized method commonly used to assess the effectiveness of dispersants for oil spill remediation.

Conclusion and Discussion: The results obtained in this study highlight the promising potential of bio-based alternatives in detergent and dispersant formulations. Particular attention was given to the medium's influence by comparing performance in deionized water and artificial seawater to better reflect both standard laboratory conditions and more realistic marine environments. While some variations were observed depending on the formulation and the tested conditions, the overall results suggest that bio-based alternatives can achieve relevant performance levels in terms of interfacial activity and dispersion efficiency. These findings underline the importance of considering physicochemical parameters such as ionic strength and salinity, especially for applications related to marine pollution and industrial cleaning processes involving saline media. However, further optimization of the innovative strategies remains necessary to achieve full equivalence with conventional systems, particularly in terms of stability, robustness, and cost-effectiveness.

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Switchable boron nitride-based colloidal device for passive daytime radiative cooling

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As global warming intensifies, managing heat exchanges in and out of buildings has become crucial to adapt, and limit our greenhouse gas emissions. Today, cooling and heating of buildings together account for about half of the global energy consumption and energy-related CO₂ emissions.

In the context of buildings energy efficiency improvement, intelligent technologies based on innovative materials are urgently needed. Indeed, such materials, placed on buildings or roofs, can dissipate excess heat into space through mid-infrared (MIR) thermal radiation via a physical effect called radiative cooling. These radiations, whose wavelength matches the atmospheric transparency window (ATW), are emitted without any energy consumption ¹. During the day, this phenomenon can cool objects below ambient temperature; it is called passive daytime radiative cooling (PDRC).

We aim to develop an energy-saving PDRC device able to switch between a radiative cooling state and an absorptive heating state. For this purpose, the radiative cooler needs to highly reflect solar radiation and to emit in the ATW. To achieve high solar reflectance, we identified hexagonal boron nitride (h-BN) as a good candidate due to its exceptional physical and chemical properties. The compacted pristine powder (thickness below 1 mm) exhibited, for instance, a solar reflectance above 0.92, better than what we could achieve with titanium dioxide. We report here the development of colloidal suspension of coated boron nitride nanosheets (BNNSs) and its optical characterization. This suspension was used in the formulation of electrophoretic inks. Contrast, time to switch and optical properties were compared to TiO₂-based inks ².

Such devices are promising for roof applications, dynamically adapting to heating or cooling needs with minimal energy input.

Keywords:

colloids, boron nitride, radiative cooling, energy savings

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Tuning Surfactant Microstructure and Rheology: From Micellar Anisotropy to Associative Network Formation

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This work presents a comparative analysis of two distinct strategies for tuning the structure–property relationships in surfactant-based personal care formulations: the use of a low-molecular-weight co-surfactant (cocamide monoethanolamide, CMEA) in AOS/CapB systems, and a polymeric associative thickener (PEG-120 Methyl Glucose Dioleate, ANTIL 127) in SLES/CapB formulations.

In the AOS/CapB system, CMEA induces a transition from spherical to anisotropic ellipsoidal micelles, accompanied by reduced electrostatic repulsion and increased micellar volume fraction. These changes enhance intermicellar interactions and lead to a significant increase in viscosity, without the formation of a viscoelastic network, as confirmed by the predominance of viscous behavior ($G'' > G'$). Upon incorporation of the botanical oil as a dispersed phase, the system is also capable of forming a stable emulsion without significant changes in viscosity and shows enhanced wettability.

In contrast, the addition of ANTIL 127 to SLES/CapB promotes the formation of more complex supramolecular assemblies through polymer-mediated associative interactions. This mechanism enables the recovery of viscosity and the development of viscoelastic properties even under low surfactant concentration and weak electrolyte conditions, where conventional thickening strategies are ineffective.

Overall, the comparison highlights two fundamentally different thickening mechanisms: micellar growth and anisotropy in the case of CMEA, versus network formation via associative bridging in the case of ANTIL 127. While the former offers a simple and effective route to viscosity enhancement, the latter provides a more versatile and robust strategy for achieving structured, viscoelastic formulations. These findings offer a rational framework for selecting formulation strategies based on targeted rheological and interfacial performance.

Keywords:

Structure-Property Relationships, Thickening Mechanisms, Micellar Anisotropy, Associative Bridging, Rheological Control

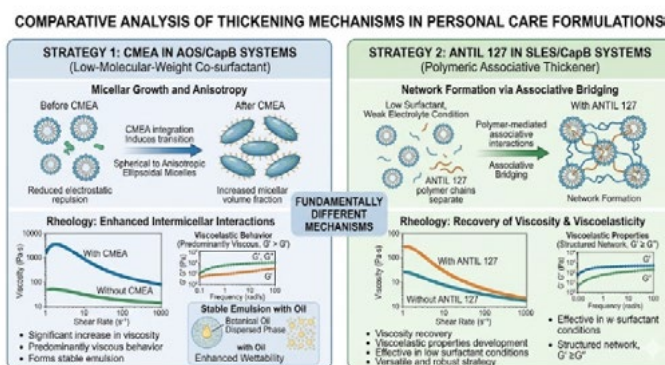


Figure 1. Structure-property relationships in thickening mechanisms. Comparison between CMEA-induced micellar anisotropy and ANTIL 127 associative bridging. Molecular architectures define the system's rheological profile. (Image generated with AI assistance).

Molecular Simulations of Complex Formulations

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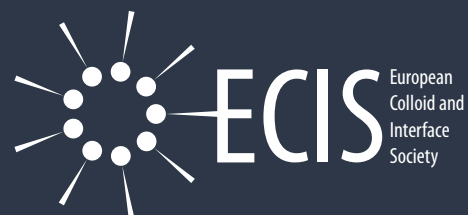
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A mesoscale simulation approach for designing and screening complex chemical formulations is shown. Interaction parameters are derived from first principles via COSMO-RS chemical potentials, converted into Flory-Huggins parameters and mapped onto DPD bead interactions. Benchmark systems demonstrate near quantitative accuracy for interfacial tensions and critical micelle concentrations across anionic, cationic, and non-ionic surfactants. The method is applied to designing a polymer for an emulsion concentrate formulation of a novel fungicide, where the composition space is too large to screen experimentally. Open challenges include strongly differing bead sizes, high coarse-graining levels, charged beads, and directed interactions.

Topic 3

Colloids at Interfaces, Membranes,
Films, Emulsions, and Foams

! **POSTER**



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Impact of the Electrical Double Layer and Ionic Strength on Antimicrobial Peptides' Mode of Action

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The global emergence of multi-drug-resistant (MDR) bacteria has raised serious concerns about the future effectiveness of currently used antibiotics [1]. A possible solution to this issue lies in peptide-based antimicrobial agents known as antimicrobial peptides (AMPs). Most AMPs share a similar main mode of action, focused on disrupting or dispersing bacterial membranes [2]. Regardless of the exact mechanism of a given peptide, initial interactions of the compound with the membrane require accumulation of peptides on the membrane surface [2]. We propose that this aggregation is driven by locally elevated ionic strength arising from the electrical double layer formed on the membrane surface [3]. Additionally, the outer layer of the membrane is rich in anionic polymers, such as teichoic acids and lipopolysaccharides, which induce polyelectrolyte-like properties to the surface [4].

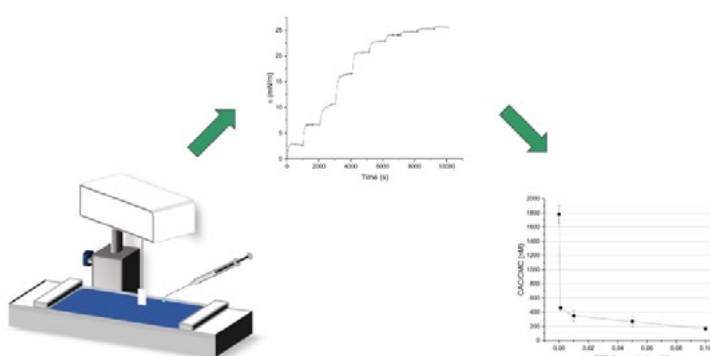
To validate this hypothesis, we employed the Langmuir technique to determine the aggregation behavior of model peptides in environments with an increasing ionic strength. These results were then correlated with experiments on compressed monolayers containing an increasing content of anionic lipids. We compared the changes in required peptide concentration to achieve a plateau in the surface pressure. Furthermore, peptide adsorption and aggregation on the model membrane systems were monitored using a quartz crystal microbalance (QCM). The compiled experimental data allowed us to estimate the peptide-to-lipid (P/L) ratio across all studied scenarios.

Our initial findings indicate that AMPs' aggregation characteristics are similar to the critical micellization concentration (CMC) of surfactants [5]. A clear trend emerged, showing a decrease in the peptide concentration required for aggregation as the ionic strength of the environment increased. The presence of the lipid mono- and bilayer systems further alters these mechanisms. It manifests as a plateau in the surface pressure at lower peptide concentrations.

In summary, we have defined the relationship between the ionic environment and the aggregation behavior of model AMPs, both in the absence and presence of model lipid systems. It provides a foundation for further research regarding the specific interactions of the peptides with different membrane components and the dependence of these interactions on membrane surface potential and ionic environment at the membrane interface.

Keywords:

Electrical double-layer, Antimicrobial peptides, Ionic strength, Langmuir monolayers



Schematic overview of the experimental workflow to determine model antimicrobial peptides aggregation behavior using the Langmuir technique.

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Ionic liquids with antineoplastic activity influence the stability and physicochemical properties of lipid membrane models

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Betulinic acid has been extensively studied as a natural pentacyclic triterpene with numerous pharmacological activities, including inhibition of tumour cell proliferation, as well as anti-inflammatory, antiviral, antibacterial, and neuroprotective effects, and protective activity on the cardiovascular system [1-3]. Incorporation of cations derived from charged or polar amino acids has been shown to improve its water solubility and enhance its activity and selectivity toward neoplastic cells [4]. The resulting ionic liquids exhibit cytotoxic effects against breast cancer MCF-7 cells, with notable differences among the studied salts [4]. To elucidate the mechanism of membrane damage underlying this cytotoxic activity, the present study examines the hypothesis that selectivity arises from alterations in membrane lipid organization. The mechanical and dielectric properties of model lipid membranes were investigated to quantify the effects of L-amino acid ethyl ester betulinate on membrane bending elasticity and electrical capacitance. The obtained results provide insights into the effects of structural modification of betulinic acid, through the synthesis of ionic liquids organic salts, affects the lipid matrix, with the aim of enhancing the selective cytotoxicity of the designed betulinic acid-derived pharmacophores.

Keywords:

ionic liquids, lipid membranes, thermal shape fluctuations, giant vesicles, bending elasticity, electrochemical impedance spectroscopy

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Acknowledgements:

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Tracking fluid interfaces: Role of emulsifiers, oil phase composition and co-solvents

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Flavour emulsions are widely used in the food industry to facilitate uniform flavour dispersion across diverse food matrices, protect volatile compounds from acid, thermal, and oxidative degradation, and maintain stability upon dilution in beverage systems. Despite their ubiquity, flavour emulsions are often formulated empirically, and limited research has addressed the interfacial stabilization mechanisms of emulsifiers or the influence of complex polar oils (e.g., essential oils with weighting agents) and co-solvents (e.g., propylene glycol and glycerine). [1]

In this study, the interfacial stabilization (adsorption kinetics and interfacial rheology) of various emulsifiers (Acacia gum, OSA-starch, and quillaia saponin) have been characterized and compared using a pendant droplet tensiometer and an interfacial shear rheometer initially at the medium-chain triglyceride (MCT) oil-water interface as a model system. A phase exchange experiment was designed to simulate emulsion dilution in beverage applications. Gum Acacia, a macromolecular hydrocolloid, exhibits relatively slow adsorption and interfacial tension reduction, and forms a strong irreversibly adsorbed solid-like elastic interfacial layer. In contrast, OSA-starch shows fast surfactant-like adsorption, and develops a slightly elastic to nearly viscous interfacial multilayer, [2] which can be partially removed upon dilution. Quillaia saponin also demonstrates rapid interfacial tension reduction and forms a brittle solid-like elastic interfacial layer, which also partially desorbs when diluted.

Cold pressed single-fold orange oil is then characterized as a model flavour oil, and the effect of the weighting agents sucrose acetate isobutyrate (SAIB) and ester gum (EG) has been investigated. The orange oil shows high polarity and very low interfacial tension. Adding weighting agents to adjust the density to that of the aqueous phase increases the interfacial tension, facilitates emulsifier adsorption and thereby enhances flavour emulsion stability. The impact of the co-solvents propylene glycol (PG) and glycerin in the aqueous phase was also investigated. Although both co-solvents reduced interfacial tension, Acacia gum remained able to adsorb and further decreases the interfacial tension. However, co-solvent addition diminished interfacial viscoelasticity: PG reduced the elasticity of Gum Acacia films, while glycerine rendered the interface fully viscous. These results indicate that co-solvent inclusion may hinder interfacial stabilization and compromise flavour emulsion stability.

Keywords:

Interfacial stabilization mechanism, food hydrocolloid, flavour emulsion

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Spectroscopic and differential scanning calorimetry studies of the impact of amide-functionalized single-walled carbon nanotubes on the structure and dynamics of lipid bilayers

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The limited solubility and high cytotoxicity of carbon nanotubes hinder their use in biomedicine (1-4). However, functionalizing them with amide groups can mitigate these limitations by improving solubility and biocompatibility while reducing toxicity (5). Therefore, understanding the interactions between amide-functionalized single-walled carbon nanotubes (af-SWCNTs) and lipid bilayers is crucial to grasping the biophysical effects of these nanomaterials on membranes and their potential biomedical applications (5). In this study, we examined the interactions between af-SWCNTs and two types of lipid bilayers: one prepared from saturated phosphatidylcholine (1,2-dimyristoyl-sn-glycero-3-phosphocholine [DMPC]) and one prepared from monounsaturated phosphatidylcholine (1-stearoyl-2-oleoyl-sn-glycero-3-phosphocholine [SOPC]). We examined these interactions using differential scanning calorimetry, Raman spectroscopy, and attenuated total reflectance Fourier transform infrared spectroscopy. Our results suggest that increasing af-SWCNT concentration decreases acyl chain lateral packing density, accompanied by enhanced rotational disorder and an increased population of gauche conformers. These changes are reflected by reduced intermolecular chain coupling and a shift in the intramolecular gauche/trans ratio, collectively indicating a reduction in intermolecular packing order. Overall, these findings suggest that af-SWCNTs disrupt the structural organization of lipid membranes. This offers insight into their potential effects on membrane fluidity and permeability, as well as their possible applications in biomedicine and nanobiotechnology.

Keywords:

lipid membranes, thermal shape fluctuations, giant vesicles, bending elasticity, Attenuated Total Reflectance-Fourier Transform Infrared Spectroscopy

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Dimeric Copper and Zinc Metallosurfactants for Antimicrobial Coatings: Interplay of Bulk and Interfacial Properties

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Metallosurfactants, surfactants that contain metal ions bound to the molecule itself or as part of complex counterions, show great potential for applications both in the solid state and in solution [1,2]. By incorporating metal ions with known antimicrobial properties, such as copper(II) [3] and zinc(II) [4], dual-action systems suitable for the development of multifunctional coatings can be designed.

In this work, building on the well-established physicochemical properties of the dimeric surfactant, bis(*N*, *N*-dimethyl-*N*-dodecyl)ethylene-1,2-diammonium dibromide (12-2-12) [5], (12-2-12)[CuBr₄] and (12-2-12)[ZnBr₄] were synthesized [1] and characterized, including contact angle on stainless steel (SS), and rheological measurements. To obtain antibacterial coatings, a concentrated metallosurfactant solution was spray-coated onto SS plates using an airbrush, while alginate was applied as the topmost layer to improve mechanical stability. Additionally, copper(II) oxide or zinc(II) oxide nanoparticles were incorporated to enhance antimicrobial properties. The resulting coatings were characterized by scanning electron microscopy (SEM), streaming potential measurements, and mechanical testing, while their antibiofilm activity was evaluated against two bacterial species, *Staphylococcus aureus* and *Pseudomonas aeruginosa*.

In comparison to the metal-free precursor, dimeric metallosurfactants exhibit a shifted onset of viscoelasticity and lower contact angles on stainless steel at the low millimolar range. The SEM images of the coating surfaces showed an island-like morphology, while peel-off and scratch tests confirmed good adhesion. Interestingly, the coatings have similar isoelectric points, irrespective of their composition. Antibacterial testing confirmed pronounced antibiofilm performance, while the presence of nanoparticles did not significantly affect the final antibacterial properties.



Graphical abstract

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Remote Actuation of Bioinspired Micro-Compartments Using External Forcefields

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Compartmentalization is a key feature of living systems, enabling spatial organization of biochemical processes and efficient regulation of energy and matter fluxes. In this work, we exploit liquid–liquid phase separation (LLPS) as a strategy to engineer internal organization within protocell models based on water-in-oil droplets. By combining polyethylene glycol (PEG) and dextran, we generate biphasic droplets with well-defined subcompartments that allow selective localization of functional cargoes.

We demonstrate that dextran-functionalized magnetic nanoparticles are preferentially sequestered within the dextran-rich phase, where they act as energy transducers capable of converting external alternating magnetic fields (AMFs) into localized heat. This enables remote actuation of the droplets without direct physical interaction. Meanwhile, the PEG-rich phase remains available for the encapsulation of complementary components, such as enzymes.

The spatial segregation of these elements allows decoupling of energy transduction and biochemical activity. In particular, we show that heat generated in the dextran phase can be used to enhance enzymatic reactions occurring in the PEG phase, demonstrating controlled energy transfer between subcompartments.

These results establish LLPS as a powerful tool for hierarchical organization and modular design in protocell systems, enabling the integration of multiple functionalities within a single microenvironment. This approach opens new avenues for the development of stimuli-responsive microreactors and advanced synthetic cell models.

Keywords:

liquid-liquid phase separation, magnetic nanoparticles, plasmonics, biphasic droplets, microreactors

References:

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Acknowledgements:

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Bio-based Reactive Surfmer for Water-Resistant Acrylic PSAs

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Waterborne pressure-sensitive adhesives (PSAs) prepared by oil-in-water emulsion polymerization commonly rely on low-molecular-weight surfactants. While effective for latex stabilization, these additives can remain mobile after film formation, enriching at interfaces and undermining water resistance and adhesion durability under wet conditions. Here, we introduce a biomass-derived reactive surfactant (surfmer) designed to mitigate such post-film migration while maintaining robust colloidal stability. The surfmer is synthesized from 10-undecenoic acid (castor-oil-derived feedstock) and incorporates an allyl-ether functionality that allows covalent incorporation during acrylic emulsion polymerization. Notably, stable latexes were obtained using this surfmer as the primary stabilizing species, enabling surfactant immobilization within the polymer network.

Surface-sensitive spectroscopy indicates a markedly reduced enrichment of the bio-surfmer at the air-film interface compared with a conventional anionic surfactant reference, consistent with suppressed “blooming” during drying. This interfacial stabilization translates into substantially improved water tolerance of the resulting PSA films, as evidenced by significantly lower water uptake and better retention of adhesive performance after aqueous exposure. In parallel, mechanical testing reveals enhanced cohesive integrity at increasing surfmer incorporation, which we attribute to ionic associations acting as reversible physical cross-linking domains within the adhesive matrix. Adhesion on a pigskin model substrate further highlights the practical impact: formulations based on the reactive bio-surfmer show sustained peel resistance after saline immersion, whereas the control exhibits pronounced degradation (and loss of cohesion).

Overall, the work demonstrates how a sustainable, inedible biomass-based surfmer can couple latex stabilization with interfacial and bulk-property control, offering a promising route to high-performance PSAs for moisture-challenging applications.

Keywords:

reactive surfactant (surfmer), emulsion polymerization, pressure-sensitive adhesive, surface migration, wet adhesion, biomass-derived materials

Comparison of foam stabilized by plant protein microgels

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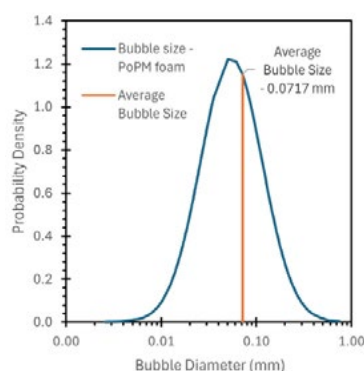
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Protein microgels are soft, deformable colloidal particles that can adsorb strongly at fluid-fluid interfaces, offering a route to forming highly stable foams, stabilised via the Pickering-type mechanism, much more stable than those stabilised by plant protein isolates, for example. Microgel-stabilised foams exhibit substantially longer half-lives than isolate-stabilised foams across all protein sources, consistent with Pickering-type stabilisation ¹.

In this work, microgels prepared from potato protein isolates are investigated as stabilisers of aqueous foams, with the ultimate objective to achieve sustainable dietary shifts by transitioning from animal to plant protein based food ingredients. Protein microgels were produced via thermal gelation of the protein (80 °C/ 30 min) followed by high pressure shearing.

Bulk rheological characterisation of the parent potato protein gels confirmed the formation of elastic protein networks ², providing insights into the mechanical properties and deformability of the resulting microgels, which possessed a mean hydrodynamic diameter of 170 nm. Potato protein microgels were able to form stable foams, reaching at least 100% foam capacity. Image analysis of 1600 bubbles revealed an average bubble size of 72 µm, with approximately 80% of the number of bubbles < 100 µm in diameter and at least 5 % ‘microbubbles’ (diameters < 10 µm) indicating effective suppression of bubble coalescence and especially disproportionation.

These findings demonstrate that the microgel state of the protein, rather than the protein isolate itself, has a larger impact on foam stability. The formation of robust, particle-stabilised foams makes plant protein microgels a promising platform for the development of sustainable foams. Future research will focus on understanding the impact of these microgels on long-term stability of the foams and their other physical characteristics.



Probability density distribution of bubble diameters in potato microgel foam. The blue curve shows the measured size distribution, and the orange line indicates the mean diameter (71.7 µm). The distribution indicates a mostly fine and moderately polydisperse bubble structure.

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Preparation of Highly Stable Microalgal Oil-Water Emulsions Using Homogenization-Extrusion Process with Polyvinylidene Difluoride Filter Membrane

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In response to sustainable development issues, the microalgae industry possesses significant development potential. Microalgae oil, rich in omega-3 fatty acids that are essential to the human body but cannot synthesize on its own, can be extracted from microalgae biomass, exhibiting substantial biomedical value. This study used microalgae oil as raw material, employing the surfactant Tween 80 combined with a hydrophobic polyvinylidene difluoride (PVDF) filter membrane to fabricate a stable microalgae oil emulsion with uniform droplet size distribution and high oil utilization through a homogenization-extrusion process. Experimental results showed that using a PVDF membrane with an appropriate concentration of the surfactant could prepare an emulsion with uniform droplet size distribution. This is probably attributed to the surfactant's ability to promptly cover the newly formed oil-water interfaces of the emulsion, preventing oil droplet aggregation and effectively improving the stability and uniformity of the emulsion. Compared with more hydrophilic filter membranes such as mixed fiber ester membranes and dopamine-modified membranes, under the same operating conditions, the PVDF membrane exhibited higher flux and oil utilization, and could prepare a uniform emulsion at lower pressures. This may be because the PVDF membrane was modified by the adsorption of surfactants during the extrusion process, thus reducing the retention of oil droplets on the membrane surfaces. In this study, using 0.8 mM Tween 80 and 2.63 g/L microalgae oil as raw materials, combined with a PVDF membrane and a pressure of 8 kg/cm², an emulsion with uniform droplet size, an oil utilization rate as high as 92.7%, and stability exceeding 274 days was fabricated, thus successfully improving the quality of the microalgae oil emulsion.

O-Carboximethyl Chitosan Nanogels as Emulsion Stabilizers

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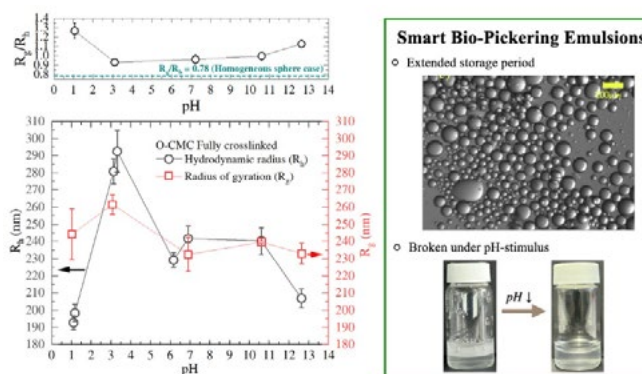
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We present a physicochemical characterization using a wide range of scattering techniques (DLS, SLS, and SAXS) of O-carboximethyl chitosan (O-CMC) nanogels crosslinked with formaldehyde and isopropyl isocyanide via a Ugi reaction, considering three distinct crosslinking densities: low, intermediated and fully crosslinked. The scattering techniques reveal a non-isotropic structure, in which, near the pI, the nanogels aggregate, increasing the hydrodynamic radius. The polymer density is proportional to the crosslinking density, yielding a soft structure for the partially crosslinked nanogels, consistent with AFM measurements of the dry surface. The O-CMC nanogels and the linear polymer were tested as emulsifiers; all structures formed stable emulsions and broke under pH stimuli. Here, the O-CMC nanogel partially achieved a more stable and monodisperse emulsion, following the same trend in the softness dependence of synthetic polymer nanogels. We introduce a new candidate for creating biodegradable, smart Pickering emulsions and demonstrate how scattering techniques from soft matter physics can enhance the understanding of innovative food systems.

Keywords:

Chitosan nanogels, scattering characterization, green Pickering emulsion



Hydrodynamic radius and radius of gyration for O-CMC nanogels as a function of pH, with a ratio $R_g/R_h > 0.78$, demonstrate a non-spherical expanded structure and their application as emulsion stabilizers.

Structure and Mechanical Properties of Polymer-Grafted Nanoparticle Thin Films using Molecular Simulations

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Polymer nano thin films are quasi-two-dimensional materials with nanometer-scale thickness, currently being explored for applications in flexible electronics and drug delivery systems. Recent attention has shifted toward polymer nano thin films filled with nanoparticles (NPs), which offer the potential to achieve physical properties unattainable with conventional polymer films [1]. Among these, polymer-grafted nanoparticles (PGNPs) [2], which are surface-modified with polymer chains, are expected to enable the control of more complex self-assembled structures than those formed by traditional nanoparticles. However, the self-assembled structure and mechanical properties of PGNPs within the confined geometry of polymer nano thin films remain insufficiently understood. In this study, we employed coarse-grained molecular dynamics simulations to investigate the conditions required for superlattice formation within these thin films. Furthermore, we elucidated the relationship between the resulting self-assembled structures and the overall mechanical response of the system.

As a result, we identified the specific graft density and chain stiffness required to induce superlattice formation. Furthermore, we elucidated the mechanical mechanisms by analyzing the elastic modulus and the dynamic behavior of these self-assembled structures under uniaxial tension (Fig. 1).

Keywords:

Polymer nano thin film, Polymer nanocomposite, Polymer-grafted nanoparticle, Self-assembly, Molecular dynamics, Mechanical properties

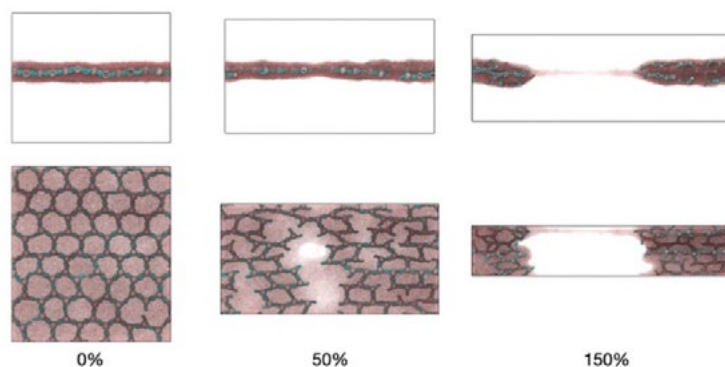


Figure 1. The snapshot of the systems before uniaxial tensile simulation (0%) and under uniaxial tensile simulation (50%, 150%)

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Sustainable bio-based nanoparticles for interfacial stabilization of Pickering emulsions

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Natural and biodegradable materials are attracting increasing interest as sustainable alternatives to synthetic surfactants for stabilizing Pickering emulsions. In this work, nanoparticles derived from natural, biodegradable, and GRAS materials are investigated as interfacial stabilizers for oil-in-water (O/W) Pickering emulsions designed as platforms for encapsulation and controlled delivery.

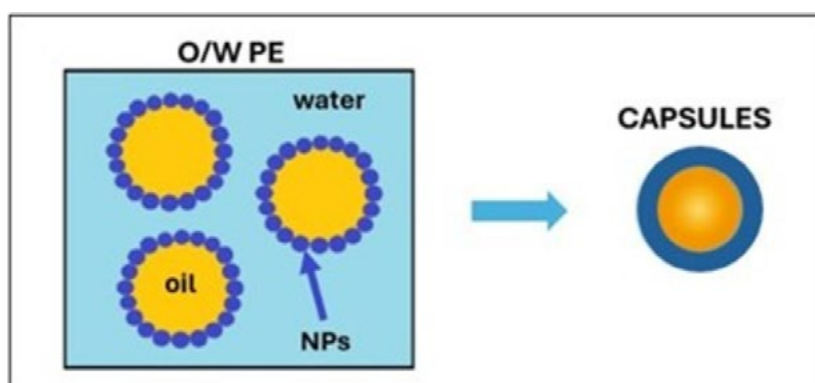
In the first step, a bio-derived material (A) was processed into nanoparticles via an anti-solvent precipitation method and characterized for interfacial properties. Contact angle measurements suggested a favourable amphiphilic balance for adsorption at the oil–water interface ($\sim 90^\circ$). However, the intrinsic hydrophobicity and lyotropic behaviour of material A limited its dispersion in water and hindered efficient interfacial stabilization. To overcome these limitations, composite nanoparticles were prepared by combining material A with a hydrophilic polysaccharide (B) [1]. This strategy improved aqueous dispersibility and enhanced nanoparticles adsorption at the oil–water interface, enabling the formation of Pickering emulsions at lower nanoparticles concentrations than previously reported.

Two homogenization techniques were explored to tune the emulsion microstructure: Ultra-Turrax (UT) mixing and sonication. UT produced emulsions with larger droplets ($\approx 20\ \mu\text{m}$) that were stable for about one week, whereas sonication produced smaller droplets and significantly improved stability. This tunability is advantageous at the application level, as it allows the emulsion properties to be tailored to specific needs.

While stabilizing the emulsion, the assembly of nanoparticles at the oil–water interface provides a platform for interfacial structuring. The resulting interfacial nanoparticle layer will be consolidated through green hardening strategies to form robust capsule shells with tunable permeability. Encapsulation and release processes will be investigated using confocal laser scanning microscopy (CLSM) [2], enabling correlation between interfacial structuring, capsule formation, and fluorophore diffusion.

Keywords:

Composite bio-based nanoparticles, Pickering emulsions, interfacial stabilization, encapsulation



Pickering emulsions as templates for capsules formation.

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Tuning Bijel Channel Permeability Through Silica Deposition for Particle Infiltration Purposes

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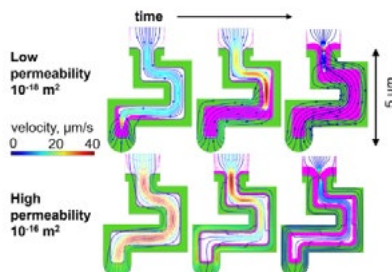
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Bicontinuous interfacially-jammed emulsion gels (bijels) consist of two immiscible phases, typically oil and water, that form continuous, interwoven networks, stabilized at the interface by nanoparticles. Due to the interwoven nature of their networks, bijels boast large interfacial areas per volume, making them attractive for energy storage applications [1]. In this research, we will utilize the two networks of the bijel to create the cathode and anode of a lithium-ion battery, facilitating higher power delivery and faster charging due to the reduced diffusion length of the lithium ions. In order to create the cathode, the oil channel of the bijel will be infiltrated with colloidal lithium iron phosphate (LFP) nanoparticles. However, simulations show that, if the permeability of the water channel is sufficiently high, the LFP colloidal suspension will penetrate into the water channel, thereby depositing the nanoparticles on the network walls, leading to clogging of the channel before it can be adequately filled. Therefore, in order to ensure proper infiltration, the permeability of the water channel must be reduced. This will be achieved by introducing tetramethyl orthosilicate (TMOS) into the water channel. Upon contact with water, TMOS hydrolyzes to silica which deposits onto the anode nanoparticles in the water network, filling up voids in between the particles, thereby reducing the permeability of the channel [2]. Through a combination of confocal laser scanning microscopy, scanning electron microscopy, and pressure gradient measurements, the influence of the TMOS treatment can be studied. Based on these results, adjustments in TMOS concentration and reaction time facilitate control over the bijel channel permeability.

Keywords:

Bijel, Battery, Permeability



Snapshots of fluid dynamics simulations showing the change in particle depositing behavior for different bijel channel permeabilities.

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Soy Lecithin Foam Stabilization: Thin Foam Films and Interfacial Rheology Study

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Lecithins are phospholipidic mixtures of natural origin, which are known for their ability to stabilize colloidal systems such as foams and emulsions. They are widely applied in various processes in the food, pharmaceutical, cosmetic, and other industries due to their biocompatibility, minimal environmental impact and potential health benefits.

The present study explores the interfacial behavior of Soy Lecithin (Soy PC) as well as its ability to stabilize foams. The investigations are focused on the physicochemical properties of the basic elements of foams: thin liquid films and adsorption layers, in view of a better understanding of the underlying mechanisms of foam stabilization.

Dynamic surface tension and surface rheology are measured using a profile analysis tensiometer. Thin foam films characteristics (drainage kinetics, film thickness, disjoining pressure isotherm, critical pressure of film rupture, etc.) are explored using the microinterferometric method of Scheludko-Exerowa and the TLF Pressure balance technique.

The results are correlated to the stability of Soy PC based foams studied under the same experimental conditions. The data shed additional light on the mechanism of foam stabilization and might be helpful for optimization and control of foams with potential industrial applications.

Keywords:

thin liquid films, interfacial rheology, foam

Acknowledgements:

Research equipment of the project № BG16RFPR002-1.014-0006 "National Centre of Excellence Mechatronics and Clean Technologies" was used for experimental work financially supported by European Regional Development Fund under "Research Innovation and Digitization for Smart Transformation" program 2021-2027.

The research was partly funded by the European Union – NextGenerationEU through project BG-RRP-2.015-0009.

Comparative Interfacial Stabilization by β -Lactoglobulin and Cruciferin in Protein-Stabilized Oil-in-Water Emulsions Using a Microfluidic Approach

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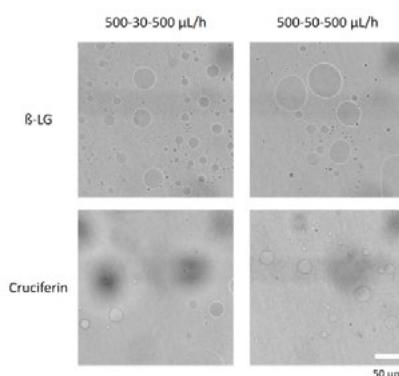
Emulsions used in plant-based milk alternatives are frequently formulated with relatively low protein contents, where interfacial crowding is limited and adsorption kinetics become critical for long-term stability and sensory quality. In this regime, it is still unclear how animal- and plant-derived globular proteins differ in their ability to stabilize freshly formed oil–water interfaces under well-defined flow conditions. Here, we employ a microfluidic 3D flow-focusing geometry to generate well-defined oil-in-water emulsions and directly compare the interfacial stabilization provided by the dairy protein β -lactoglobulin (β -LG) and the plant storage protein Cruciferin.

Medium chain triglyceride (MCT) oil droplets are produced in a single flow-focusing chip while keeping the flow-rate ratio fixed and varying only the protein identity and its bulk concentration between 0.25 and 0.75 wt%. This design yields monodisperse droplets whose formation history and residence time after pinch-off are precisely controlled, allowing hydrodynamic effects to be decoupled from compositional ones. Confocal laser scanning microscopy is used as a real-time probe of droplet size, spatial organization and coalescence dynamics during the first minutes after emulsification, when interfacial films are still developing.

Across the investigated concentration range, Cruciferin-stabilized emulsions displayed smaller droplet diameters and improved resistance to coalescence compared to β -LG at identical bulk concentrations, which consistently yielded larger, less stable droplets. The contrasting droplet size and stability suggest differences in the efficiency with which plant- and dairy-derived proteins stabilize freshly formed interfaces at low concentrations. This hypothesis will be examined in ongoing work by correlating microfluidic data with small-angle X-ray scattering and Raman microscopy to resolve interfacial nanostructure and molecular organization.

Keywords:

protein-stabilized emulsions, Cruciferin, β -lactoglobulin, microfluidics



Bright-field micrographs of MCT oil-in-water emulsions stabilized by 0.5 wt% β -lactoglobulin (top) and Cruciferin (bottom), produced in a microfluidic device at the flow rate of 500–30–500 and 500–50–500 $\mu\text{L h}^{-1}$. Scale bar: 50 μm .

Click-derived triazole chitosan as a bio-based polymeric emulsifier for oil-in-water emulsions: a comparative formulation study and simulation-guided insight into interfacial stabilization

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The development of sustainable emulsifiers from renewable polymers is an important challenge in colloid and interface science. Chitosan (CS) is an attractive bio-based candidate owing to its biocompatibility, biodegradability, film-forming ability, and broad functionalization potential. However, its practical use as an emulsifier in oil-in-water (O/W) systems is often limited by weak intrinsic amphiphilicity, pH-dependent solubility, and insufficient interfacial activity under formulation-relevant conditions.

In this study, CS was structurally modified with a triazole-phenyl moiety through Cu(I)-catalyzed azide-alkyne cycloaddition (CuAAC) click chemistry to tune its hydrophilic-hydrophobic balance and investigate how click-derived structural changes affect emulsion stabilization behavior. The emulsifying performances of native CS and click-derived triazole CS were comparatively evaluated in O/W emulsions using the creaming index and volume-weighted mean droplet diameter $D[4,3]$ as principal stability descriptors. To obtain a systematic understanding of formulation-dependent behavior, the effects of pH, oil volume fraction, and emulsifier concentration were further analyzed by response surface methodology (RSM), enabling identification of stability trends, interaction effects among formulation variables, and operating windows in which each material exhibited distinct colloidal performance.

The results showed that chemical modification of CS significantly altered its emulsification characteristics, leading to measurable differences in droplet size, macroscopic phase stability, and sensitivity to formulation conditions. Compared with native CS, the modified CS exhibited enhanced emulsion stability and more robust formulation behavior over a wider condition range, including systems containing relatively high oil fractions.

Importantly, the modified CS did not exhibit uniformly superior behavior under all tested conditions, indicating that enhanced hydrophobic character alone is insufficient to guarantee optimal stabilization and that emulsion performance is governed by a complex balance among polymer solubility, conformational flexibility, interfacial adsorption, and continuous-phase structuring. In addition to emulsification performance, antioxidant activity was evaluated to assess whether click-derived modification could introduce added functionality beyond colloidal stabilization, further supporting the design of multifunctional bio-based emulsifiers.

To complement the experimental findings, molecular simulation is currently being conducted to elucidate the interfacial affinity, preferred molecular organization, and adsorption tendency of the modified CS at the oil-water interface. This simulation work aims to provide mechanistic insight into the contribution of the triazole-phenyl group to interfacial localization and molecular arrangement, with the goal of rationalizing the experimentally observed differences between native and modified CS in terms of interfacial packing and polymer-medium interactions.

Overall, this combined experimental, statistical, and simulation-based study provides a structure-property-function framework for understanding click-functionalized CS in O/W emulsion systems. The findings demonstrate that triazole-based modification is an effective strategy for tuning CS toward bio-based emulsifier applications, while also establishing a foundation for the future development of nanoparticulate or hybrid particulate stabilizers, including systems incorporating bio-waste-derived components for sustainable Pickering-type emulsification.

Keywords:

Chitosan; Click chemistry; Oil-in-water emulsion; Bio-based emulsifier; Response surface methodology; Molecular simulation

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On the Tolman Length Puzzle: A Comparative Study of Interfacial and Bulk-Pressure Routes for Sign and Critical Scaling

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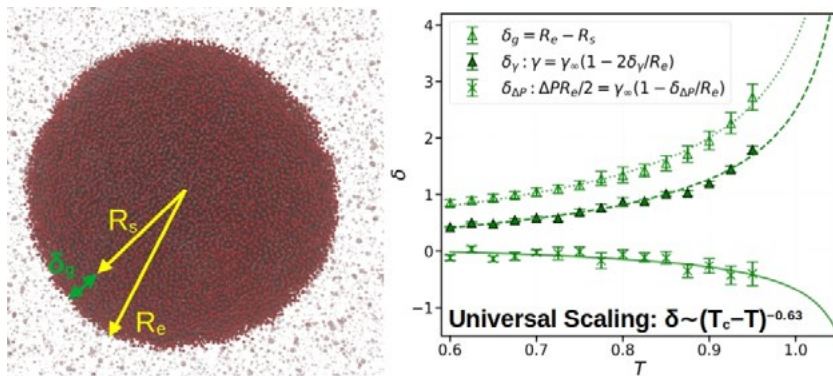
The Tolman length, δ , a fundamental parameter describing the curvature dependence of surface tension, remains contentious due to persistent discrepancies in its sign and magnitude. In this work, we systematically investigate these inconsistencies for a truncated and shifted Lennard-Jones fluid ($r_c = 2.5$) using molecular dynamics simulations. We evaluate δ through three distinct methodologies: the geometric difference, $\delta_g = R_e - R_s$, the surface tension expansion, δ_γ , and the bulk-pressure route, $\delta_{\Delta P}$. To address the non-uniqueness of the pressure tensor, we implement a discretized Irving-Kirkwood contour with K sampling points, finding that $K \geq 3$ is required for numerical consistency in interfacial-based routes.

Our results show that interfacial definitions (δ_g, δ_γ) are consistently positive, with δ_g being approximately twice as large as δ_γ across all studied conditions. In contrast, the bulk-pressure route yields a small negative Tolman length, $\delta_{\Delta P} \approx -0.03$ at $T = 0.8$. Both the δ_γ and $\delta_{\Delta P}$ frameworks exhibit a remarkable dual self-consistency: they quantitatively recover the planar surface tension $\gamma_\infty(T)$ for all K as curvature vanishes, while capturing the expected qualitative trends for critical point shifts and droplet vapor pressure via the modified Kelvin equation. This dual consistency helps explain the historical difficulty in reaching a consensus on the sign of δ .

We suggest that the bulk-pressure route is more robust, as it is independent of the discretization parameter K and avoids numerical integration across the anisotropic interfacial region. Finally, we found that all δ definitions exhibit temperature dependence consistent with the universal scaling $\delta \sim (T_c - T)^{-\nu}$, with the 3D Ising critical exponent $\nu = 0.63$.

Keywords:

Tolman length, Molecular dynamics simulation, Nanoscopic droplets, Surface tension, Pressure tensor, Lennard-Jones fluid



(Left) Simulated liquid droplet illustrating equimolar, R_e , and surface of tension, R_s , radii. (Right) Tolman length, δ , from geometric, δ_g , surface tension expansion, δ_γ , and bulk-pressure, $\delta_{\Delta P}$, routes vs. temperature (T), showing universal scaling near T_c .

Foam coarsening dynamics within non-Newtonian fluids

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Injecting additive-stabilized foam fluids presents a promising approach for geological carbon storage (GCS) in complex reservoir environments. The effectiveness of this technique critically depends on foam stability and flow behavior within a confined space. However, the mechanisms governing the transition from foam coarsening to structural equilibrium, especially in non-Newtonian systems, remain insufficiently understood. This study investigates the gas-diffusion-driven coarsening of quasi-2D foams in non-Newtonian fluids, and the interaction between fluid rheology and gas diffusion in shaping foam morphology. Non-Newtonian precursor fluids were prepared using cellulose nanofibrils (CNF), and their rheological properties were systematically correlated with foam evolution. Fluorescence imaging combined with custom analysis tools enabled quantitative tracking of bubble morphology and dynamics. Results show that increasing CNF concentration leads to a nonlinear enhancement in foam stability, as indicated by extended half-life times. Analysis of bubble size distribution and lamella curvature revealed that higher CNF content suppresses gas diffusion and bubble rearrangement, especially within confined pore spaces. Overall, this work reveals how non-Newtonian rheology modulates foam stability and structure, offering valuable insights into the design of more effective foam-based GCS strategies under challenging reservoir conditions.

Keywords:

Foam coarsening; non-Newtonian fluids

Foam Disinfection Mechanisms

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Foam-based disinfection is a promising sustainable alternative to conventional cleaning methods for contaminated solid surfaces, as it enables significant reductions in water and detergent consumption [1]. However, despite extensive studies on foam stability and interfacial properties, the relationship between foam structure and cleaning efficiency is not clarified.

This study aims to elucidate, with a multiscale approach, how interfacial tension, foamability and thin liquid film dynamics influence detergency. Three model surfactants are selected, with the same alkyl chain length but different hydrophilic groups, to vary interfacial effects. The study includes two non-ionic surfactants, C12E6 and sugar based β -C12G2, and a cationic benchmark, C12TAB.

Surface tension measurements are performed using Wilhelmy plate tensiometry. Foaming properties are tested using a commercial FoamScan, which allows direct observation of foam collapse and measurement of bubble size distributions. These macroscopic observations are correlated with the dynamics of freestanding thin liquid films at the microscale, probed using the dynamic thin film balance technique [2]. Comparisons between the two experiments, performed at the same capillary pressure, provide a link between microscopic film dynamics and macroscopic foam response.

Finally, detergency is evaluated by investigating the wetting behavior of the different surfactant systems at the scale of thin liquid films formed between a single bubble and a hydrophobic substrate (*Fig. 1*) [3]. This approach provides insights into how surfactant structure governs wetting, film stability and cleaning performance.

Keywords:

Foam, hydrophobic surface, wetting film, cleaning

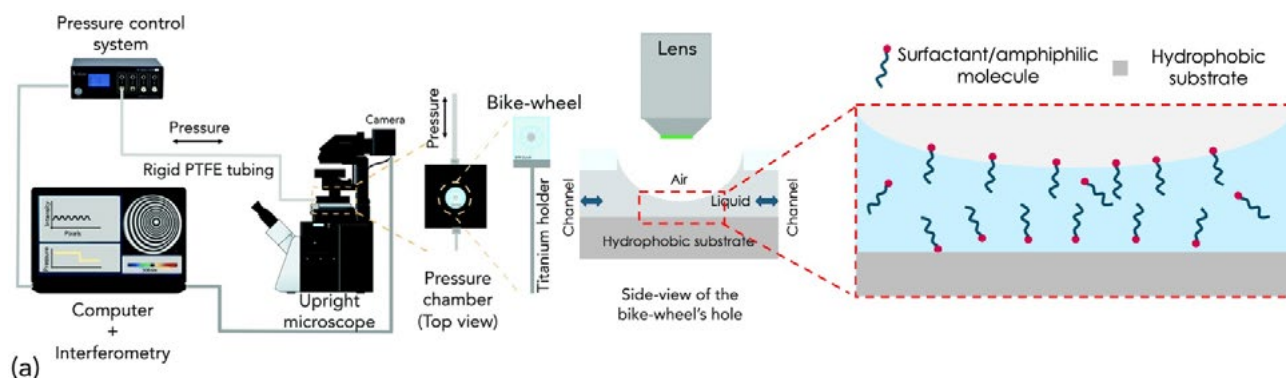


Figure 1: Schematic of the dynamic thin film balance setup and a zoom in the cross section of the thin liquid film formed between a single air bubble and a hydrophobic substrate.

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Towards a Polar Phase in Organic–Inorganic Metal Halide Thin Films for Ferroelectric Applications

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Metal halide perovskite semiconductors have attracted significant interest for their ability to facilitate the fabrication of devices with excellent optoelectronic and electrical properties through affordable and efficient chemical solution methods.[1] As electrical properties such as polarisation and charge transport are intrinsically dependent on crystal structure, the occurrence of polymorphism presents challenges in the solution processing of thin films.[2] Here, we report the synthesis and thin-film fabrication of novel cobalt halide complexes with *N*-methyl-1,4-diazabicyclo[2.2.2]octanium cations (CH₃-DABCO), aiming to prepare new ferroelectric molecule-based materials. The initial reaction between (CH₃-DABCO) iodide and cobalt(II) chloride yields the non-polar compound [(CH₃-DABCO)CoCl₃], which cannot exhibit ferroelectric behaviour. Chemical solution-based composition engineering produced a new mixed halide compound, [(CH₃-DABCO)CoCl₂I], which crystallises in two polymorphic forms at room temperature: one with a ferroelectric polar structure and one with a non-polar structure. This research focuses on the preparation and characterization of thin films to selectively obtain and stabilise the ferroelectric polar polymorph. Thin films are fabricated using spin coating, drop casting, and dip coating techniques, while systematically varying deposition parameters and environmental conditions to investigate their influence on phase formation.[3] Capturing the polar phase in thin films is a crucial step towards enabling ferroelectric characterisation and understanding the structure–property relationships in these hybrid organic–inorganic systems.[3] This research highlights the importance of combining chemical synthesis with thin-film processing strategies to control polymorphism and material polarity, offering a pathway towards molecular thin films with tuneable ferroelectric properties and potential applications in functional devices.

Keywords:

ferroelectrics, thin films, hybrid organic–inorganic systems

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Acknowledgements:

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Asymmetric hydration of enantiomers at aqueous interfaces

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Hydration of chiral supramolecular assemblies by chiral molecules breaks the mirror symmetry of interfacial water through electrostatic interactions and hydrogen bonding, thereby imprinting molecular chirality onto the surrounding water hydrogen-bond network and giving rise to so-called “chiral water.”¹ Understanding whether and how individual chiral molecules induce such chiral structuring in their hydration environment is crucial for elucidating the fundamental properties of, and rationally guiding the design of, chiral supramolecular assemblies.² However, addressing this question requires molecular-level insight into interfacial water structure, particularly its hydrogen-bonding organization, which remains a significant experimental challenge. Here, to address this challenge, on a model system of amphiphilic peptide enantiomers, we employ chiral heterodyne-detected sum-frequency generation (HD-SFG) spectroscopy to directly resolve the chiral molecular structure of both the peptide enantiomers and the interfacial water. Our preliminary results of distinct spectroscopic features for two enantiomers suggest their asymmetric hydration properties, which could be further tuned by the interfacial conditions, such as pH. Furthermore, the complementary Langmuir isotherms reveal differences in membrane phase behaviour and compressibility that correlate with these molecular-level observations. Together, our results provide initial evidence for the enantioselective hydration at the air/water interface and the feasibility of HD-SFG in resolving chiral interfacial structure.

Keywords:

chiral water, heterodyne-detected sum-frequency generation spectroscopy, amphiphilic peptides

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Acknowledgements:

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Unraveling Oil–Water Interfacial Mechanisms in Chitosan-Modified OEG Microgels via Dissipative Particle Dynamics

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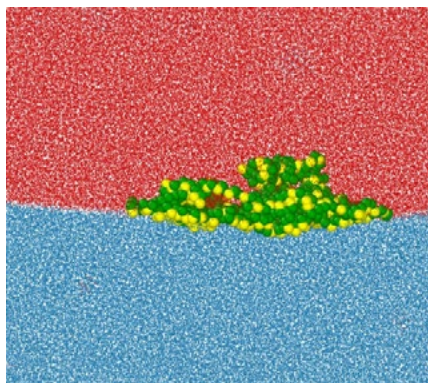
Oligo(ethylene glycol) (OEG)-based microgels have recently emerged as promising alternatives to traditional Poly(N-isopropylacrylamide) (PNIPAM) systems due to their non-toxicity, excellent emulsion stabilization, and robust mechanical properties. Their ability to form soft, stimuli-responsive networks makes them particularly attractive for biomedical and interfacial engineering applications [1]. To further enhance their biocompatibility and functional tunability, OEG microgels can be combined with methacrylated chitosan, a naturally derived, biodegradable polymer known for its intrinsic biocompatibility, antimicrobial activity, and pH-responsive behavior. This combination introduces a new class of fully non-toxic, environmentally benign microgels capable of responding to multiple external stimuli [2].

While OEG/chitosan microgels show promise, their interfacial mechanisms remain unclear due to the limitations of experimental techniques in resolving nanoscale interactions. We address this using Dissipative Particle Dynamics (DPD) simulations, a mesoscopic approach ideal for capturing microgel morphology and interfacial tension [3].

This study uses numerical simulations to investigate the volume behavior, temperature sensitivity, and pH responsiveness of OEG/methacrylated chitosan microgels. By emphasizing their role in oil–water compatibilization, we provide a mechanistic understanding of how chitosan modulates swelling and interfacial anchoring. These findings facilitate the rational design of biocompatible microgels for drug delivery, food emulsions, and eco-friendly formulations.

Keywords:

Microgel, Chitosan, Simulations, Dissipative Particle Dynamics



DPD snapshot of a microgel particle adsorbed at an oil-water interface. The oil (red) and water (blue) phases are clearly separated, with the microgel beads (yellow/green) flattening into a fried-egg structure.

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Acknowledgements:

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Tailored Lamellar Structures for Highly Stable Thermoresponsive High Internal Phase Emulsions

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This contribution will describe a protocol for emulsion preparation that renders highly stable concentrated emulsions at lower temperatures, that may be de-stabilized above a certain transition temperature.

This methodology relies on the deposition of lamellar phases, prepared with a few wt.% of ionic surfactants such as CTAB and stearate, and fatty alcohols, at the oil-water interface, whose thermotropic behavior account for the observed changes in stability. Their mesophases were characterized by SAXS/WAXS analyses confirming the transition from gel to liquid crystalline (Lb to La) lamellae upon heating. The temperature of transition could be determined by DSC and interfacial tension measurements and is shown to be dependent of the surfactant and alcohol used, as well as on their ratio. The high stability of emulsions at lower temperature allows their concentration up to 85% dispersed phase, providing an interesting alternative to preparation of high stability HIPEs (high-internal phase emulsions).

This transition range could be tuned from below room to above body temperature, rendering a versatile protocol to produce temperature responsive emulsions. These could be envisaged for applications in personal care formulations, as irreversible temperature indicators among others.

Keywords:

emulsions, HIPEs, lamellar phases

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Control the partitioning of Pickering miniemulsion particles in bicontinuous interfacially jammed emulsion gels (bijels)

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Bicontinuous interfacially jammed emulsion gels (bijels) feature intertwined, continuous water and oil domains separated by a densely packed nanoparticle layer at the interface [1]. Most applications utilize the jammed interfacial layer or solidify one of the continuous channel as a scaffold [2,3]. However, the incorporation of additional functional particles within the continuous channels remains unexplored.

We synthesize Pickering miniemulsion particles that serve as fluorescent tracers which has a polymer core fully armored by a shell of silica nanoparticles [4]. The polymer core can incorporate a range of lipophilic dyes, allowing flexible selection of excitation and emission wavelengths. The silica shell enables robust surface modification, providing delicate control over particle surface properties.

By tuning the degree of silane functionalization, we observe a transition in particle partitioning from dispersing in the water phase, then attaching to the interface, and finally to the oil phase. This behavior is achieved through the signature in-situ particle modification during the solvent transfer-induced phase separation (STrIPS) process. We attribute the transition to the interaction between the functionalized surface groups and surfactants.

This work opens up the possibility to introduce multiple types of functional particles into bijels, thereby facilitating applications in catalysis and energy storage.

Keywords:

Bijels, Miniemulsion, Pickering emulsion

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Hierarchically Structured Grating Films Constructed via Confined Self-Assembly of Cellulose Nanocrystal Colloidal Particles

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Colors generated by continuous and periodic micro/nanoscale structures play an important role in nature. Inspired by those structures, various micro/nano optical devices with diverse morphologies have been developed and made a difference across multiple fields. Metal/semiconductor colloidal particles, polymers, and organic small fluorescent molecules can all serve as the fundamental building blocks for structural optical devices. ^[1–3] Depending on different optical mechanisms, the resulting colors can be attributed to thin-film interference, diffraction, or scattering. ^[4] Such optical devices are widely used for waveguides, displays, photoelectric conversion, and optical sensing. ^[5] In this work, a hierarchic transparent cellulose nanocrystals (CNCs) film that integrates both linear structures and cholesteric structures is formed through evaporation-induced self-assembly (EISA) of renewable CNCs colloidal particles. ^[6] The asymmetric structural morphology was studied along with the asymmetric optical properties under polarized plane-wave illumination. A wrinkled surface was introduced as the template for utilizing its spatial confinement effect. CNCs colloidal particles undergo EISA within this confined one-dimensional wrinkling surface. During the helical self-assembly of CNCs, interfacial bending occurs in accordance with the template scale, resulting in the successful fabrication of diffraction grating structures with various wavelengths and heights up to approximately ten times the width of a single CNC. The resulting linear gratings exhibit unidirectional reflective grating properties. A clear resolution of ± 3 diffraction orders can be observed with a first-order diffraction efficiency of up to 9%. The cut-off wavelength range covers from the visible region (508 nm) to the infrared region (1539 nm). Furthermore, due to a kinetic arrest effect during EISA, the fabricated films remain the left-handed helical layered structure even after interfacial bending and spatially confined drying. The stacked layered structure extends from flat regions into the linear grating regions. These films produced single-channel left-handed optical activity, and their circular dichroism (CD) signal intensity and reflection spectral position can be tuned by adjusting the helical structure of CNCs. Within this framework, additional composite structures (with or without diffraction grating features) can be patterned on the film to produce optical anti-counterfeiting elements that are both visually observable and specifically detectable. This work provides a scalable and cost-effective platform for fabricating optical components using natural renewable colloids and lays a foundation for the development of optical signal technologies based on green and sustainable resources.

Keywords:

Cellulose Nanocrystals, Self-Assembly, Gratings, Wrinkle Template

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Interfacial Engineering of FAPbI₃ Perovskite Solar Cells via Tetramethylammonium Iodide (TMAI) Surface Passivation for Enhanced Phase Stability and Efficiency

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The commercialization of **Formamidinium lead iodide (FAPbI₃)** perovskite solar cells (PSCs) is primarily hindered by the spontaneous phase transition from the photoactive α -phase to the non-perovskite δ -phase under ambient conditions [1]. This study investigates an effective interfacial modification strategy using Tetramethylammonium Iodide (TMAI) as a surface passivation agent to stabilize the α -FAPbI₃ lattice and **suppress interfacial charge recombination**.

In a typical fabrication, the FAPbI₃ perovskite films were deposited via a one-step spin-coating process. The TMAI surface treatment was performed by dynamic spin-coating of a TMAI solution onto the perovskite surface, followed by a brief thermal annealing process to ensure proper interfacial interaction. The introduction of TMAI onto the perovskite surface significantly modifies the surface energy and chemical environment of the film. X-ray diffraction (XRD) analysis confirms that the TMAI treatment effectively inhibits the formation of the δ -phase. Specifically, the iodide (I⁻) anions provided by TMAI **passivate the iodine vacancies**, while the bulky tetramethylammonium (TMA⁺) cations reside on the surface, providing a robust **hydrophobic barrier and stabilizing the perovskite lattice** against moisture-induced degradation.

Contact angle measurements reveal an increased surface hydrophobicity following TMAI treatment, suggesting a robust barrier against moisture ingress. The energy level alignment was further elucidated by Ultraviolet Photoelectron Spectroscopy (UPS), which revealed a more favorable band alignment at the perovskite/HTL interface, facilitating efficient hole extraction. Furthermore, steady-state photoluminescence (PL) and J-V characterization indicate a significant reduction in voltage loss and improved carrier extraction efficiency. Optimized devices achieved a power conversion efficiency (PCE) exceeding **21.17%** with remarkably improved long-term stability. This work provides deep insights into the molecular-level interfacial interactions between quaternary ammonium halides and perovskite surfaces, offering a scalable route toward stable and high-performance optoelectronic devices.

Keywords:

Perovskite solar cells, FAPbI₃, Interfacial modification, TMAI, Phase stability, Surface passivation

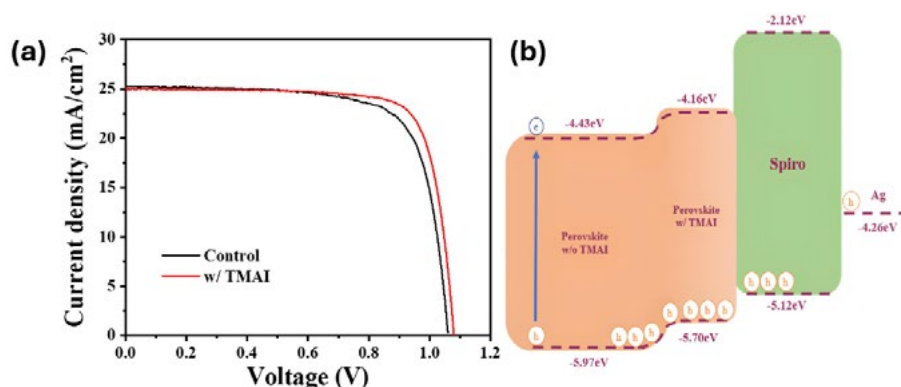


Fig 1. (a) J-V curves of FAPbI₃ devices with/without TMAI, achieving 21.17% PCE. (b) Energy level diagram derived from UPS, demonstrating improved band alignment for enhanced interfacial charge extraction.

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Structured Liquid-in-Liquid Emulsion Stabilized by Surface-Engineered Liquid Metal Droplets as "Mutant" Pickering Emulsifiers

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Liquid metals (LMs), i.e., metals and alloys that exist in a liquid state at room temperature, have recently attracted considerable attention owing to their electronic and rheological properties useful in various cutting-edge technologies. In this study, eutectic Ga-In (EGaIn), one of the most studied LMs, in its microdroplet form was engineered to produce a novel droplet-type surfactant that can stabilize a liquid- *in* -liquid emulsion with unique functionality and processability. Dual-engineered LM droplets with a robust SiO₂ encapsulation shell and adsorbed amphiphilic cetyltrimethylammonium bromide (CTAB) exhibited high chemical stability against water-mediated oxidation while possessing excellent oil-water interfacial activity. These engineered droplet-type surfactants densely adsorb at microscale water-oil interfaces and prevent coalescence of the dispersed oil droplets in the liquid continuous phase, thereby producing long-term stable oil- *in* -water (O/W) emulsions; these droplet-type surfactants were named as "mutant" Pickering emulsifiers, indicating *particle* emulsifiers (different from *molecular* surfactants) that are similar to conventional Pickering emulsifiers, but consisting of the *liquid* core instead of the *solid*. The resulting emulsions exhibited enhanced yield stresses with viscoelastic properties, even at a minimal LM load, and showed remarkable sedimentation stability, indicating significant implications in terms of processability in versatile applications. The "structured" nature of such emulsions combined with the excellent photothermal conversion ability of LM droplets adsorbed at O/W interfaces resulted in the extremely localized photothermal heating effect. Furthermore, photothermally responsive phase-change oil droplets were produced using engineered LM droplets, which can be used for the on-demand release of valuable oil-soluble cargo as a potential application. We expect that engineered LM droplets as novel droplet-type emulsifiers of immiscible liquids in colloidal multidisperse systems will provide unique opportunities for various applications.

Keywords:

Liquid Metal, EGaIn, Pickering Emulsion, Droplet-Type Surfactant, Photothermal Conversion

Self-assembly of binary mixtures as potential replacements for per- and polyfluoroalkyl substances (PFAS) in firefighting foams

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A critical use of per- and polyfluoroalkyl substances (PFAS), known as “forever chemicals,” is in the aqueous film-forming foam (AFFF), which could lead to significant public health risks ¹. As shown in **Fig. 1**, the foam blanket isolates heat and oxygen from the fire and vapour, with fluorocarbon surfactants and compounds located at the gas-liquid interface and the liquid-liquid interface in contact with the fuel.

Current PFAS alternatives in AFFFs include partially perfluorinated surfactants ¹, mixtures of silicone and hydrocarbon surfactants, hydrolysed proteins, nanocellulose-stabilised gel foams, and thermo-responsive triblock copolymers ². These potential replacements, however, face less-than-optimal properties and economic viability. This study aims to systematically investigate binary surfactant-polymer mixtures as a PFAS alternative.

Aerosol-OT (AOT), a hydrocarbon surfactant, is effective in stabilising water-in-oil (W/O) microemulsions ¹. Amphiphilic triblock Pluronic copolymers containing PEO-PPO-PEO can form temperature-responsive nanostructures, transforming between micellar assemblies at ambient conditions and mechanically rigid films with ordered micellar packing at elevated temperatures (e.g. 45°C) ², rendering them suitable for fire suppression. Pluronic F127, a tri-block copolymer exhibiting surface tensions of 36 mN·m⁻¹ at 1 wt% (above its CMC), is chosen for the binary mixture with AOT.

The preliminary small-angle neutron scattering (SANS) and surface tension measurements revealed a dynamic micellar architecture under different experimental conditions of AOT-based binary mixtures (Fig. 1C). F127 was found to synergise with AOT, achieving a reduced surface tension of 29 mN·m⁻¹ in the binary system (Concentration: 10.5 mM dm⁻³ AOT + 1 wt% F127). SANS data show that the AOT-F123 binary mixture formed spherical nanostructures. These results demonstrate the potential to systematically investigate micellar microstructures across single- and multi-phase media using SANS to establish general principles governing optimal design parameters using the binary system to replace PFAS. This study ultimately aims to optimise the performance of these alternatives and eventually develop a design guide for the environmentally friendly classes in fluorine-free surfactants.

Keywords:

PFAS, self-assembly, thermal response, SANS

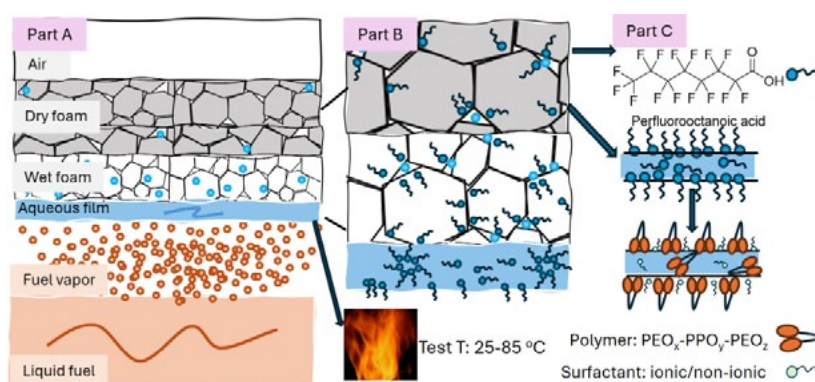


Figure 1

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Designing of Plasmonic Resonators for Artificial Optical Magnetism

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Over the past decades, meta-materials & surfaces have attracted huge attention due to their emergence as a powerful platform for enabling advanced optical functionalities, owing to their exceptional wave propagation properties, which are not found in naturally occurring materials¹. Metamaterials have widespread applications, especially as nanolasers, optical antennas, sensors and for nonlinear optics². Key components of metasurfaces (the 2D version of metamaterials) are the optical resonators that can be constituted of assembled plasmonic nanoparticles. These NPs clusters were shown to exhibit strong magnetic response when interacts with electromagnetic fields, which is referred to as optical magnetism. Moreover, the intensity of this response can be tuned by the clusters structure and density³.

Here in this work, we have engineered plasmonic nano resonators through bottom-up self-assembly of noble metal nanoparticles. To achieve those clusters, we used two specific methods, namely the Ouzo fabrication route and the emulsion-based route⁴. With this latter one, we now aim at producing monodispersed and reproducible clusters through the use of microfluidics technique, which enables precise control over cluster formation. The clusters were systematically characterized by TEM, DLS and SAXS to determine their morphology, shape and size distribution. Additionally, we have designed plasmonic resonators with specific optical resonance modes in the visible wavelength range through the development of NP-shells⁵ via Ouzo route, where gold nanoparticles were self-assembled on Ouzo droplets generated from liquid-liquid phase separation of hydrophobic solutes in a ternary system by the addition of a non-solvent.

Measurement on these two formulated resonators with our home-made Polarization-resolved Static Light Scattering (SLS) exhibit promising signals that corresponds to magnetic scattering of resonators when interacting with light. Our findings demonstrate that these optical resonators will have significant contribution and potential applications in the development of future photonic devices where magnetic responses in the visible range is crucial.

Keywords:

Meta-materials & surfaces, Emulsion, Optical resonators, Microfluidics, Optical magnetism.

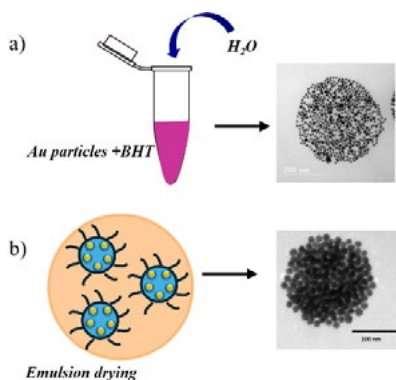


Figure1: Formulation of Plasmonic resonators through a) Ouzo and b) Emulsion route.

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Developing endosome membrane mimics to study lipid nanocarrier interactions

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Lipid nanoparticles (LNPs) are established vehicles for intracellular RNA delivery [1,2,3]. They are uptaken through endocytosis and transported to the endosomal compartment, which is separated from the cell cytosol by a lipid membrane bilayer. For RNA cargo to be therapeutically active, it must be released from the endosome into the cytosol through a process called “endosomal escape” [4]. However, this remains a major barrier in RNA delivery, with a significant proportion of RNA remaining trapped in the endosome [5].

To better understand the process of endosomal escape, we probe interactions of LNPs with supported lipid bilayers (SLBs). Using QCM-D and TIRF, we examined how vesicles interact with SLBs that mimic the endosomal membrane. Additionally, during a neutron reflectometry (NR) experiment, we investigated vesicle interactions with SLBs and floating supported bilayers (FSBs), which serve as more biologically realistic membrane models. Notably, the nature of the membrane bilayer deposition (FSB vs SLB) of membranes with the same lipid composition was also found to influence their interaction with nanocarriers. Together, we show that endosome-mimicking lipid bilayers of increased lipid complexity can be formed using SLB and FSB methods. These membranes can provide insights into lipid organization and applied to study LNP/vesicle fusion and lipid exchange processes. Such improved endosomal membrane mimics are highly relevant tools for uncovering mechanisms behind endosomal escape.

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Adsorption and Lubrication of Alanine-based Anionic Surfactant with Cationic Polyelectrolyte at Solid/Aqueous Solution Interfaces

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Anionic surfactants and cationic polyelectrolytes form complexes through electrostatic interactions in water. These complexes change their phase state due to charge balancing and are typically formulated in shampoos [1, 2]. In recent years, amino-acid-based surfactants are of increasing interest due to aspects of their environmental and human-friendly nature [3].

In this study, we characterized adsorption of surfactant-polymer complexes on a solid surface. We employed sodium dodecanoyl β -methylalanine (C12MeAlaNa) as an amino-acid-based anionic surfactant and a quaternary ammonium-type cationic polyelectrolyte (CP). The solid surface used in this study was negatively charged hydrophilic silica. The adsorption and desorption behaviors on the solid surface were evaluated using a quartz crystal microbalance with dissipation monitoring (QCM-D) technique and atomic force microscopy (AFM). Furthermore, lubrication of the adsorbed complexes was assessed using a ball-on-plate type automatic friction analyzer.

QCM-D measurements demonstrated that premixing aqueous solutions of C12MeAlaNa and CP resulted in decreased frequency ($\Delta F_3/3$) and increased energy dissipation (ΔD_3), suggesting the formation of a relatively thick and viscosity-dominant adsorption film. This adsorption is driven by positive charges of CP as anchoring sites, even though negative charges originating from C12MeAlaNa predominate in the mixtures. Subsequent rinsing with pure water resulted in increases in both $\Delta F_3/3$ and ΔD_3 . This reflects increased viscosity of the adsorption film remaining on the solid surface.

Regarding lubrication properties, the adsorption of these complexes significantly reduced kinetic friction coefficients compared to a pristine silica surface. The excellent lubricity was maintained even after rinsing with pure water, due to the adsorption film remaining on the surface.

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Hybrid synthetic/biogenic non-lamellar lipid films

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In recent years multiple efforts have been devoted to the development of reliable biomimetic systems, able to reproduce, in simplified and controlled conditions, relevant characteristics of biological membranes [1]. In this respect, synthetic non-lamellar lipid interfaces are particularly attractive, as tools to investigate the behavior of complex biological assemblies [2]. Indeed, despite the ubiquitous nature of non-lamellar membranes in biological systems, most of their specific functions are still unclear [3].

In this contribution we challenge supported lipid bilayers (SLBs) of variable composition with lipid nanoparticles (LNPs) of different structure (hexosomes, cubosomes), as a strategy to build-up new biomimetic surfaces. Quartz Crystal Microbalance experiments highlighted a tunable interaction mechanism between LNPs and SLBs, dependent on the SLBs composition. Structural studies in solution (Small Angle X-ray and Neutron Scattering) and at the solid-liquid interface (Neutron Reflectometry) revealed the successful permanent anchoring of the LNPs to the target lipid membrane, in a charge-dependent manner, with the liquid crystalline structure of the LNPs preserved. Confocal Microscopy experiments revealed that the adhesion of the LNPs to the target SLBs occurs via diverse mechanisms, implying lipid exchange and/or extensive adsorption, eventually leading, in selected conditions, to the formation of patterned surfaces, with discrete LNPs exhibiting a regular arrangement.

These results show that, by tuning the SLBs composition, LNPs-SLB interaction can be modulated, eventually leading to the controlled formation of patterned surfaces decorated with discrete non-lamellar lipid nanoparticles, which could represent a new biomimetic platform for studies on non-lamellar membranes.

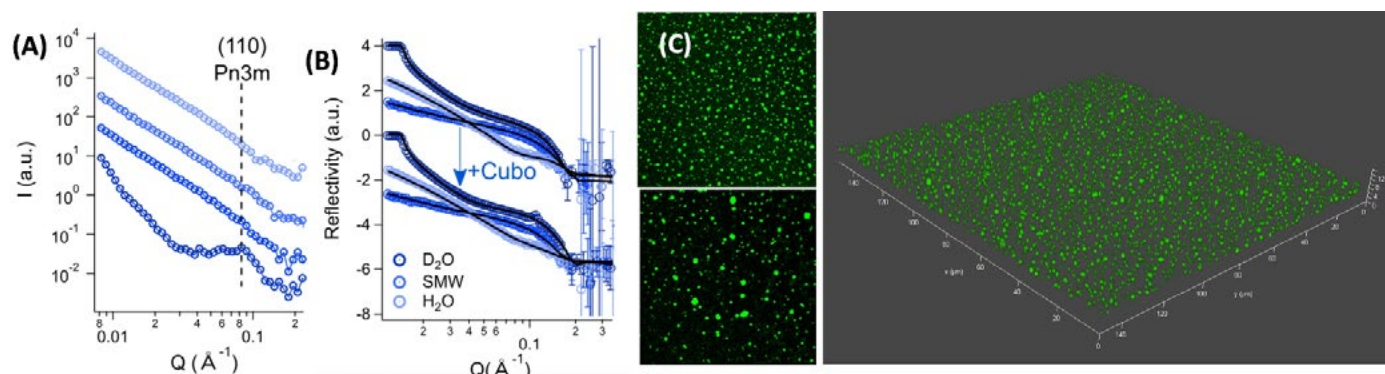


FIGURE 1 (A-B) SAS and (B) NR data on LNPs - lipid vesicles (A) and LNPs SLBs (B) interaction; (C) patterned surfaces visualized via confocal microscopy

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Influence of selected bronchodilators used in chronic obstructive pulmonary disease on Langmuir monolayers serving as models of lung surfactant

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Lung surfactant (LS) is a layer lining alveolar epithelium, which is composed of approximately 90% of lipids by weight and 10% of proteins. It has an essential role in the process of breathing and in minimizing entering of inhaled particles into the bloodstream [1]. Recently conducted research showed decreased total phospholipid amounts in lung surfactant of COPD patients [2]. Chronic obstructive pulmonary disease (COPD) is a common incurable lung disease, which is one of the leading causes of death worldwide. The main goals of COPD management are to alleviate symptoms and prevent exacerbations. Recommended treatment are inhaled bronchodilators: muscarinic antagonists and β_2 -adrenoreceptor agonists [3,4].

Our research objective is to deepen knowledge about the influence selected inhaled drugs used in COPD have on the surface properties of models of lung surfactant. In order to achieve this goal we used models mimicking lung surfactant of a healthy person which reflected simplified LS composition: DPPC:DPPG (8:2) and DPPC:Chol:DPPG (7:1:2) and as a model imitating lung surfactant of a COPD patient: DOPC:Chol:DPPG (7:1:2). We have recently also started investigating models of LS containing ether PC lipids which are second most abundant class of phospholipids in LS [2]. We studied the effect of selected bronchodilators including tiotropium bromide (TTB) on lung surfactant models. Research was carried out with the use of Langmuir technique, Brewster Angle Microscopy (BAM), compression-expansion experiments, oscillating barriers method, grazing incidence X-ray diffraction (GIXD) and total reflection X-ray fluorescence (TRXF). All these methods enabled us to characterize the organization of the monolayers, tendency of the monolayers to form assemblies and their reorganization, viscoelasticity of the monolayers as well as lateral 2D packing of the monolayers and their changes upon the exposure to selected drugs. Moreover TRXF allowed for detection of TTB in the monolayer.

Obtained results show that changes in the surface properties of the monolayers upon exposure to drugs are dependent on the model of lung surfactant. Model monolayers mimicking lung surfactant of a healthy individual and person suffering from COPD differ in the ability to incorporate selected drugs and in the effect on the organization. Moreover, they vary in the influence of the investigated drugs on the ability to reorganize when expanded and on the elasticity.

Keywords:

Lung surfactant, chronic obstructive pulmonary disease, Langmuir technique, BAM, compression-expansion experiments, oscillating barriers method, GIXD

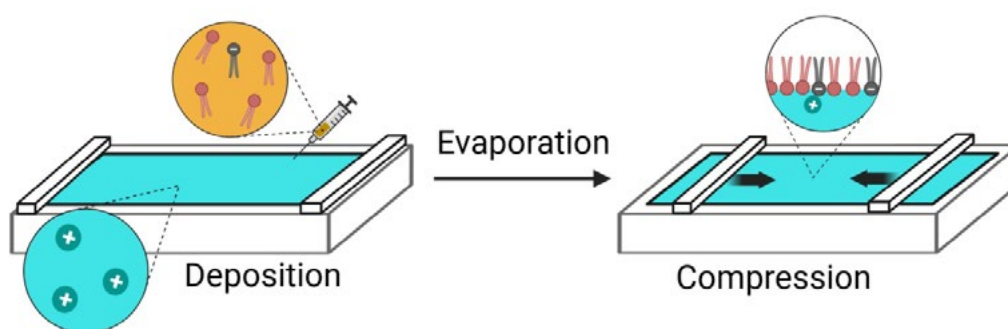


Figure 1. Schematic illustration of the preparation of experiments.

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Original effects of sphingomyelin on liposomal properties clarified by comparing crude and highly purified sphingomyelin

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Sphingomyelin (SM) is expected to form rigid lipid bilayers due to its ceramide backbone and hydrophilic headgroup, having a high potential as a carrier for drug delivery systems and cosmetics in terms of its high water-retention ability and skin affinity property. However, previous studies have mainly focused on pharmacological studies of drug disposition in the body [1][2], and detailed studies of the membrane structure and properties of liposomes remain limited. In our previous study, liposomes mixed with crude SM (purity: 70%) showed high dispersion stability and trapping efficiency while maintaining membrane fluidity. In this study, highly purified SM was used to clarify the original effects of SM on liposomal membrane properties.

Dipalmitoylphosphatidylcholine (DPPC) was used as a phospholipid, highly purified milk-derived sphingomyelin (SM, purity 99%) was used as SM. Dicapryl phosphate (DCP) and sodium β -sitosteryl sulfate (PSO₄) were used as charged additives. Liposomes (5 mM total lipid concentration) with DPPC/charged substance/SM molar ratios of 10 : x : y (x = 0, 1; y = 0, 1) were prepared by the Bangham method.

Visual observation showed that phase separation occurred after one week in the DPPC/ SM system, whereas homogeneous dispersion maintained in the systems containing charged additives. Dynamic light scattering measurements showed that the particle size of DPPC/SM liposomes increased over time, but it remained almost constant for one week when charged additives were added because the zeta potentials were largely negative. The addition of SM and charged additives to DPPC increased the trapping efficiency. In particular, the trapping efficiency in the DPPC/PSO₄/SM system was more than 10%.

Compared with the previously systems using crude SM, the highly purified SM systems showed lower dispersion stability, suggesting that negatively charged components in crude SM affected the dispersion stability. In contrast, the trapping efficiency of liposomes prepared using highly purified SM was higher than that of liposomes in the crude SM systems. This finding suggests differences in bilayer structure and bilayer numbers between liposomes containing crude SM and those containing highly purified SM.

Keywords:

sphingomyelin, liposome, bilayer membrane, stabilization

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Metamaterials for passive daytime radiative cooling

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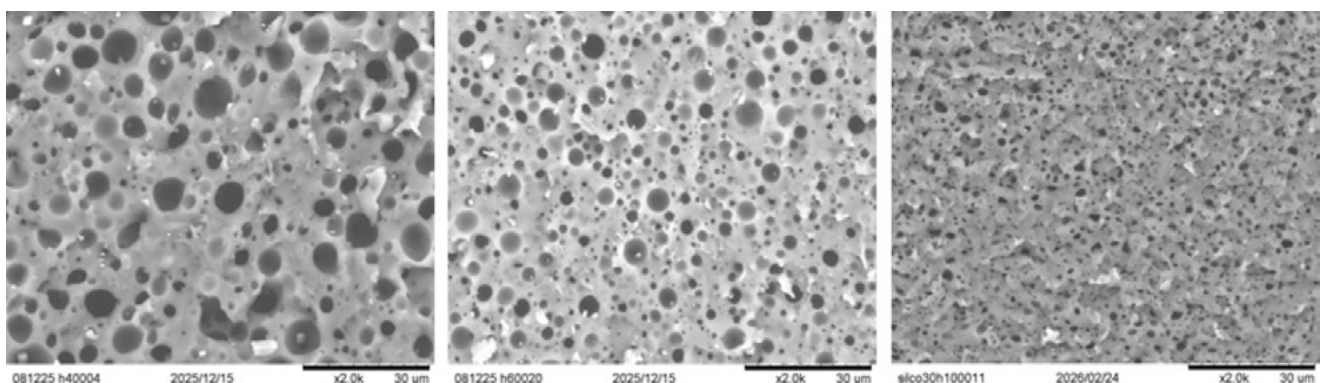
In recent decades, the acceleration of global warming has become increasingly obvious. Research has expanded in the fields of renewable energy and materials with the ability to produce cooling without energy input.

Classical building air-conditioning is highly energy demanding and results in a global increase of temperature outside of the room. Both effects are problematic given the current climatic and economic context. Passive radiative cooling is a natural phenomenon that helps regulate the Earth's temperature. The Earth's atmosphere has a transparency window (wavelengths 8 to 13 μm) that coincides with the peak radiation of terrestrial objects (black body radiation peak at 298 K) [1]. This radiation can therefore be lost into deep space, which acts as a thermal sink at 3 K. Materials capable of emitting electromagnetic radiation at these wavelengths thus exhibit a strong cooling effect when exposed to the sky. Moreover, if these materials also reflect solar light in the solar range (0.2 μm - 2.5 μm), they maintain this cooling effect even when exposed to sunlight. This referred to as "Passive Daytime Radiative Cooling" (PDRC), which is the process by which a surface exposed to the sky emits more energy than it absorbs from incident solar radiation. This unbalance leads to passive cooling of the surface, meaning no external energy input is required.

To achieve this effect, it is necessary to design materials that strongly emit within the 8-13 μm range while being highly scattering in the 0.2-2.5 μm range [2]. Simulations conducted in our team at CRPP (PhD Nigar NAMAZZADE) have helped to determine the optimal material properties in terms of both polymer matrices (for the emitting function in the IR) and inclusion sizes and number density (for the scattering in visible-NIR) [3]. For this reason, we study porous PDMS, varying both pore size and volume fraction to optimize the PDRC efficiency. To create such materials we use the templating emulsion method, crosslink the PDMS with a UV lamp, and dry the sample. The optical properties are measured with an integrating sphere to measure the total reflection (IR and UV-visible) of the material. We managed to achieve solar reflectance comparable with the literature (around 96%) but also probe the evolution of this value as a function of the materials structure and composition. Our study opens new routes for the optimization of passive cooling devices.

Keywords:

Radiative cooling, Polymer, Porous, Optical properties



Scanning electron microscopy image of samples with different pore sizes

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Acknowledgements:

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Tunable and Sustainable UV-Protection: A Chromoprotein-Based Approach to Sensing and Shielding

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Ultraviolet light (UV) tracking and shielding are critical for safeguarding food, pharmaceuticals, and electronics. Nature has addressed this issue by using proteins as dynamic UV shields. For example, the dorsal skin of marine vertebrates exhibits dynamic patterns of protein expression that change with UV exposure. In contrast, current man-made indicators and filters rely on synthetic dyes and inorganic compounds with a poor environmental footprint, limited tunability, and restricted suitability for integration into sustainable materials. Chromoproteins (CPs) offer a sustainable alternative since they can be produced cost-effectively via microbial biofermentation and tuned through genetic engineering.

Here, we exploit controlled Fluorescence Resonance Energy Transfer (FRET) between two CPs as the basis for a ratiometric UV sensor. A significant challenge of traditional FRET constructs is that they rely on large, fused protein tandems that display low solubility and expression yield, hindering their scalability and integration into materials. We avoid this limitation by developing a pipeline for the high-yield production of stable, non-fused CP heterodimers. By modifying monomeric proteins like mGreenLantern and mKillerOrange, we promote dimerization through rational protein design and targeted mutagenesis. Computational prediction and optimization identify key amino acid substitutions that favour intermolecular binding at defined interfaces, achieving FRET proximity without the steric burden of fusions. Engineered CP pairs are cloned into co-expression plasmids for microbial hosts, enabling robust production and purification. The resulting dimers function as sensitive, ratiometric UV sensors whose fluorescence ratio reports the cumulative light-exposure history, enabling sustainable UV tracking and shielding in next-generation packaging and protective coatings.

Keywords:

Chromoproteins, FRET, protein engineering, heterodimerization, biosensors, sustainable materials

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Acknowledgements:

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Modelling ion flotation for the recycling of metals

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Rare-earth metals are crucial in different areas of application, such as magnets, catalysts, metal alloys, batteries, and electronics[1]. These metals are scarce in European soil, so recycling them from end-of-life products may be an important way to obtain them. However, these rare-earth elements are mixed with other elements, making them difficult to isolate and reuse for new applications. Chemical separation methods like ion foam flotation are a resource to separate elements from one another. In ion flotation, a surfactant agent is used to extract ions from the liquid-gas interface [2]. The difference in the ion selectivity with the surfactants is the principle for the separation process.

We performed atomistic simulations to characterize the water-air interface involved in the flotation process, based on previous experiments conducted at our research institute by C.Micheau et al [3,4,5]. In these experiments, they used a commercial carboxyl surfactant (AKYPO RO 90VG) for the ion flotation process. Their findings show that ion flotation using this surfactant can be used to selectively separate mixed ions in solutions, being trivalent ions the ones showing higher selection.

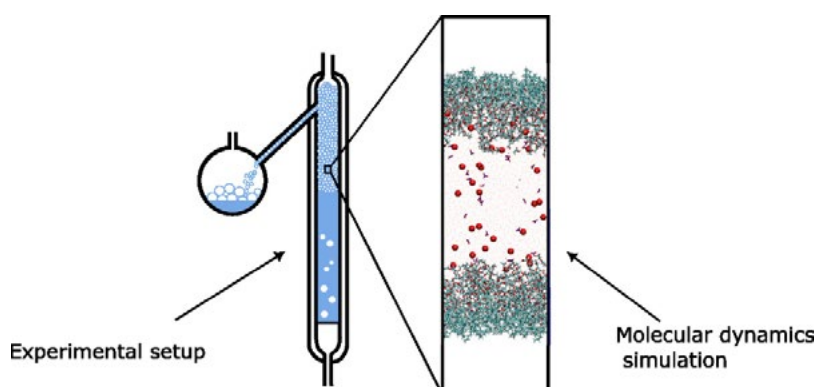
We did molecular dynamics simulations considering different surface excess concentrations of surfactant and calculated the surface tension of the system and its density profile. We then compared the surface tension as a function of the surface excess (obtained from simulations) and the surface tension as a function of bulk concentration (obtained from experiments [3] and simulations). The calculated bulk and surface activity coefficients show that the interactions between the surfactants at the interface are repulsive but attractive in the bulk.

After modelling the water-air interface with a realistic surface excess, we introduced metals to the system, including rare-earth metals. We considered LiNO_3 , NaNO_3 , $\text{Ca}(\text{NO}_3)_2$, $\text{Sr}(\text{NO}_3)_2$, $\text{Nd}(\text{NO}_3)_3$ (as in the experiments [4]). We studied two opposite situations: low and high pH. This is, cases in which the carboxyl group of the surfactant is mostly protonated or deprotonated. We observe a significant difference in the selectivity of the ions depending on the pH due to their complexation with the carboxyl group. We also see that calcium and neodymium offer higher selectivity towards the surfactant by calculating the fraction of adsorbed ions and their residence time at the interface.

Overall, this work lays the groundwork for a molecular prediction of the specific effects that govern flotation, a highly significant method for separating elements.

Keywords:

Rare-earth, Ion foam flotation, separation chemistry, molecular modelling



Experimental setup scheme of the ion flotation process and snapshot of the molecular dynamics simulation.

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The authors acknowledge financial support from the CYCLAMET project, funded by the French National Research Agency (ANR) under the France 2030 program (grant No. ANR-22-PERE-0003).

Light-Driven Catalytic Oxidation At The Floating Au–Silica Interface: A Planar Model For Pickering Foams

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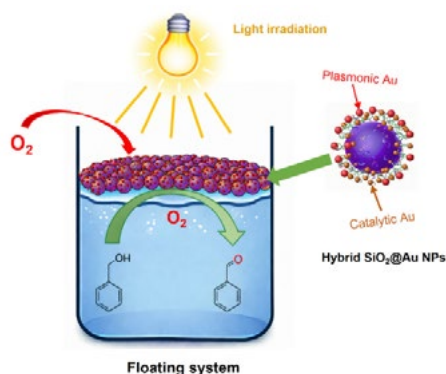
Pickering foams, stabilized by solid nanoparticles, generate a well-defined three-phase environment between air, solid, and liquid – that concentrates catalytic sites within the foam lamellae and promotes efficient mass transfer in multiphase reactions [1]. Exploiting this architecture for catalysis is highly attractive; however, the complex and dynamic nature of real foam systems makes it difficult to precisely characterise and control the active interfacial region.

Gold nanoparticles are particularly appealing in this context, as their tuneable size can combine catalytic activity and plasmonic properties, generating localized heating under light irradiation. Our group previously developed Pickering emulsion systems in which plasmonic Au-loaded amphiphilic silica nanoparticles were co-assembled with catalytic nanoparticles at the water/oil interface, affording a five-fold increase in catalytic activity compared to thermal heating for alkene oxidation [2].

To deepen understanding of the interface encountered in Pickering foam systems, we developed a simplified planar model: a floating catalytic layer composed of self-assembled amphiphilic Au-silica particles at a flat air-liquid interface. This tractable geometry reproduces the essential physicochemical features of the foam lamella. At the interface, Au nanoparticles play a dual role as catalytic centres and plasmonic nano-heaters, while both substrate and oxidant remain readily accessible. Although the macroscopic geometry limits the available interfacial area and catalytic activity compared to emulsion or foam systems, this floating configuration uses air as the sole oxidant and minimizes organic solvent consumption, contributing to a greener process. As such, this system serves as a well-defined model for investigating the interfacial processes that govern catalysis in Pickering foam architectures.

Keywords:

Pickering foam, plasmonic nanoparticles, Pickering interfacial catalysis, hybrid particles.



Light-driven aerobic oxidation at the air–water interface

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Small-angle X-ray scattering analysis of interfacial membranes in O/W emulsions prepared using polyether-modified silicone

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Oil-in-water (O/W) emulsions are oil droplets dispersed in water and are widely used in cosmetics and industrial formulations. However, they are inherently unstable and undergo destabilization processes such as creaming, flocculation, coalescence, and Ostwald ripening. Polyether-modified silicones (PEMS) are widely used as emulsifiers in cosmetic formulations because of their excellent sensory properties. Previous research has reported that stable O/W emulsions can be prepared through the adsorption of PEMS vesicles at the oil–water interface [1]. However, the detailed structure and physicochemical properties of the interfacial membranes formed by PEMS have not been fully understood. In this study, O/W emulsions were prepared using PEMS through different preparation methods, and the effects of the preparation process on the structure and physicochemical properties of the interfacial membranes were investigated using small-angle X-ray scattering (SAXS).

Polyoxyethylene (12) dimethylpolysiloxane (PEMS) and glyceryl tri-isooctanoate (TIOG) were used as a surfactant and oil, respectively. O/W emulsions were prepared by the following three preparation processes: (A) emulsification by agitating oil together with an aqueous vesicle dispersion of PEMS, (B) emulsification of an oil solution of PEMS by adding water, and (C) emulsification by adding oil and water to a lamellar liquid crystalline phase of PEMS. The emulsion droplets were observed by optical microscopy. The interfacial membrane structure of the emulsions was characterized by SAXS and generalized indirect Fourier transformation (GIFT) analysis of the obtained data.

Optical microscopic observation showed the emulsions prepared by processes A and C exhibited less droplet growth than those prepared by process B, indicating higher stability against coalescence. Since coalescence is closely related to the structure of the emulsion interface, it was suggested that the interfacial structures of the emulsions varied depending on the preparation process. Bragg peaks corresponding to the lamellar structure were observed in the SAXS profiles of the emulsions prepared through processes A and C, whereas no such peaks were observed in the process B system. Furthermore, freeze-fracture transmission electron microscopy (FF-TEM) revealed that thick interfacial membranes were formed at the interface of the emulsions in processes A and C. In contrast, process B emulsions had no thick interfacial membranes. These results indicate that the structure of the interfacial membrane depends on the preparation process, and that the lamellar structure formed at the interface contributes to the suppression of coalescence.

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Bacterial Lipid Extracts as Advanced Model Membranes: Studying new Sample Architectures and Interactions with LL37

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Bacterial membranes exhibit significant compositional and structural complexity. Gram(-) bacteria like *E. coli* possess membranes with high contents of glycerophospholipids, whereas Gram(+) bacteria like *B. subtilis* possess membranes enriched in anionic lipids. Their membranes also differ in acyl chain composition, with *E. coli* lipids being dominated by linear fatty acid chains and *B. subtilis* lipids being rich in branched-chain fatty acids. Most biophysical studies of bacterial membranes have so far involved model systems composed of only a few synthetic lipids [1, 2]. To overcome this limitation, we use lipid extracts obtained from both hydrogenated and deuterated *E. coli* and *B. subtilis* [3], enabling the development of more realistic model membranes compatible with characterization techniques such as X-ray and neutron scattering. In order to access these membranes also with surface-sensitive methods like grazing-incidence X-ray diffraction (GIXD, now applicable also to non-crystalline lipid layers [4]) and total-reflection X-ray fluorescence (TRXF), we aim to create sample architectures in which the membranes are loosely adsorbed to functionalized air/water interfaces, as was demonstrated earlier for synthetic bilayers [5, 6]. Moreover, we comprehensively investigate the interaction of bacterial lipid layers with the human antimicrobial peptide LL-37, using a combination of neutron reflectometry (NR), X-ray reflectometry (XRR), GIXD, and TRXF.

Keywords:

Bacterial membranes; Natural lipid extracts; Antimicrobial peptides; X-ray and neutron scattering.

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Tribofilm Formation from Mixtures of Sulfur and Phosphorus-Type Extreme Pressure Agents

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Lubricants are generally composed of base oils and additives. An extreme pressure (EP) agent is a lubricant additive that can form a tribofilm on a metal surface under sliding conditions at high temperatures and pressures. The tribofilm prevents wear of the metal surface. In this study, we focused on mixtures of sulfur (S) and phosphorus (P)-type EP agents. These mixtures provide a synergistic effect on friction reduction and antiwear performance, leading to their widespread use in various industrial applications. The main focus of this study is to elucidate reaction mechanisms of sulfur and phosphorus-type EP agents in terms of (i) adsorption of each component or their mixtures and (ii) composition of tribofilms formed by sliding.

n-dodecane was selected as a base oil. As a sulfur-type EP agent, 10,10'-trisulfanediylidistearic acid (COOH) was used. As a phosphorus-type EP agent, di(2-ethylhexyl)phosphate (di-P) was used. The adsorption/desorption of the EP agents on/from an iron oxide substrate was characterized using a quartz crystal microbalance with dissipation monitoring (QCM-D) technique. Friction coefficients were measured on a SPCC substrate by means of a ball-on-plate-type friction analyzer. After friction measurements, the surface composition of the SPCC substrate was analyzed by X-ray photoelectron spectroscopy (XPS).

In the COOH and di-P mixtures, friction coefficients increased during the initial stage of sliding and subsequently decreased to approximately 0.2 in the steady state. The initial increase in friction coefficients arises from adsorption of di-P on the SPCC substrate, whereas the subsequent decrease in friction coefficients reflects the predominant effect of COOH on the reactivity. XPS measurements revealed that, in the steady state, the tribofilm formed from COOH and di-P contained a larger quantity of sulfur than phosphorus. This supports higher adsorption capability and reactivity of COOH compared with those of di-P.

Polymer physisorption at cellulose surface from non-polar medium

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Physisorption of hydrophobic polymers from non-polar solvent medium is an underutilized tool for modification of surfaces, especially of soft matter. In the case of the inherently hygroscopic cellulose, the well-established routes for surface modification via polymer physisorption have traditionally been limited to adsorption of polysaccharides or cationic polyelectrolytes from aqueous solutions. The potential of utilizing non-polar solvent medium for modification of cellulose surface was demonstrated in our earlier work [1] where the wettability of cellulose nanopapers was successfully tuned using physisorption of hydrophobic polymers. In the current study [2], physisorption phenomenon from non-polar medium on cellulose is studied in more detail utilizing quartz crystal microbalance with dissipation monitoring (QCM-D). The effect of the molecular size of the adsorbate polymer are investigated at theta condition. Comparison of cellulose surface to another hydrophilic adsorbent, silica, is also presented. Despite some conformational differences upon the polymer layer formation process depending on the adsorbent, adsorption of hydrophobic polymer from non-polar environments was shown to be mainly irreversible and to result in effective hydrophobisation on both studied surfaces. The non-aqueous treatment is truly surface-specific, preserving the structural integrity of the interfibrillar cellulose network. The approach opens up an arsenal of alternatives to covalent surface modifications.

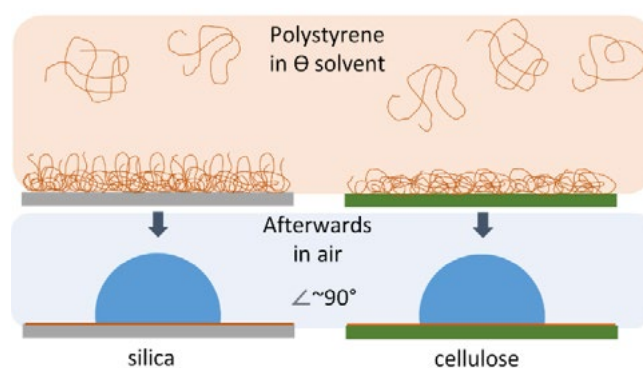


Figure 1. Polystyrene physisorption onto silica and cellulose from a non-polar θ -solvent, and the resulting hydrophobisation in air.

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Light-Driven Pickering Interfacial Catalysis Using Polydopamine-Based Particles

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Pickering emulsions constitute a sustainable alternative to conventional surfactant-based systems, offering enhanced stability while reducing environmental impact. In this work, bio-inspired polydopamine (PDA) particles were synthesized via the spontaneous auto-oxidation of dopamine under alkaline conditions, allowing straightforward control over particle size through polymerization time. Owing to their catechol- and amine-rich surface chemistry, PDA particles exhibit strong interfacial adhesion properties.

PDA particles and their metal-functionalized counterparts were employed as stabilizers for oil-in-water emulsions with different oil phases, yielding stable systems. Beyond emulsion stabilization, these particles were investigated as platforms for Pickering interfacial catalysis under visible light irradiation, taking advantage of the inherent photoactive character of polydopamine and the plasmonic properties of metal nanoparticles.

This study highlights the potential of polydopamine-based materials as multifunctional and sustainable Pickering systems, bridging interfacial stabilization and light-driven catalysis.

Keywords:

Pickering interfacial catalysis, polydopamine, light-assisted catalysis, Pickering emulsion

Understanding stabilization mechanisms of SU-8 microrods in Pickering foams

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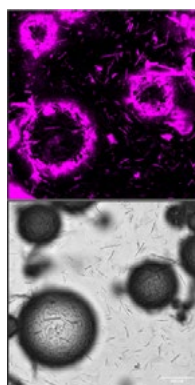
Particle-stabilized liquid foams have attracted significant attention in colloid and interface science due to their enhanced stability and reduced reliance on surfactants. While the effects of particle size [1], surface charge, and wettability [2] are well established, the role of particle shape in foam stabilization remains comparatively underexplored [3].

In this work, we investigate the stabilization mechanisms of liquid foams formed by anisotropic SU-8 microrods fabricated via a solvent attrition method. First, the fundamental mechanism of rod formation has been investigated, imaging the batch at different mixing times. Here, a tip streaming origin of the rods was confirmed thanks to the presence of droplets with highly elongated tips in the continuous phase at limited mixing times. Subsequently, foams were generated by simple hand shaking, without any surfactant or co-stabilizer, using microrods with varying weight fractions and polydispersity. An optimal intermediate microrod concentration was identified, yielding maximal long-term foam stability.

Foam conductivity measurements and X-ray tomography were used to quantify the incorporated air fraction and to distinguish between bubbly liquid and true foam regimes. The resulting “hairy” armoured bubbles, arising from the high aspect ratio of the absorbed particles, significantly hinder film drainage and coalescence between approaching bubbles.

Interfacial properties were further investigated using Langmuir trough experiments and interfacial shear rheology, both coupled with optical microscopy. These measurements revealed predominantly elastic interfacial behaviour, supporting an interfacial stabilization mechanism, relevant for interfacial deformation occurring during bubble deformation.

In Figure 1 an example interfacial adsorption of SU-8 rods is shown. Here, rods can be seen adhering at the interface, having some rods also protruding out from the bubble. Overall, this study demonstrates how particle anisotropy and wettability can be exploited as key design parameters for surfactant-free foam systems.



Confocal and optical micrographs of air bubbles in the liquid medium of water/glycerol 80:20 with SU-8 rods

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Bio-based membrane surfaces with tunable properties for water-borne impurities removal

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Water-borne impurities and pathogens such as microplastics, viruses, nutrients, pharmaceuticals, hormones, industrial chemicals and many others affect human lives all over the world and are linked to numerous health issues. Pressure-driven membrane filtration technologies are one of the most energy-efficient pathways for water purification. However, conventional membrane structures are fabricated from relatively expensive and synthetic materials, and therefore are often non-sustainable. On that note, there has been several efforts to use plant-based building blocks in the preparation of water purification systems.

Bio-based membranes can be fabricated, for example, using nanocellulose, a material directly obtained from plants and produced by disintegrating biomass-sourced fibers, therefore it is biodegradable and renewable. The combination of high strength, chemical inertness, high density of hydroxyl groups offering numerous opportunities for further functionalization, hydrophilicity and high surface area makes (nano)cellulose a promising material for high-performance membranes and filters to capture various chemical species, where the removal selectivity relates to both microstructure and chemistry of the membrane material.

We conducted a systematic study to investigate the structure-property relationship of plant-derived membranes to fulfill the specifications and final application requirements relevant for wastewater treatment to capture pollutants and recover valuable elements. The approach was based on fine-tuning the structure of nanocellulosic networks towards addressing porosity, flux, and rejection rates while simultaneously assuring required mechanical performance. Moreover, proposed routes were designed to enable large-scale production and roll-to-roll processing. Developed nanocellulose-based membranes had tunable pure water permeances in the range of 3-60 L m⁻² h⁻¹ MPa⁻¹ and could reject nearly 90% of nanoplastics and 80% of BSA.

Keywords:

nanocellulose, membranes, water purification, nanoplastics, pilot scale

Toward a new route for water remediation via microgel stabilized emulsions

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Microgels are soft and deformable colloidal particles, capable of irreversibly adsorbing at liquid-liquid and liquid-gas interfaces thereby stabilizing Pickering foams and emulsions [1-2]. The microgels undergo conformational changes from a flattened shape to a more compressed state depending on their concentration and processing history, which impact the interfacial properties [3]. Thanks to their porous structure, microgels also have excellent sorbent properties, making them ideal candidates for payload entrapment and delivery. A key feature of microgels is their stimuli-responsiveness. An interesting consequence is the possibility to destabilize emulsions / foams on demand, upon application of a stimulus.

Here, we investigate the potential of microgels as sorbents for small molecular contaminants in water, followed by interfacial adsorption of the loaded microgels to enable extraction from the medium. In particular, we evaluate the ability of microgel-stabilized emulsions to physically separate the contaminant from the medium by skimming the droplets, by analogy with the flotation process [4]. Emulsion destruction on demand allows collecting the concentrated dye and the recovery of oil and microgels.

In the present study, we select methylene blue, a cationic dye as a model contaminant. Using poly(N-isopropylacrylamide) (PNIPAM) microgels incorporating negatively charged carboxylate groups, we obtained up to 90% removal of MB from aqueous solution. These microgels were used to stabilize emulsions in the limited coalescence regime, *i.e.* the regime where all microgels are adsorbed at the oil-water interface, thereby concentrating the dye at the surface. Thanks to droplets creaming, a concentrated emulsion layer is created, which concentrates the contaminants, offering its rapid and easy extraction by skimming. Emulsion destruction on demand allows collecting the concentrated dye and the recovery of the microgels. This concept could bring interesting perspectives for the decontamination of water with a good recovery of the extracted species and sorbents.

Keywords:

Emulsion, responsive microgel, water remediation.

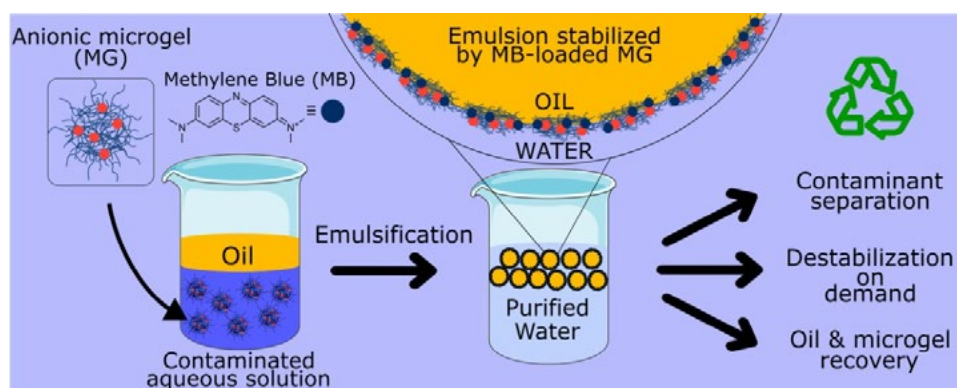


Fig. 1: pNIPAM-stabilized emulsion to extract contaminant from aqueous phase.

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When lipid nanoparticles meet lung surfactant: a comprehensive study of their potential for inhaled therapeutic applications

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Lung surfactant (LS) is a lipid-protein complex system that stabilizes the respiratory air–liquid interface by reducing surface tension and thus facilitating breathing dynamics. Furthermore, LS has also been proposed as a potential carrier to transport inhaled therapeutics over the respiratory interface, known as interfacial delivery. However, its ability to effectively transport nanomaterials over the mentioned interface is still not completely understood.

In this work, we studied the interfacial pulmonary transport of lipid nanoparticles (LNPs), which are often used for drug delivery, in the presence of LS using biomimetic *in vitro* models. To do so, we combined a double Langmuir surface balance and a custom-built interfacial delivery device to quantify transport of LNPs across a continuous air-liquid interface under both static conditions and breathing-like compression-expansion dynamics. Physicochemical stability of LNPs at 4 °C and 25 °C was assayed under storage-relevant conditions. In parallel, cargo release kinetics were studied both in the absence and presence of LS. The absence of surfactant was aimed at measuring intrinsic nanoparticle stability, while the presence of LS allowed us to evaluate cargo release in a controlled manner under conditions that better mimic the pulmonary context. Additionally, the impact of LNPs on LS biophysical performance was assessed using a Captive Bubble Surfactometer. Finally, preliminary experiments in alveolar A549 epithelial cells and THP-1-derived macrophages are currently ongoing to evaluate nanoparticle uptake, cytotoxicity, and inflammatory responses, including metabolic activity (MTT assay) and IL-6/IL-8 secretion. Overall, these experiments provide a more comprehensive picture of how suitable LNPs are for interfacial delivery, helping to clarify the strengths and weaknesses of LNPs as platform for inhaled drug delivery.

Keywords:

Lipid nanoparticles (LNPs); Lung surfactant; Air–liquid interfaces; Interfacial delivery; Nanoparticle–interface interactions.

Influence of Hydrophobic Character and Anionic Size on the Adsorption of Halogenated Borate Salts on Model Colloids

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This study presents a comparative analysis of the adsorption behavior of a series of halogenated borate salts ($\text{Na}_2\text{B}_{12}\text{X}_{12}$, where $\text{X} = \text{H}, \text{F}, \text{Cl}, \text{Br}, \text{I}$) on two distinct colloidal systems: hydrophobic polystyrene latex particles and hydrophilic chitosan particles. Both systems possess a positive surface charge, with the divalent borate anions acting as counter-ions and sodium as co-ions. Electrophoretic mobility measurements demonstrate a remarkable sensitivity of the hydrophobic system to the nature of the specific anion used showing significant charge reversal with all tested salts. By contrary, for the hydrophilic system, only with the biggest anions a small charge reversal was observed. Hence, anion adsorption is significantly higher on hydrophobic particles compared to hydrophilic ones across all tested salts. A critical finding is the direct correlation between the size of the halogen atoms surrounding the boron cluster and the adsorption capacity: as the ionic radius increases, the drop in electrophoretic mobility becomes more pronounced, leading to charge reversal at lower concentrations. For instance, while differences for the $\text{Na}_2\text{B}_{12}\text{H}_{12}$ anion become relevant above $5 \cdot 10^{-4} \text{ M}$, the $\text{Na}_2\text{B}_{12}\text{Br}_{12}$ anion shows significant effects starting from concentrations as low as 10^{-7} M . Finally, a comparison with "classical" inorganic salts such Na_2SO_4 (also with a -2 charge) is done. The results obtained with the sulfate ion highlight the differences in interaction between hydrophobic and hydrophilic systems, aligning with observations made regarding borate ions. This underscores that in order to explain the specific interaction of these nanoions with any interface, one must consider not only their size and charge density [1] but also the nature of the colloidal surface with which they interact as in the classical Hofmeister effects.[2]

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Formation and stability of highly concentrated essential oil in water emulsions

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The increasing need for sustainable alternatives across the pharmaceutical, healthcare, and food preservation sectors has driven extensive research into essential oils (EOs)[1]. While these natural compounds present remarkable functional properties, their widespread industrial application is frequently limited by inherent challenges such as high volatility, poor water solubility, and chemical degradation. Encapsulation methods, particularly ionic gelation, serve as a crucial strategy to circumvent these limitations[2]. The effectiveness of this process relies heavily on formulating a robust oil-in-water (O/W) emulsion that incorporates the encapsulating matrix within its continuous phase. To address the scarcity of comprehensive studies regarding this primary emulsification stage, the present study evaluates how different surfactant-derived bio-emulsifiers influence the stability of O/W systems engineered with a high EO payload. Formulations were prepared using EOs with diverse chemical profiles (specifically orange, peppermint, lavender, and vetiver) enabling an in-depth assessment of the dynamics between the oil composition and the emulsifying agents. Emulsion integrity was meticulously assessed using macroscopic phase separation, microscopic characterization (droplet size and polydispersity index), and rheological testing. It was observed that both orange and lavender oils formed o/w emulsions using emulsifiers that exhibited high Hydrophilic-Lipophilic Balance (HLB), the more hydrophilic behaviour. On the other hand, peppermint and vetiver oils presented a more curious profile of emulsion formation. As for the stability as a function of the time, lavender and orange emulsions exhibited small increase in droplet size, not impacting significantly, however, in their rheological behaviour. Furthermore, it was found that viscosity is a key factor for the long-term stability of the samples.

Keywords:

Essential oil, emulsion, bio-emulsifiers, rheology, microscopy

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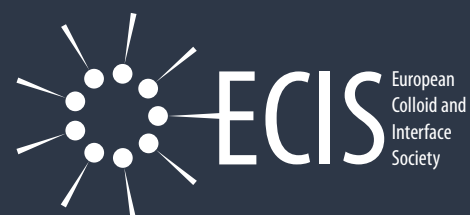
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Topic 4

Micro-, Nano-, Optofluidics, and
Rheology of Complex Fluids

! POSTER



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Microemulsions made from pulp and paper side-streams as a potential alternative to conventional wood impregnation. Exploring complex liquid systems with turpentine.

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The Nordic forest sector produces considerable quantities of side-streams including sulphate turpentine and birch bark. Turpentine is currently sold for external refining, while betulin-rich birch bark is typically incinerated for low-value energy recovery. Developing high-value internal applications for these streams is essential for enhancing resource efficiency and supporting a circular bioeconomy. This study investigates the potential of turpentine-based microemulsions for sustainable wood preservation.

Microemulsions – thermodynamically stable, isotropic liquid systems – facilitate the solubilisation of hydrophobic compounds and their controlled delivery into porous substrates. Characterised by low viscosity and ultralow surface tension, these systems enable effective wood impregnation at ambient conditions, potentially eliminating the need for energy-intensive vacuum or high-pressure treatments [1] [2] [3]. While turpentine has traditionally served as a solvent with documented antiparasitic, disinfectant, antifungal, and insect-repellent properties [4], its high volatility limits long-term efficacy. Although previous research confirmed turpentine's fungicidal performance against wood-decaying fungi (e.g., *Coniophora puteana*) via surface painting [5] [6], this study explores its utility as the oil phase in microemulsion systems to achieve deeper penetration.

To maximize the microemulsion fraction, salinity, surfactant concentrations, water-to-oil ratios (WOR), and surfactant-to-alcohol ratios (SAR) were systematically optimised. To address turpentine's volatility, betulin – valued for its antibacterial, antifungal, and antiviral properties [7] was selected as a reinforcing agent. Although raw betulin exhibited poor dispersibility, its hydrophobic derivative, betulin diacetate, significantly improved stability.

To evaluate impregnation depth and distribution, a novel tracing approach was explored. A complex formed between a chelating surfactant and copper ions was incorporated into two chosen microemulsions, enabling detection by energy-dispersive X-ray spectroscopy (EDS). Impregnated wood samples and freeze-dried microemulsions were analysed using scanning electron microscopy (SEM) coupled with EDS mapping. The results demonstrate the feasibility of turpentine-based microemulsions as carriers for active compounds in sustainable wood preservation.

Keywords:

Microemulsions, wood impregnation, anti-fungal, anti-microbial, turpentine, wood preservation

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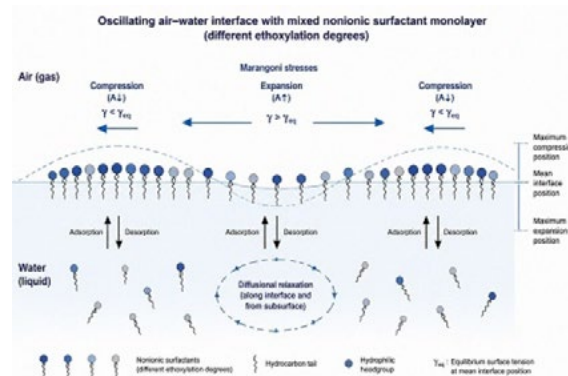
A multicomponent model for the dilatational viscoelasticity of soluble non-ionic surfactant mixtures

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A multicomponent model is developed for the complex dilatational viscoelastic modulus of fluid interfaces stabilized by mixtures of n soluble non-ionic surfactants [2,7]. The formulation couples the diffusion-controlled exchange of each surfactant species with the composition dependence of the interfacial equation of state and adsorption isotherms, yielding an analytical expression for the complex modulus in terms of equilibrium surface concentrations, diffusion coefficients, and the corresponding thermodynamic derivatives [1,6-7]. The model recovers, as limiting cases, the classical Lucassen-van den Tempel description for a single surfactant and the established binary-mixture formulations reported by Jiang et al. and Joos, thereby supporting its internal consistency [1-3,7]. The approach is applied to literature data for ethoxylated alcohol systems, with particular emphasis on the ternary mixture C10EO5/C12EO5/C14EO8 [4-5,7]. Two thermodynamic closures are examined, Langmuir and a reorientation model that accounts for interfacial compressibility and molecular reorientation [4,6-7]. The Langmuir model overestimates the experimental modulus, whereas the reorientation model provides better agreement [4-7]. These results indicate that the predictive performance of a multicomponent dynamic model depends strongly on the physical realism of the thermodynamic submodel used to represent the interfacial layer [4,6,7]. This model provides a rigorous basis for the analysis and design of multicomponent surfactant formulations with tailored interfacial rheology in foams, emulsions, and related dispersed systems [2,7]



Schematic representation of cases of expansion and contraction of the surface

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Rheological and thermal insights into temperature-dependent viscoelasticity of corn oil oleogels

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Oleogels are lipophilic colloidal systems in which a vegetable oil is structured into a three-dimensional solid network, providing consistency and viscoelastic properties similar to those of solid fats. In this study, corn oil was used due to its high content of unsaturated fatty acids and its potential for application in functional food products. Oleogels were formulated with three types of oleogelators: CO_BW (beeswax), CO_CW (carnauba wax), and CO_SW (sunflower wax), at concentrations ranging from 2 to 10 % w/w.

Rheological properties were investigated using a Haake MARS 40 rheometer, through oscillatory frequency sweep tests and temperature-dependent measurements, while thermal transitions were analyzed by differential scanning calorimetry (DSC). All oleogels exhibited pseudoplastic behavior, with viscosity decreasing as shear rate and temperature increased. At 20 °C, the viscosity at 1 Hz increased proportionally with wax concentration: CO_BW ranged from 6 to 80 Pa·s (2–10 % wax); CO_CW from 2 to 90 Pa·s; and CO_SW from 6 to 85 Pa·s.

Frequency-dependent analysis of the viscoelastic moduli showed a predominance of elastic behavior ($G' > G''$), with G' at 1 Hz ranging from 500 Pa (2 % CO_BW) to 4200 Pa (10 % CO_BW). Networks displayed reduced frequency dependence at higher concentrations, indicating increased colloidal stability. Temperature-dependent measurements revealed a progressive decrease in G' between 5 °C and 90 °C, correlating with melting and solidification transitions. DSC analysis identified melting/solidification points consistent with the rheological data: CO_BW 62/58 °C, CO_CW 82/78 °C, CO_SW 55/52 °C.

The results indicate that both the type and concentration of the oleogelator govern the viscoelastic and thermal properties of corn oil-based oleogels. Correlating rheological behavior with thermal transitions provides essential insights for the design of functional lipid colloidal systems with optimized mechanical and thermal performance.

Keywords:

oleogels, corn oil, rheology, viscoelasticity, DSC

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Soybean Oil-Based Oleogels: Analysis of Rheological, Structural, and Thermal Properties

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In this study, oleogels based on soybean oil were developed, structured with carnauba wax at concentrations ranging from 2 to 10% (w/w), used as a lipid gelation agent. The results demonstrated that increasing the concentration of carnauba wax significantly enhances the structuring capacity of the oil phase, leading to the formation of a denser three-dimensional crystalline network, characterized by increased consistency and superior mechanical stability. Microstructural and thermal analyses indicated the progressive development of a more ordered crystalline network with increasing wax content, which promotes the efficient immobilization of the oil phase and confers high physicochemical stability to the obtained systems. Differential scanning calorimetry (DSC) results, conducted over the temperature range of -60 to 100 °C using a DSC 25 calorimeter (TA Instruments, USA), revealed an increase in melting and crystallization temperatures with increasing wax concentration, suggesting improved crystalline organization and intensified intermolecular interactions between the wax and the lipid matrix. Additionally, rheological analysis was performed using a Haake Mars dynamic rheometer equipped with a parallel plate geometry, highlighting the viscoelastic behavior of the systems under controlled shear and temperature conditions. From a rheological perspective, all systems exhibited pseudoplastic behavior, characterized by a decrease in viscosity with increasing shear rate and temperature. Viscoelastic analysis showed the predominance of the storage modulus ($G' > G''$), indicating solid-like behavior, more pronounced at higher wax concentrations, where the internal network exhibits increased rigidity and mechanical strength. Temperature-dependent tests demonstrated a significant influence of wax concentration on the stability of the oleogel network, through the intensification of crystalline interactions and modification of thermal transitions. Frequency sweep analyses indicated a reduced viscoelastic dependence at higher wax concentrations, suggesting the formation of more stable and better interconnected colloidal structures. Overall, the results demonstrate that soybean oil can be effectively structured into stable oleogels using carnauba wax, yielding lipid systems with controllable rheological and thermal properties. These systems exhibit high application potential in the food sector, offering functional alternatives to conventional solid fats, with thermal stability confirmed by DSC analyses.

Keywords:

Oleogels, soybean oil, carnauba wax, rheological properties, thermal properties

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Autonomous Waste Heat Recovery Interface: Converting Vertical Heat Supply into Horizontal Motion for Self-Powered Fluid-Transport in Microenvironments

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Microelectronic power densities surge due to the rise of high-performance-computing utilizing AI and its extended applications due to its rapid scaling down and increasing packing density. With this an increasing amount of waste heat is produced and thermal management has become a critical bottleneck. ¹⁻³ Traditional micropumps for active cooling solutions are often energy-intensive and difficult to integrate at the microscale. In this work, we introduce a fundamentally new class of self-powered and sustainable micro pumping classified as 'passive pump' that transform unavoidable waste heat autonomously into productive fluid motion and is well integrate able on the microscale. ⁴ The core innovation lies in the conversion of vertical heat supply on only one channel wall into horizontal fluid motion. In addition, it takes place under autonomous waste heat recovery as a self-powering phenomenon due to the microstructural interfacial design. While existing experimental thermocapillary (Marangoni) pumping requires a heat supply applied along the flow in the channel's length direction ⁵⁻⁷, a condition rarely met in real-world electronics and other applications, our design enables horizontal pumping with a uniform and vertical heat flux applied across only one channel wall. By combining geometric symmetry breaking with a heterostructure of varying thermal conductivities on a superhydrophobic surface, we demonstrate that this combination supports the autonomously conversion of vertical heat supply into horizontal fluid motion. **Key highlights Proof-of-Principle:** We validated the mechanism through both rigorous numerical simulations and experimental implementation, showing excellent agreement between the respective flow fields. **Operational Effectivity:** Due to the interfacial microstructural design the pumping operates under significantly lower temperature differences along the channel height than that was required by previous designs that applied the temperature difference along the channel's length (flow direction). **Modular Scalability:** The modular design of the pump allows for complex, non-linear microfluidic routing and "lab-on-a-chip" architectures. **Sustainability:** The concept enables fully autonomous waste heat recovery and offers potential for solar-driven applications via light-absorbing self-heating coating. Our findings offer a versatile platform for heat-driven microfluidics, providing a starting point for sustainable and thermal management utilizing autonomous fluid transport on the microscale for high energy density applications in electronics, manufacturing, energy harvesting, research laboratories and other future applications.

Keywords:

waste heat recovery, autonomous, self-powering, complex interface, Marangoni flow, sustainability, microfluidics, micropumping, functional interfaces.

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Intrinsic dynamics of PNIPAM microgels by Diffusing Wave Spectroscopy

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Thermoresponsive PNIPAM microgels are soft colloids whose size, hydration and interparticle interactions vary strongly with temperature. They therefore provide a suitable model system to study how crowding and thermal collapse affect microscopic dynamics in concentrated suspensions. We use Diffusing Wave Spectroscopy (DWS) to investigate low-crosslinked PNIPAM microgels in water without adding external tracer particles.

In this tracer-free approach, the measured decorrelation arises from the microgels themselves. The extracted mean-square displacements and viscoelastic moduli are therefore interpreted as apparent microrheological descriptors of the intrinsic microgel dynamics, rather than as conventional tracer-based bulk moduli. These quantities include contributions from microgel motion, local confinement, particle deformation, internal network fluctuations and microgel–microgel contacts.

The results indicate a slowing down of the dynamics with increasing concentration, consistent with the development of local caging in crowded soft microgel suspensions. The temperature dependence is more complex. Below and close to the PNIPAM volume-phase transition, the response is mainly governed by swelling and effective volume fraction. Above the transition, microgel collapse may reduce the effective particle volume while also promoting stronger interparticle contacts. The high-temperature behaviour is therefore interpreted as a collapsed or attractive regime, rather than as a simple fluidization process.

Tracer-free DWS provides direct access to the intrinsic dynamics of thermoresponsive microgels and highlights the competition between concentration-induced confinement and temperature-induced changes in interparticle interactions.

Keywords:

PNIPAM microgels, soft colloids, Diffusing Wave Spectroscopy (DWS), intrinsic dynamics, concentration-induced caging; thermoresponsive collapse.

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Acknowledgements:

The authors acknowledge the support of grant PID2022-136540NB-I00 funded by MICIU/AEI/10.13039/501100011033 and FEDER, UE.

Viscoelastic Structuring of Hybrid Fumed Silica–Cellulose Nanocrystal Suspensions toward Advanced Emulsion Stabilization

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The rheological behavior of hybrid suspensions composed of fumed silica nanoparticles (T30) and cellulose nanocrystals (CNC) was investigated to understand the combined effects of particle concentration and nanoparticle interactions on steady shear and viscoelastic properties. Steady shear measurements were conducted over a broad range of T30 concentrations, while oscillatory rheology was performed on selected high-silica formulations (7 and 8 wt% T30).

All suspensions exhibited shear-thinning behavior, indicating progressive microstructural breakdown under increasing shear rate. The addition of CNC significantly increased the suspension consistency, suggesting enhanced particle–particle interactions and structural connectivity.

Oscillatory measurements revealed elastic-dominated behavior ($G' > G''$) across the entire investigated frequency range for the selected formulations. The incorporation of CNC led to a substantial increase in both storage and loss moduli, with a more pronounced enhancement in the elastic response. In particular, the storage modulus increased by more than one order of magnitude (from ~200 Pa to ~8000 Pa at 1 rad/s), indicating the formation of a strongly interconnected viscoelastic network.

The enhanced rheological behavior is attributed to synergistic interactions between fumed silica aggregates and rod-like CNC particles, which promote network formation and mechanical reinforcement. Gap-dependent measurements showed negligible variation in the measured moduli, confirming the reliability of the rheological data.

These findings demonstrate that small additions of CNC can transform silica suspensions into strongly interconnected gel-like viscoelastic networks, which can be leveraged to couple bulk rheological structuring with interfacial stabilization mechanisms, providing a pathway toward dual-stabilized emulsion systems.

Keywords:

Rheology
Colloidal suspensions
Hybrid nanomaterials
Emulsion stabilization

Acknowledgements:

I sincerely appreciate the consideration of this submission by the organizing committee. Given the strong alignment of this work with the symposium themes, I would be truly grateful for the opportunity to present this research as an oral presentation, if possible

Opto-Electrothermal Control of Polystyrene Microparticles in Microfluidic Systems

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The control of particles and/or fluid flow at the microscale using optical and electric fields has become a central topic in microfluidics and lab-on-a-chip techniques [1-3]. In this study, we investigate the behavior of polystyrene particles in an electrolyte solution under simultaneous laser irradiation and an applied electric field in a microfluidic platform [4,5].

Experiments were conducted with different chip geometries and electrode configurations, including both commercially manufactured and in-house designs, to study the generation of electrothermal flow and its use to control suspended microparticles in a commercial optical tweezers device. The position of the laser relative to the sample was systematically varied to investigate its influence on particle motion and fluid dynamics. High-speed imaging was used to capture the particle trajectories, which were subsequently analyzed using custom Python-based routines to extract motion patterns, velocity distributions, and statistical properties of the system.

The analysis shows the occurrence of ordered and directed flow structures in particle motion. The observed dynamics indicate a strong coupling between optical heating and electric field effects, leading to thermoelectrically driven transport. It was shown that changes in the laser position significantly influence the flow behavior, suggesting a strong dependence on the local temperature gradient and field distribution.

These results underline the importance of combined photoelectric effects for controlling particle motion and provide valuable insights to improve retention and transport mechanisms in microfluidic systems.

Keywords:

Electrothermal flow

Microfluidics

Microelectrodes

Optical tweezers

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Study of ionic transport spatially varying ion diffusivity in capacitive deionization

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Capacitive deionization (CDI) is an emerging technology for water desalination based on ion electrosorption in porous carbon electrodes [1]. Classical continuum models for capacitive deionization (CDI) typically assume a uniform ion diffusion coefficient across the entire cell, despite the strong heterogeneity of porous electrodes. However, experimental observations and pore-scale considerations suggest that ion transport inside the electrode is hindered by structural factors such as tortuosity, water affinity and pore accessibility [2], which are not explicitly captured in standard models.

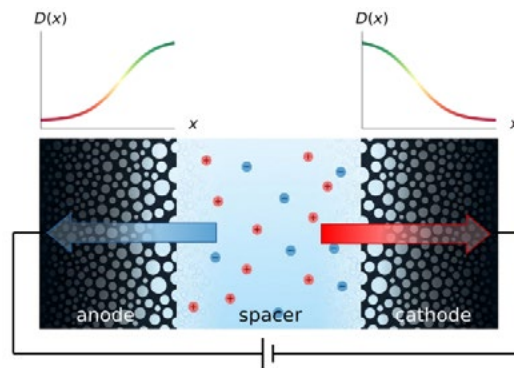
In this work, we extend a previously developed one-dimensional CDI model [3] by introducing a spatially dependent effective diffusion coefficient to account for transport limitations within porous electrodes. Several physically motivated profiles are explored, representing reduced ion mobility toward the inner regions of the electrode. The modified model is solved numerically and compared against the baseline constant-diffusion formulation.

Results show that spatial variations in diffusivity significantly affect the transient dynamics of ion transport, leading to slower ion depletion in the inner electrode regions while preserving equilibrium adsorption levels. This behavior is consistent with the separation of time scales between electromigration and diffusion previously reported. The proposed approach provides a simple yet effective way to incorporate electrode microstructure effects into continuum CDI models without increasing their complexity.

These findings highlight the importance of accounting for spatial transport limitations when interpreting experimental data and optimizing electrode design in CDI systems.

Keywords:

capacitive deionization (CDI), porous electrodes, spatially dependent diffusion, ion transport



Schematic of a CDI cell with depth-dependent transport. Top plots show a representative diffusion coefficient profile $D(x)$, reflecting hindered diffusion due to a possible pore size distribution. Fading arrows indicate resistance as ions penetrate the electrode bulk.

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First-Principles Investigation of the Structural and electronic properties of Ag-Based II–VI and III–V Semiconductor Compounds

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Silver-based compounds have attracted considerable attention due to their promising applications in optoelectronic, photovoltaic, and thermoelectric devices. In this work, the structural and electronic properties of AgRM (M = S, Se, Te; R = Sb, Bi) compounds in the chalcopyrite, zinc-blende, and rock-salt phases were systematically investigated using density functional theory (DFT) within the full-potential linearized augmented plane wave (FP-LAPW) method. The equilibrium lattice constants and bulk moduli were determined using several exchange-correlation approximations, including the local density approximation (LDA), Perdew–Burke–Ernzerhof generalized gradient approximation (PBE-GGA), and Wu–Cohen generalized gradient approximation (WC-GGA), in order to assess their influence on the structural parameters. The calculated results indicate that the chalcopyrite phase is the energetically most favorable configuration for most of the studied compounds, whereas the zinc-blende and rock-salt phases are found to be metastable under ambient conditions. The calculated equilibrium lattice constants range approximately from 5.3 to 6.1 Å, while the bulk moduli vary between 66 and 102 GPa, depending on the compound and crystal structure, and are in good agreement with available theoretical and experimental data. Furthermore, the electronic properties were investigated through band-structure and density-of-states (DOS) calculations, performed both without and with spin–orbit coupling (SOC). The results show that all the studied compounds exhibit a semimetallic character, while the inclusion of SOC modifies the band dispersion near the Fermi level due to the strong relativistic effects associated with the heavy elements Sb and Bi. These findings provide reliable structural and electronic parameters and offer valuable insights for future investigations of the optical, elastic, and thermoelectric properties of Ag-based compounds.

Keywords:

Density Functional Theory, WIEN2k, FP-LAPW, Silver Chalcogenides, Chalcopyrite, Structural Properties.

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Rheology of magnetic capillary suspensions

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Capillary suspensions are prepared by adding an immiscible secondary fluid to a *conventional* suspension, typically formed by solid particles dispersed in a liquid carrier. The secondary fluid becomes a third phase that induces bridges between the particles and generates a network that dramatically affects the stability and mechanical properties of the suspension [1, 2].

Magnetorheological (MR) fluids [3] are suspensions of relatively large ($d \sim 0.5\text{--}10\text{ }\mu\text{m}$) magnetizable particles in a liquid carrier. Upon the application of a uniaxial magnetic field, the magnetic interaction between particles prevails and leads to their aggregation and the formation of columnar aggregates. This structuration is the origin of the so-called magnetorheological effect: a large reversible increase in the viscosity of the suspension, and sometimes the emergence of a yield stress, upon the application of the field. The fact that the mechanical properties of suspensions can be dynamically controlled with an external stimulus (the field) makes them attractive for numerous applications, such as dampers, clutches, or brakes [4].

In this work we studied the rheology and structure of magnetic capillary suspensions, i.e. suspensions prepared with magnetizable particles (carbonyl iron) and two immiscible liquids (mineral oil and water). The presence of the secondary liquid mitigated particle sedimentation but also resulted in a non-negligible elastic modulus and yield stress even in the absence of a field (the off-state), which could be detrimental to some applications. The on-state behavior of the suspensions was dominated by the magnetostatic interactions. More interestingly, the suspensions showed a rich rheological behavior with a strong influence of the preshear history. Differences of up to an order of magnitude in the yield stress were observed under various preshear protocols.

Keywords:

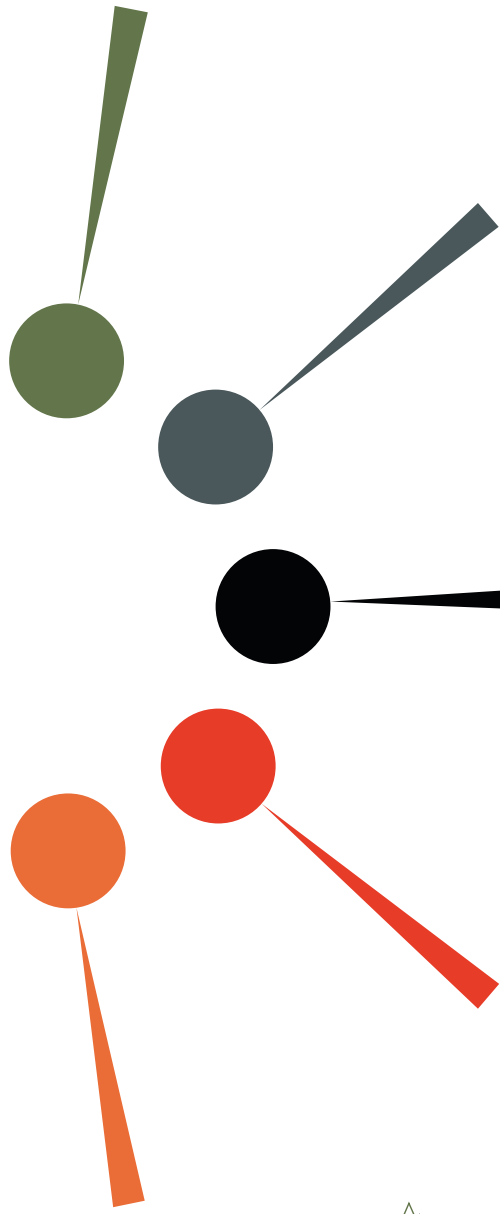
Capillary Suspensions, Magnetorheological Fluids, Magnetic Fluids, Yield Stress

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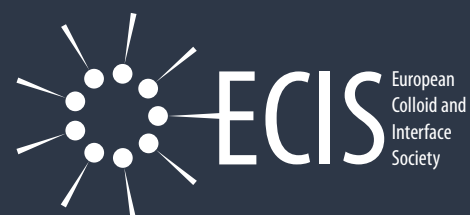
F. Vereda acknowledges financial support from C-EXP-262-UGR23 project (Junta de Andalucía, Spain)

A decorative graphic on the left side of the page featuring five colored circles (green, grey, black, red, orange) of varying sizes. Each circle has a corresponding colored line extending from it at an angle, creating a dynamic, abstract composition.

Topic 5

Wetting Phenomena,
Superhydrophobicity, Capillary,
and Surface Interactions

! POSTER



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Surface and colloidal mechanisms of surfactant-free cleaning

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Growing concerns about the environmental impact of detergents have driven interest in alternative, eco-friendly cleaning strategies, including the use of purified water. This work investigates how the properties of purified water can be used to achieve effective cleaning while minimizing the need for surfactants. We studied the removal of common oily soils, such as olive oil, from hydrophilic and hydrophobic surfaces and examined the interactions between oil, water, and cotton fabrics. In addition, the effect of purified water treatments on bacterial viability was evaluated.

For hydrophilic surfaces, the removal of thin vaseline films and thicker oil layers was studied under different temperatures and washing cycles using Quartz Crystal Microbalance with Dissipation Monitoring (QCM-D). Thin films were largely removed within two washing cycles, with higher temperatures improving removal efficiency. For thicker films, gravimetric analysis showed that the washing process could be divided into two regimes (exponential and linear), where each one is governed by different washing mechanisms and stability principles.

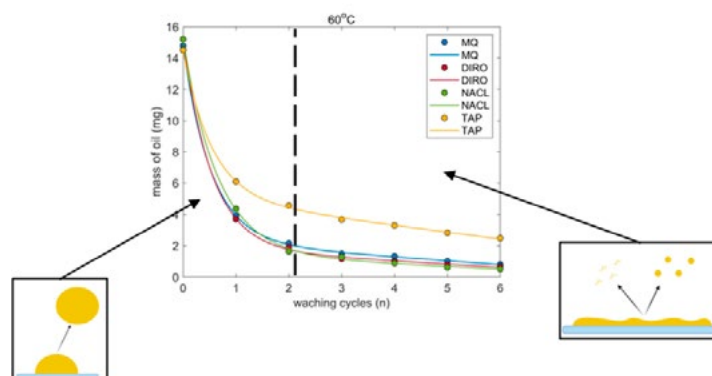
Two strategies were explored to improve cleaning on hydrophobic surfaces: pH adjustment of purified water using trace amounts of NaOH and the addition of small amounts of lipase. Both approaches significantly enhanced oil removal. Increasing the pH promotes deprotonation of fatty acids in olive oil, facilitating detachment through roll-up and reduced interfacial tension, while lipase hydrolyses olive oil into more water-soluble products that can act as natural surfactants.

Spatially resolved SAXS measurements were used to study interactions between cotton, oil, and water, revealing that these components interact with cotton at different length scales and that washing results in partial redistribution and removal of oil. Finally, isothermal calorimetry was used to assess bacterial viability, demonstrating that repeated washing cycles and longer incubation times reduce bacterial survival.

These findings highlight the potential of purified water-based systems as a sustainable approach to cleaning with reduced reliance on conventional detergents.

Keywords:

surfactant-free, washing, cleaning, hydrophilic, hydrophobic, cotton, pure water



Average amount of olive oil remaining on the surface of glass tubes (mg) as a function of the number of washing cycles for MQ, DIRO, NaCl, and TAP at 60 °C. The number of replicates is 3. The dashed black line indicates the change of regimes, while figures followed by arrows show the main mechanism

Preparation and Integrated of Special-Wettability Materials for Coalescence-Based Separation of Complex Oily Wastewater

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Introduction.

Oily wastewater generated in the petrochemical industry typically features complex oil-phase compositions and high degrees of emulsification, rendering conventional coalescence-based oil removal technologies prone to low separation efficiency and poor stability. The efficiency of coalescence-based oil removal primarily depends on whether the interfacial films of emulsified oil droplets can be effectively ruptured, and is subsequently governed by the wetting, collision-coalescence, and detachment behaviors of oil droplets on material surfaces and within material layers. In particular, coupling interfacial destabilization, wettability regulation, and directional migration of oil droplets is beneficial for full-process intensification from interfacial demulsification to droplet growth and stable separation. Based on this concept, a series of coalescence materials possessing demulsification functionality and special wettability was developed, and gradient-wettability layers were further constructed through biomimetic integration.

Experimental/methodology.

Based on thermodynamic analysis, the surface free-energy characteristics required for oil-droplet demulsification and wetting spreading were identified to guide the surface design of coalescence materials. A mussel-inspired interlayer was firmly deposited onto substrate surfaces through the oxidative self-polymerization of catechol-structured compounds. Subsequently, functional compounds containing amino groups or α,β -unsaturated carbonyl groups were grafted through Michael addition and Schiff-base reactions, yielding a series of demulsification-functionalized/special-wettability materials. This “interlayer-grafted functional layer” strategy enabled the stable construction of functional layers on various organic and inorganic substrates, showing good universality and durability. These materials were then integrated into gradient-wettability layers, and CFD simulation was further used to optimize matched coalescence-internal and device configurations.

Results and discussion.

For complex oil-water systems, this study established a coalescence material system integrating demulsification functionality, special-wettability regulation, and biomimetic integration of gradient-wettability layers, thereby strengthening the key steps of the coalescence process. Demulsification-functional compounds enhanced the destabilization and rupture of the interfacial films of emulsified oil droplets, while gradient-wettability layers promoted the migration, coalescence, and stable release of oil droplets toward strongly oleophilic regions, thus enabling continuous synergy from interfacial destabilization to intensified separation. In real oily wastewater treatment, oil removal efficiencies were improved by 26 and 35 percentage points compared with conventional polypropylene and glass-fiber materials, respectively. The technology requires neither additional energy input nor chemical dosing and generates no secondary pollution such as scum or VOC emissions. Moreover, the developed modular coalescence internals and devices can be coupled with pump-and-treat systems for the remediation of petroleum hydrocarbon-contaminated groundwater.

Keywords:

oily wastewater; coalescence separation; special wettability; gradient wettability; demulsification-functionalized materials



Schematic illustration of the coalescence material system and the corresponding internals and devices for oil/water coalescence separation.

Modulating coalescence timing of liquid marbles via wettability adaptation

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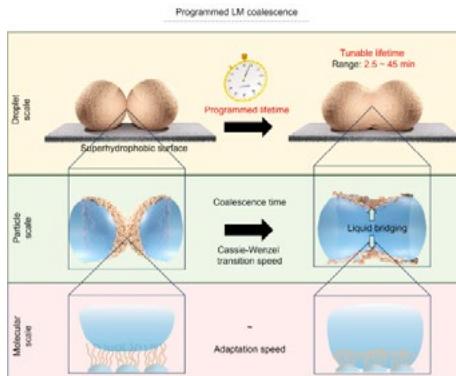
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Droplet coalescence is a common phenomenon in nature, playing an important role in various industrial and biomedical applications. While uncoated droplets merge upon contact, droplets that are covered with liquid-repellent particles known as “liquid marbles (LMs)” do not coalesce in the same way. Previous work has explored how the particle layer can be triggered to break using external stimuli to control the timing of coalescence. However, programming the timing of droplet coalescence without such stimuli has been difficult. In this study, we present LMs designed to break their particle layers at pre-set times. The particles have a core that is wettable and are connected to a low-wettability flexible molecular chain that gradually increases in wettability over time. This time-dependent change in wettability arises from how the molecular chain adapts, making it a repeatable process whose speed can be managed by adjusting the chain length. As a result, these LMs can reveal their bare droplet surfaces at predetermined times, allowing control over coalescence from 2 to 45 minutes without needing external stimuli. Additionally, the ability to combine the particles allows for precise adjustments of the coalescence timing, achieving resolutions of about one minute. Moreover, the interaction between multiple LMs with varying adaptation times facilitates cascade droplet coalescence, paving the way for new methods of droplet manipulation.

Keywords:

Automated coalescence, wettability adaptation, liquid marble, chemical modifications, 1,4-conjugate addition reaction



Scheme depicting the automated coalescence of LM on a superhydrophobic surface with a programmed coalescence time, where Cassie-Wenzel transitional speed in particle scale and water adaption in molecular scale influenced the coalescence time of LMs.

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Silica based sol-gel coating for precisely fine tune fluid transport in cotton threads and paper

Nikita Jha^a, Joanna Mikolei^a, Annette Andrieu-Brunsen^a

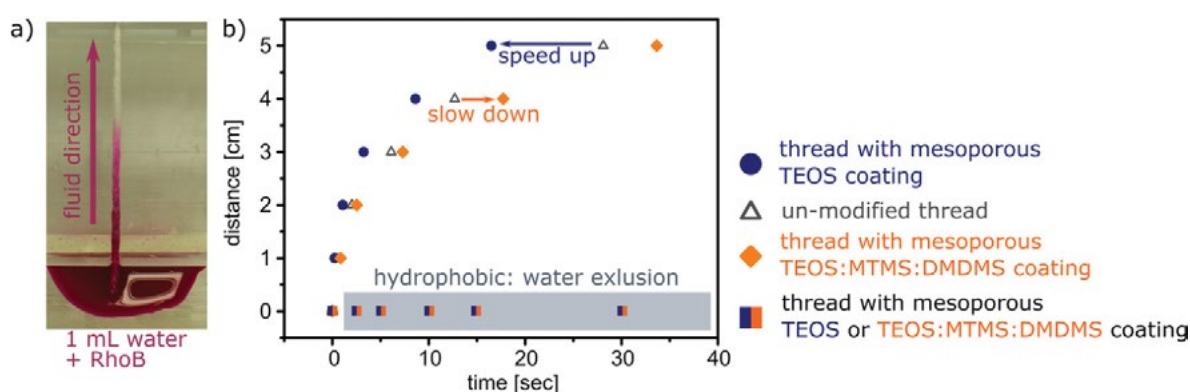
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Controlling fluid transport between different compartment in a communicating cascade reaction is of interest in the context of life-like material and sensor technology. However, currently most systems rely on self-assembly and diffusion process which has limitation in adjusting reaction spaces as well as controlling fluidics resulting in limited variability in controlling the outcome of the reaction network. Based on our work on paper [1, 2] we here present an approach to adjust the fluid speed in cotton threads by applying dense and mesoporous silica coatings onto cotton fibres using sol-gel chemistry and evaporation-induced self-assembly. This silica modification of cotton threads and paper allows to accelerate and decelerate fluid flow. A cotton thread-based fibre library was implemented allowing to knot thread networks with designed fluid flow paths. These thread networks will be investigated with respect to controlling enzymatic cascade reaction networks.

Keywords:

Mesoporous coating, Silica sol-gel, fluid transport



Mesoporous silica coated cotton threads shows higher fluid transport speed than unmodified and MTMS, DMDMS modified threads [3]

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Acknowledgements:

We acknowledge the German Research Foundation (DFG, AN1301/08) for funding.

Ti-6Al-4V (ELI) wettability modification via adsorption of polyether-silicone compound.

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The Ti-6Al-4V (ELI) alloy is one of the most commonly used metallic biomaterials in medicine. This is due to its large biocompatibility, which is caused by the ability of titanium and its alloys to passivate spontaneously in contact with oxygen. The passivation layer provides corrosion resistance and biocompatibility of metallic biomaterials. The properties of this layer (hydrophilicity, composition, thickness, homogeneity and stability) depend mainly on the titanium and titanium surface preparation and decide about its practical application. For example, its wettability and roughness play a crucial role in medicine in the context of microbial adhesion to metallic biomaterial surfaces. High implant surface roughness is advantageous for osseointegration, as it provides a larger contact area and facilitates the adhesion and ingrowth of bone cells into the implant structure. On the other hand, excessive roughness can be detrimental, as it increases the risk of bacterial proliferation and accelerates peri-implant bone loss. Consequently, the focus has shifted to the creation of micro- and nanostructures.

Adhesion of microorganisms can be inhibited by changes in biomaterial surface roughness and/or its hydrophilic–hydrophobic balance. The surface hydrophilic–hydrophobic properties depend mainly on the conditions of the material and its surface preparation or adsorption of different substances, for example, bacteriostatic compounds. One of the methods to change the biomaterial surface properties is controlled passivation. The other one is connected with using compounds that are able to adsorb at the biomaterial-liquid interface. Consequently, this adsorption modifies the wettability process in the biomaterial-liquid-air system. For this purpose, the silicone compounds can be used. They influence the wettability of biomaterials while also preventing the formation of bacterial biofilm, thus reducing the risk of biocorrosion. Therefore, the aim of this study was to evaluate the effect of polyether trisiloxane surfactant (HOL 12) on the wettability of Ti-6Al-4V (ELI) as well as to analyse the correlation between wetting and adsorption properties of HOL12. On the basis of the obtained results, it was deduced that the addition of HOL12 to water causes the complete wetting of the Ti-6Al-4V (ELI) surface in the range of surfactant critical micelle concentration (CMC). This is strictly connected with the presence of the hydroxyl groups on the Ti-6Al-4V (ELI) surface and their interactions with the oxygen atoms that are present in the trisiloxane chain as well as the specific structure of the HOL12 molecule.

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All-atom molecular dynamics study of thermo-osmotic flow in Janus nanoslits

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Thermo-osmosis refers to fluid transport induced by a temperature gradient and typically occurs from the hot region to the cold region. It is known to be influenced by pressure gradients, surface tension, and other factors; however, under certain conditions, a reverse flow from the cold region to the hot region, known as negative thermo-osmosis, has also been reported [1]. Such phenomena are relevant to applications such as seawater desalination and energy conversion, and understanding thermo-osmotic transport at the nanoscale remains an important scientific challenge. In particular, the effects of surface wettability and interfacial interactions on the direction and magnitude of thermo-osmotic flow are not yet fully understood at the molecular level. In this study, the thermo-osmotic behavior of water was investigated using all-atom molecular dynamics simulations. Water molecules were modeled using the SPC/E water model, and a nanoslit with Janus walls having different wettabilities on each side was considered. A temperature difference was applied by varying the temperature inside the slit and the interaction between the walls and water molecules, in order to examine the influence of asymmetric surface properties on fluid transport. Pistons were placed in the reservoirs at both ends of the slit to maintain a pressure of 0.1 MPa, thereby eliminating the effects of pressure-driven flow. This setup allows for the analysis of fluid transport induced solely by the temperature gradient. From the simulation results, velocity profiles, density distributions, and the molecular structure of water near the solid surfaces were analyzed. In addition, the excess enthalpy near the interface was evaluated to investigate the relationship between interfacial energy distribution and thermo-osmotic flow. These analyses aim to clarify how asymmetric surface wettability affects thermo-osmotic transport of water under nanoconfinement.

Keywords:

Thermo-osmosis, Molecular dynamics simulation, Janus surfaces, Nanoconfined water

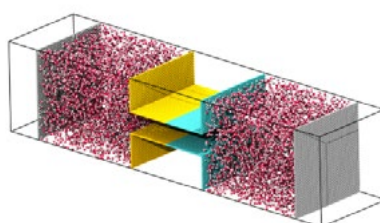


Fig.1 Simulation model of the Janus nanoslit system used for the thermo-osmotic flow study.

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Interfacial molecular dynamics govern frictional dissipation and detachment

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Water friction on solid surfaces gives rise to a variety of important phenomena, including interfacial charging, coating delamination, and surface cleaning[1-3]. Elucidating the molecular mechanisms underlying these effects at water–solid interfaces is therefore of considerable scientific and technological significance. Ice accretion on solids is also ubiquitous, yet the molecular origins of ice friction and detachment remain poorly understood, especially for interfaces with distinct molecular compositions and structural configurations. Given these considerations, our group studies how interfacial molecular dynamics control friction, adhesion, and detachment at water–solid and ice–solid interfaces. We have shown that adaptive polymer interfaces can achieve low friction despite strong adhesion by dissipating stress through rapid, reversible chain deformation and stepwise desorption. We further discovered an explosive fracture mode of adhered ice under quasi-static cooling, governed by ice grain size and thermomechanical stress accumulation. Building on these insights, we developed a polar-bear-inspired deformable coating for wind turbine blades that enables spontaneous ice shedding under real icing conditions. Field trials on utility-scale turbines demonstrated substantial improvements in power output and shutdown reduction. Together, these studies provide a molecular-to-engineering framework for designing low-friction, self-deicing interfaces and coatings for cold-environment applications.

Keywords:

interface, interfacial molecular dynamics, water friction, ice adhesion

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Bubble surface mobility regimes in aqueous solutions of simple organic solvents

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Studies of bubble behavior in mixed surfactant solutions attract rising interest due to growing industrial applications. In this work, we study the mobility of a bubble surface in two types of aqueous solutions. The first type consisted of aqueous solutions of organic solvents, namely ethanol¹, propanol¹, acetone, acetic acid, and acetonitrile. All these compounds form hydrogen bonds with water, and their arrangement at the molecular level is characterized by the formation of clusters. The second type consisted of aqueous solutions of short-chain alcohols (ethanol, propanol) mixed with a stronger fluorinated surfactant with lower surface tension, which allowed observation of changes in surface tension². The terminal velocity of bubbles ($D_b \leq 1$ mm) in a stationary liquid was measured in the above-mentioned solutions, and the normalized velocity and normalized drag coefficient were calculated from known theoretical limits. This made it possible to determine the mobility of the bubble surface. The surface of bubbles rising in highly diluted solutions of organic solvents with and without surfactant additives is immobile or partially immobile. With increasing concentrations of both types of additives, the mobility of the bubble surface changes. In aqueous solutions of organic solvents, bubble surface remobilization occurs at concentrations that correspond to the formation of clusters at the molecular level. In alcohol solutions with fluorosurfactant, as the alcohol concentration increases, alcohol molecules replace the surfactant in the surface layer. Fitting the surface tension data for the mixture using co-surfactant model shows that such replacement can be due to strong interaction between alcohol and surfactant resulting in a considerable decrease in surfactant activity. As a consequence, at propanol molar fraction 0.3 and ethanol molar fraction 0.5, surfactant adsorption is completely hindered while alcohol dominates the adsorption layer. The gradients of surface tension are diminished resulting in remobilization of the bubble surface, which manifests itself in an increase in terminal bubble rising velocity. The study revealed that surface remobilization in mixed solutions occurs at higher alcohol concentrations than in surfactant-free solutions.

Keywords:

Bubble surface remobilization, bubble velocity, surface tension, organic solvents, fluorosurfactant

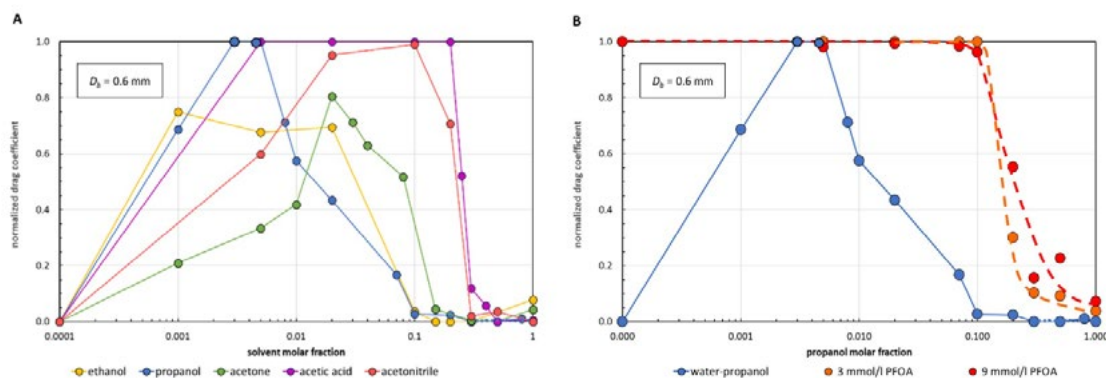


Fig. Dependence of normalized drag coefficient on mixture composition ($CD_{norm} = 1$ for mobile bubble surface, $CD_{norm} = 0$ for immobile bubble surface). A. Organic solvents C2–C3. B. Water – propanol mixture with perfluorooctanoic acid (PFOA). Bubble diameter 0.6 mm.

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Influence of particle size on surface water interactions of zeolite

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Zeolites are inorganic crystalline materials most often composed of SiO₄ and AlO₄ corner-sharing tetrahedral units that create a negatively charged framework, whose charge is compensated by the presence of Mⁿ⁺ cations (M = NH₄⁺, Na⁺, K⁺, Ca²⁺, etc.). Although their use in gas separation and petroleum refining has become indispensable, there are still many other applications that can benefit from their properties, such as high thermal stability and low production cost. The use of zeolites for potential electronic applications is a field that is slowly gaining more attention. However, to develop a material for an electronic application, it is necessary to first understand its conductivity properties. The conductivity of zeolites is largely influenced by its interactions with guest molecules, most often water. Moreover, water is not only located on the surface of zeolite particles, but it also creates hydrogen-bonded clusters inside the zeolite channels. To distinguish how different interaction between water molecules and zeolite affect its overall conductivity, two FAU type zeolites of similar composition but different particle size were chosen; nanoparticles (n-FAU, crystal size under 100 nm) and micro-sized particles (μ-FAU, average size 3 μm). Conductivity measurements were performed at different relative humidity conditions (vacuum, 60, 75 and 100% RH) and at different temperatures in order to calculate activation energy, while interactions of material with water molecules were studied using differential scanning calorimetry (DSC), thermogravimetric analysis (TG), and powder X-ray diffraction (PXRD). Particle surface defects were investigated using Fourier-transformed infrared spectroscopy (FTIR) in vacuum using deuterated acetonitrile as a probe molecule.

Keywords:

Zeolite, proton conductivity, water-material interactions,

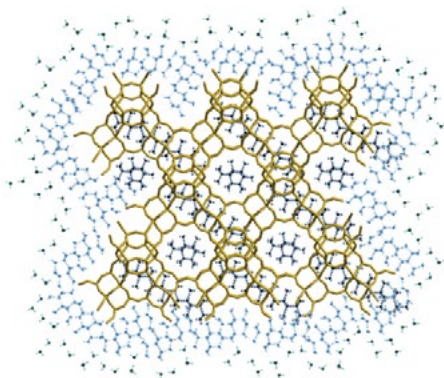


Figure 1. Schematic representation of water molecules interacting with the zeolite framework

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Acknowledgements:

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A Voltage-Modulation QCM-D Applied to the Study the Adsorption of Proteins and Particles

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Soft layers at interface are conveniently studied with the quartz crystal microbalance with dissipation monitoring (QCM-D). The QCM-D outputs sets of frequency shifts, Δf_n , and shifts in the half bandwidth, $\Delta \Gamma_n$, on a few different acoustic resonances. These parameters are turned into information on the layer much beyond gravimetry. In particular, the softness often is available in addition to the adsorbed amount.

The depth of information can be further increased by letting the adsorption occur while the electrode potential is periodically switched between two states ('high' and 'low'), thereby probing the sample's *electro-responsivity*. Mechanisms contributing to electro-responsivity are charge reversal in the diffuse double layer, adsorption and desorption, electrochemical reactions, pH effects, and effects of reversed polarity in the Helmholtz layer. Because the time resolution is two milliseconds, kinetics on the millisecond time scale aids the interpretation. Data obtained on two types of proteins and on latex spheres are shown.

The figure compares data obtained on a monoclonal antibody (mAb, supplied by Boehringer Ingelheim) and on a reference system (BSA). The left hand side shows the short-time electro-responsivity, which is large for mAb and small for BSA. The bandwidth shows a transient maximum upon switching to "low". Time constants of the switching kinetics can be derived from such plots.

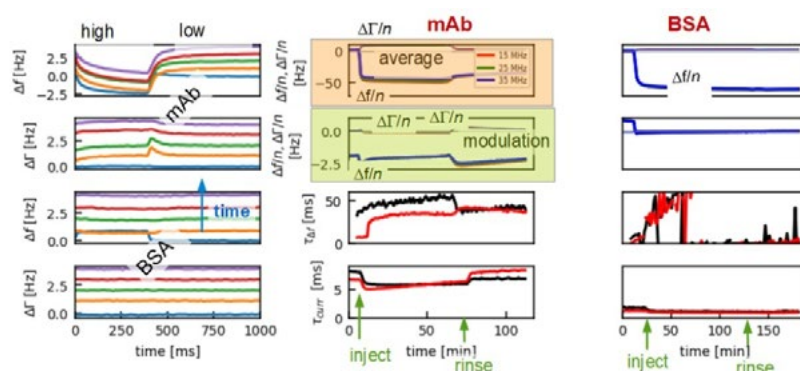
The graph overlaid in yellow shows shifts of frequency and bandwidth averaged over one modulation period. This information is equivalent to what the conventional QCM-D reports. Frequency decreases when the sample is injected. It slightly increase after the rinse. The graph overlaid in green shows the difference between "high" and "low" (the "modulation signal"). The modulation signal reports the electro-responsivity averaged over the two plateaus of the voltage trace. The electro-responsivity of mAb sample is substantial, while it just about vanishes for BSA. The modulation signal is the novel information provided by this instrument.

The time constants (shown at the bottom) are much larger for the frequency shift than for the current. Clearly, the electro-responsivity in this case is not caused by charge reversal in the diffuse double layer.

Analogous data can be obtained by replacing the square profiles with linear ramps (as employed in cyclic voltammetry). The ramps evidence events at specific potentials, often linked to redox processes at the electrode.

Keywords:

QCM-D, Proteins, Adsorption, Viscoelasticity, Electroresponsivity



A data set obtained with the voltage modulation QCM, comparing the mAb to BSA

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Acknowledgements:

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Quantifying tactile perception of fabrics using both frictional and acoustic methods

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Skin friction underpins tactile perception of formulated products, such as cosmetics, fabric softeners, and surface coatings, which are designed to deliver satisfactory tactile sensory properties. Establishing the correlation between the tribological properties of skin contacts and tactile perception is therefore critical. We have developed a novel approach to acquire the acoustic emission (AE) signal generated by human finger sliding against fabric and non-fabric substrates, whilst capturing its frictional characteristics with a force plate. Principal Component Analysis was deployed to construct clusters formed for each material based the sensory evaluation, and to establish the correlation between frictional and acoustic emission data. Our results show that the planar solid substrates could be discriminated solely based on the friction results, whilst the fabric materials were not significantly discriminated by the Coefficient of Friction values. However, AE was able to differentiate the fabric substrates successfully, and therefore evidences a promising potential to provide a complementary information on tactile perception while being versatile enough to be used as a standalone method to quantify tactile perception in a broad range of tribological measurements.

Keywords:

Tactile Perception, Skin Tribology, Acoustic Emission

References:

Kyriazis et al. *Tribo. Lett.* 2026, 74, 12

Influence of surfactant architecture on interfacial energies and work of adhesion in oil detachment

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The efficient detachment of oil from solid substrates is governed by the combined behavior of the three relevant interfaces: water-oil (WO), oil-substrate (OS), and water-substrate (WS) [1]. While recent research has mainly focused on the water-oil interface and its interfacial tension, a comprehensive understanding requires analyzing the interplay of all three interfaces and the resulting work of adhesion, which integrates their respective interfacial energies [2]. The aim of this work is therefore to investigate how the molecular architecture of surfactants modifies the interfacial energies at all three interfaces and how an optimal balance among them can minimize the energetic barrier for oil detachment.

To experimentally study the relationship between surfactant structure and the resulting work of adhesion, a suitable model surface is required. Therefore, a cellulose-imitating surface was developed. Unlike cellulose fibers, this surface provides a simplified, reproducible topography that enables reliable contact angle measurements while replicating the surface free energy and polar-dispersive contribution ratio of native cellulose. Furthermore, a microfluidic model was created to analyze oil detachment under well-defined, controlled conditions. The precisely adjustable flow dynamics allow the work of adhesion to be calculated and enable monitoring of the deformation behavior of oil droplets at varying flow velocities.

This approach provides a robust platform for gaining deeper insights into how the surfactant molecular structure, aggregation behavior, and physicochemical properties of surfactants collectively govern interfacial processes and ultimately influence application performance.

Keywords:

interfacial energies, work of adhesion, surfactant architecture, oil detachment

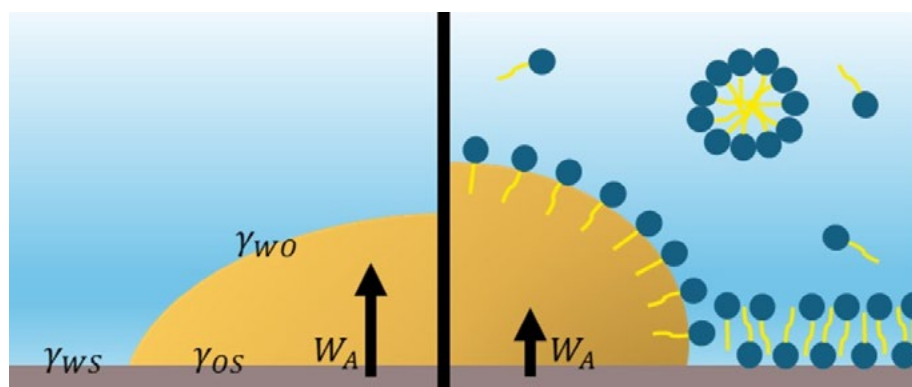


Figure 1: Change in droplet shape upon addition of surfactants. The interfacial tensions at the water-oil (WO), oil-substrate (OS), and water-substrate (WS) interfaces determine the contact angle and the work of adhesion (W_A). Introducing surfactants alters the interfacial tensions and the W_A .

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Simulating Droplet Adhesion on Superhydrophobic Surfaces

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Understanding and quantifying the topography of superhydrophobic surfaces is essential for optimising their performance in a wide range of applications including drag reduction and de-icing. Whilst contact angle goniometry remains the standard characterisation method, direct force measurements offer superior sensitivity for surfaces with complex microscale structures. However, existing approaches lack a quantitative framework linking measured adhesion forces to surface topography.

We present a novel energy minimisation approach using Surface Evolver [1] to simulate droplet adhesion on pillared superhydrophobic surfaces, replicating force probe microscopy experiments. Our numerical model captures the movement of the contact line as it advances and then recedes over the surface. We use the model to demonstrate that adhesion forces are governed by microscale deformations near the contact line. When the drop is receding, the contact line exhibits characteristic stick-slip motion with periodic jumps, generating distinctive sawtooth-pattern force signatures that reflect the underlying surface structure. Energy dissipation during contact line jumps is anisotropic, depending on surface orientation. We establish that the average tensile force during droplet recession is a better measure of surface structure than the maximum adhesion force. Direct force measurements using a commercial tensiometer on pillared silica surfaces demonstrate excellent agreement with numerical predictions across a range of pillar area fractions.

This work establishes a quantitative link between microscale surface topography and macroscopic force measurements, enabling characterisation of superhydrophobic surfaces using droplet adhesion, providing design guidance for engineering surfaces with tailored wetting properties, and advancing understanding of microscale physics governing contact line dynamics on textured surfaces. The numerical framework is freely available [2-3] and extensible to arbitrary surface chemistries and geometries.

Keywords:

Wetting, Superhydrophobicity, Droplet adhesion, Contact line dynamics

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Measuring charge transfer of contact electrification by droplet deposition on corrugated surfaces.

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Contact electrification is the phenomenon that materials become electronically charged by materials contacting or rubbing against each other. Here we investigate the charge transfer between a droplet and a particle monolayer [1,2]. The particle monolayers consist of PMMA, MF and SiO₂ with different radii to investigate the influence of curvature on the charge transfer process. In addition, the wettability and hardness of the particles are varied as well as the relative humidity conditions. We found that not only the charge transfer is affected by the different monolayers, also the particle arrangement is affected by the droplet deposition and is dependent on the particle properties. For layered materials, the layer thickness dependence on the charge transfer process is investigated.

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[1] Toward the Assembly of 2D Tunable Crystal Patterns of Spherical Colloids on a Wafer-Scale

Kai Sotthewes, Gijs Roozendaal, Andris Šutka, and Ignas S. M. Jimidar

ACS Applied Materials & Interfaces **2024** 16 (9), 12007-12017

DOI: 10.1021/acsami.3c16830

[2] Irreversible Charging Caused by Energy Dissipation from Depinning of Droplets on Polymer Surfaces

Shuaijia Chen, Ronald T. Leon, Rahmat Qambari, Yan Yan, Menghan Chen, Peter C. Sherrell, Amanda V. Ellis, and Joseph D. Berry

Phys. Rev. Lett. **134**, 104002

DOI: 10.1103/PhysRevLett.134.104002

Contact angle hysteresis and depinning behaviour of sliding droplets on chemically patterned surfaces

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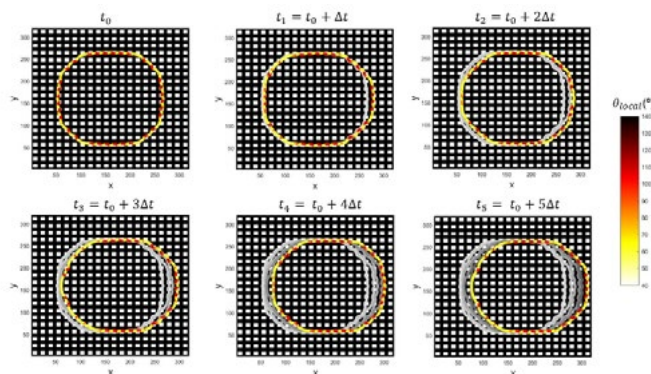
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We numerically studied three-dimensional droplets sliding on tilted and chemically heterogeneous surfaces composed of a hydrophilic base surface patterned with a square array of hydrophobic square-shaped defects. The simulations were performed with our in-house multiphase code implementing the phase-field lattice-Boltzmann method of Liang et al [1]. For each droplet simulated, and at every time step, the triple contact line shape was obtained from several thousands of discrete points interpolated thanks to a spline interpolation. The local contact angles all along the triple contact line were likewise determined from the spline interpolation. Using the method of Wang et al [2], the apparent advancing and receding contact angles of the droplet were also estimated at every time step from different 2D profiles along the symmetry planes of the surface pattern, either parallel to a row of defects or diagonal relative to the defects.

The pattern period, and the equilibrium contact angles of the base surface (equal to 60°) and of the defects (equal to 110°) remained constant for all the simulations. We investigated the dynamic of the triple contact line and the effect of the defect size within the pattern, with values of the defect size to pattern period ratio ranging between 0.25 and 0.75, with a 0.125-increment. The results show that the droplets exhibit a stick-slip motion with a periodic variation of the apparent and local contact angles. The droplets display different pinning-depinning characteristics depending on the considered axe of symmetry of the surface pattern. The study of the advancing and receding contact angles, both apparent and local, as a function of the defect size to pattern period ratio, gives further insight into the depinning regimes that can be involved in the droplet anisotropic behaviour.

Keywords:

Contact line dynamics, dynamic contact angles, pinning-depinning regimes, three-dimensional droplet, numerical simulation.



Two-dimensional views (in lattice units) of the triple contact line coloured as a function of the value of the local contact angle at different times, with gray-coloured lines corresponding to the previous positions of the contact line.

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This work was performed using computational resources from the “Mésocentre” computing center of Université Paris-Saclay, CentraleSupélec and École Normale Supérieure Paris-Saclay supported by CNRS and Région Île-de-France (<https://mesocentre.universite-paris-saclay.fr/>).

Slide electrification: Towards the chemistry and physic

Werner Steffen, Benjamin Leibauer, Rutvik Lathia, Aaron Ratschow, Hans-Jürgen Butt

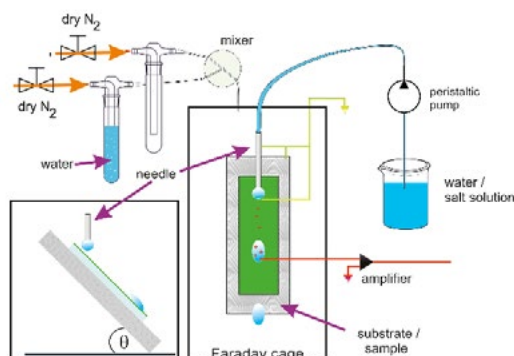
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Droplets moving over an (inclined) surface leave in general charges behind. The droplet is than oppositely charges compared to the surface. The charges of the droplets can be harvested, quantified and analysed. Here we will show the influence of the chemistry of the substrate and its surface on the generation of charges [1]. Further we will shine light on the nature of the charges transferred from experiments with a number of liquids in different physical states [2].

Keywords:

slide electrification, contact electrification, droplets, surfaces, charging of interfaces



reproduced from: S. Sbeih, A. Lüleci, S. Weber and W. Steffen, Soft Matter, 2024, 20, 558 DOI: 10.1039/D3SM01153D

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Combined Effects of Geometrical Confinement and Interaction Anisotropy on Nanofluid Thermal Conductivity

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Nanofluids, created by suspending nanoparticles in a liquid, offer transformative potential for high-efficiency thermal management. While the impact of surface interaction anisotropy on thermal transport is well-documented in bulk phases, the behavior under nanoscale confinement remains an open question. This study employs molecular dynamics simulations to investigate the thermal conductivity of copper-argon nanofluids confined within a slit-like nanochannel.

We systematically explore the complex interplay between the degree of surface anisotropy and the channel width. Our analysis focuses on how the spatial constraints imposed by the walls modulate the diffusive dynamics and the local environment surrounding the nanoparticle.

Preliminary observations suggest that the influence of surface anisotropy on heat transport is significantly coupled with the confinement scale. By integrating dynamic properties with a detailed characterization of the liquid phase, we aim to clarify the mechanisms that determine the overall thermal conductivity in these restricted geometries. This study provides a fundamental framework for understanding energy relaxation in confined anisotropic systems and discusses the potential for tailoring nanoscale thermal properties in future fluidic applications.

Keywords:

Nanofluid, Janus Particle, Confined liquid, Molecular dynamics

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Long-term Water Condensation and Collection on Elastic Polymeric Surfaces Under Mild Climatic Conditions

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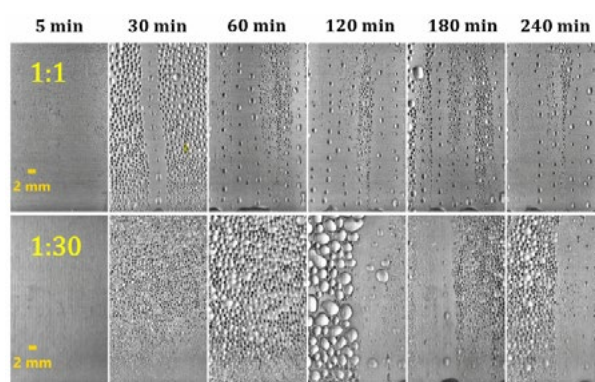
Radiative cooling-based Dew Water Harvesting (DWH) is a promising passive approach for water collection in open-air environments [1]. This strategy leverages thermodynamic principles, wherein condensation results from a temperature gradient between a surface and its surroundings. However, the formation of a liquid layer during condensation creates a thermal barrier, limiting further vapour condensation. Efficient removal and renewal of this layer are critical to enhancing the process. Therefore, polydimethylsiloxane (PDMS) surfaces have emerged as a promising passive strategy for DWH, combining high infrared radiative emissivity with a wettability regime that overcomes the nucleation-density limitations typically associated with hydrophobic surfaces [2].

In this work, the water harvesting performance of a set of PDMS surfaces with tuneable surface properties was investigated by varying the cross-linker-to-base ratio across a wide range of formulations. Long-term condensation experiments were conducted under mild climatic conditions characterised by low subcooling and controlled partial vapour saturation, representative of realistic radiative cooling scenarios. The condensation growth dynamics, droplet shedding behaviour, and the water collection dynamics were monitored simultaneously throughout each experiment.

The results reveal that the water collection rate exhibits a time-dependent behaviour modulated by both the surface properties of the PDMS formulations and the climatic conditions of the system. The total normalised water collected is governed by two interrelated parameters: the onset time of the drainage and collection phase, and the steady-state water collection rate. At experimental durations close to these characteristic timescales, water collecting efficiency was dominated by the surface wetting properties, with clear differences observed between formulations. As experimental duration increased, collection efficiency became controlled by the vapour exchange conditions of the surrounding atmosphere.

Keywords:

Condensation, Elastomeric Surfaces, Drop Adhesion, Collection Time, Water Collection Rate



Front views of the PDMS surfaces 1:1 and 1:30 showing the temporal evolution of the DWH process. Overall, an early condensation stage dominated by nucleation can be distinguished, followed by droplet coalescence, and subsequent removal at later stages of the process.

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Thermal Transport of Confined Water in Nanotubes using Molecular Dynamics Simulations

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Nanoscale confinement can qualitatively alter liquid structure and transport, as the surface-to-volume ratio is high and solid-liquid interfacial effects become dominant. In carbon nanotubes, water can adopt distinct molecular organizations such as single-file and layered states, which strongly influence axial thermal transport. While confinement geometry has been recognized as a key control parameter [1], the role of nanotube surface wettability in thermal transport remains less established, despite its direct impact on interfacial interactions and molecular structuring [2].

To study these wall-induced effects on liquid structure and thermal conductivity, we performed non-equilibrium molecular dynamics simulations of water confined in nanotubes with different surface wettabilities. We find that more hydrophilic nanotubes lead to higher thermal conductivity. Under hydrophilic conditions, molecular diffusion is suppressed and the local density increases, indicating a more solid-like character that facilitates axial heat transport.

Keywords:

Nanoconfinement: Wettability: Molecular dynamics

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Electrocapillary effects at the air/liquid interface. A neutron reflectometry study.

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Self-assembled nanocrystals of nanoparticles (NPs) offer the opportunity to create devices with collective properties from the individual NP building blocks. Applications in plasmonic, optoelectronic, catalysis, magnetic, phonon, biomedical and electrochemical devices with much improved performance are expected [1, 2]. Large area 2D nanocrystals may be prepared by Langmuir type deposition, where particles are dispersed at a liquid/air interface and compressed by barriers to form close packed 2D nanocrystals. These can then be transferred onto solid substrates. The formed layer at the interface and its long-range order can be tuned by the particle size, surfactant shell properties, solvent interaction, charge, and magnetic moment of the particles among others. One important parameter is the contact angle of the particles and the interface, which is related to the NPs affinity to adsorb at a fluid surface. Previous studies [3] and theory [4] suggests that the contact angle is dependant on the magnitude and sign of the charge of a single particle, since the air/water interface is believed to possess a negative charge. Also, a distance dependant out-of-plane force, pushing particles downwards and deforming the interface has been observed [3]. This is explained by the dipolar nature of the assymetric charge distribution of the particle surface in air and liquid medium. To add to this, we have tuned the charge magnitude and sign of negatively charged SiO₂ nanoparticles by varying the amount of cationic surfactant coating. For these samples we aim to present results with neutron reflectometry, surface pressure-area isotherms, GISAXS and UV-spectroscopy on the charge dependant electrocapillary effect, colloidal stability and long range order of films at the air/liquid interface and of transferred films to solid substrates.

Keywords:

Nanoparticles, nanocrystal, electrocapillary, neutron reflectometry

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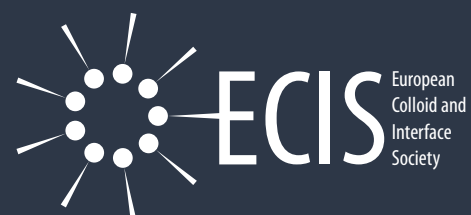
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Topic 6

Active and Bioinspired Soft Materials

! POSTER



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Graphene oxide as a novel component in optical biosensors for the detection of biomolecular interactions and enhancement of detection sensitivity

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The development of advanced nanostructured materials offers new opportunities for the design of high-performance optical sensors, including those based on surface plasmon resonance (SPR). Optical biosensing based on SPR is widely used today to investigate biochemical reactions in scientific and pharmaceutical and food research or medical diagnostics. The integration of graphene oxide (GO) with SPR-based biosensors represents a promising strategy for enhancing sensitivity and selectivity in real-time, label-free detection. Owing to its unique structure, large specific surface area, and abundance of functional groups, graphene oxide can amplify the detection signal through π - π interactions and an increase in the local refractive index, while also serving as an efficient interface between the gold sensor surface and biomolecules. This work presents a methodology for modifying gold SPR sensor surfaces with graphene oxide, along with an analysis of the impact of this functionalization on the biosensor's detection performance.

The aim of this study was the controlled and reproducible deposition of mono- and multilayer graphene oxide (GO) films on gold surfaces, along with their comprehensive physicochemical characterization. Various GO suspensions were analyzed, including the determination of particle size, zeta potential, stability, and the presence of functional groups using techniques such as DLS, UV-Vis spectroscopy, and XPS. Model gold-coated QCM-D crystals and dedicated gold SPR sensors were employed for layer deposition. The films were fabricated using the layer-by-layer (LbL) approach, applying both dip-coating and spin-coating techniques. By employing the layer-by-layer (LbL) self-assembly technique (based on electrostatic interactions between layers of charged various nano-objects), we construct hybrid films with precise control over thickness, charge distribution, and chemical functionality, allowing us to directly correlate the structural evolution of the multilayers with their characteristics. Comprehensive spectroscopic, microscopic and morphological analyses were done using: quartz crystal microbalance with dissipation monitoring (QCM-D) measurements, scanning and transmission electron microscopy (SEM/TEM), atomic force microscopy (AFM), ATR-FTIR and SPR cell combined with ellipsometer EP4 Accurion. Through systematic variation of the layer composition and choice of polyelectrolyte such as PDADMAC, PEI, PAH and PLL we demonstrate that the sensory behavior of these hybrid films can be tuned. The obtained mono- and multilayer GO films were expected to exhibit high surface coverage and stability. A correlation between the sensitivity of the gold SPR sensor signal and the number (thickness) of GO layers deposited on its surface was also established. Subsequently, protein solutions (antibodies/antigens) were immobilized on Au and GO surfaces through appropriate reactions or interactions. The immobilization process of antibodies/antigens was monitored and analyzed in real time using the QCM-D technique.

Surface functionalization with graphene oxide can significantly enhance the sensitivity and selectivity of SPR sensors, making it a promising approach for modern detection platforms. These studies will contribute to expanding knowledge on the application of advanced nanomaterials, including graphene oxide, in the biochemistry of sensor systems, as well as in diagnostics, environmental monitoring, and biomedical research.

Keywords:

graphene oxide, polyelectrolytes, sensors, SPR, coatings, layer-by-layer

Acknowledgements:

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Synergistic Triple-Stimuli Responsive Ferrogels: From Microstructural Control to Multi-Modal Soft Actuation

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Polymeric hydrogels are soft, deformable, and highly hydrated materials that serve as versatile platforms for tissue engineering, soft robotics, and sensors. Their inherent biocompatibility makes them particularly suitable for biomedical devices. A defining characteristic of these "smart" systems is their ability to respond to external stimuli such as pH, light, temperature, and magnetic fields [1]. While magnetic actuation is prized for being fast, remote, reversible, and biologically safe, most current actuators are limited by single-stimulus responsiveness. This work addresses the need for multi-stimuli responsive hydrogels to achieve complex, reconfigurable deformation.

In this work, we report novel triple-stimuli responsive hydrogels (pH, temperature, and magnetic field) synthesized via a sequential fabrication approach. The matrix consists of a pH-responsive chitosan network coordinated by Ag ions, sequentially interpenetrated with agarose to impart thermal responsiveness. The integration of iron micro-particles confers precise magnetic field responsiveness. We conducted a thorough characterization of the hydrogels' physical and chemical properties, focusing on the interplay between microstructure, mechanical behavior, and swelling kinetics across a range of pH and temperature conditions.

Our results show that the swelling behavior strongly depends on pH, reaching a maximum under slightly acidic conditions, while contraction is observed at basic pH due to deprotonation of the chitosan chains. The mechanical properties vary significantly with composition and environmental triggers: while pure chitosan hydrogels exhibit limited stability in acidic media, the hybrid network remains stable and gel-like across a broader pH range. This synergy between the biopolymer blend and the magnetic phase enables controlled multi-stimuli actuation.

Finally, a proof-of-concept application was designed to demonstrate the material's potential as a soft robotic gripper. The system utilizes a magnetic field to achieve macro-positioning (claw-like configuration), while pH or temperature changes maintain the new configuration even after the magnetic field is switched off. This dual-action mechanism enables the magnetically guided transport and subsequent release of cargo, highlighting the potential of these triple-responsive ferrogels for advanced controlled manipulation and soft robotics.

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Design of Asymmetric Soft Actuators Based on Functional Colloidal Gradients in Magnetic Hydrogels

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We report the fabrication of a pH-sensitive polyacrylamide hydrogel [1] loaded with high-remanence neodymium-iron-boron (NdFeB) micro-particles, leveraging the controlled spatial distribution of the colloidal phase to program macroscopic deformation.

A key aspect of this study is the exploitation of sedimentation kinetics and magnetic field alignment during the polymerization process. This allows for the generation of a colloidal density gradient, resulting in a functionally graded material with a bilayer-like architecture. We analyze how this structural asymmetry, combined with the pH-dependent swelling of the hydrogel network, dictates the interfacial mechanics and the subsequent bending macroscopic response.

Furthermore, the magnetic moments of the NdFeB particles are pre-aligned to create preferential axes of magnetization. Under low-frequency alternating magnetic fields, the interplay between interfacial elastic forces and magnetic torque induces a large-amplitude, asymmetric oscillatory motion. We demonstrate that this non-reciprocal movement enables directional fluid transport. These results highlight the potential of colloid-filled hydrogels as programmable platforms for microfluidics and biomimetic interfacial engineering.

Keywords:

Magnetic Colloids, Soft Matter Composites, Colloidal Gradients, Stimuli-Responsive Hydrogels, Soft Actuators

References:

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Acknowledgements:

This study was supported by the grant PID2023-151913NB-I00 funded by MICIU/AEI/10.13039/501100011033, Spain, and by ERDF, EU

Determination of cellular viscoelastic properties from AFM stress relaxation data via SOM analysis

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Cells are complex viscoelastic systems whose mechanical properties are governed by the organization of semiflexible cytoskeletal filaments, their crosslinking, and the active remodeling of the cytoskeletal network. Atomic force microscopy (AFM) is a powerful tool for studying cell mechanics, as it enables time- and frequency-dependent measurements using nanometric tips or colloidal probes. When subjected to an external stress, cells exhibit time-dependent deformation behavior. In this study, we investigated the stress relaxation response of HeLa cells under conditions of constant strain. The applied force (1, 2, 4, and 8 nN) and the residence (pause) time (1, 10, and 60 s) were systematically varied to evaluate different linear viscoelastic models (1). The experimental data were fitted using the standard linear solid model, the five-element Maxwell model, and a power-law model. Our results indicate that the five-element Maxwell model provides the best description of the observed stress relaxation behavior. This work is intended to serve as an introduction and practical guide for performing AFM-based stress relaxation experiments on soft matter. To facilitate visualization and interpretation, the data were organized using self-organizing maps (2).

Keywords:

cell mechanics, linear viscoelasticity, relaxation time, elastic modulus, viscosity, atomic force microscopy, self-organized maps

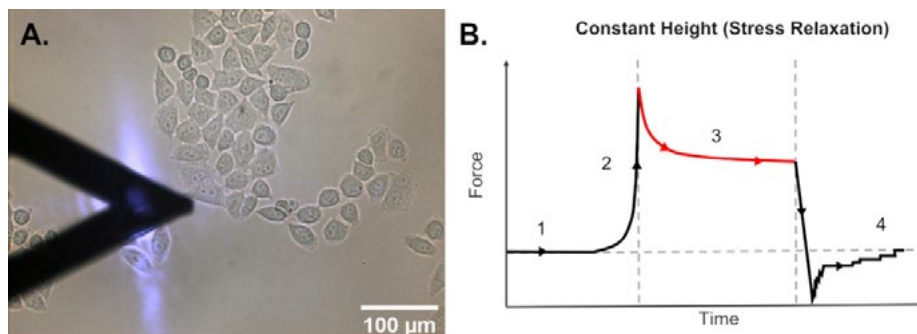


Figure. A. Schematic of the experimental setup illustrating the cell of interest, the AFM cantilever, and the detection laser spot. B. Representative force–time curve showing the relaxation of the applied force over time, with the stress relaxation phase highlighted in red.

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How anisotropy reshapes dense active phases: from hexatic order to MIPS

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Many mesoscopic phenomena in soft and living matter arise under non-equilibrium conditions, where thermal, mechanical, or chemical imbalances lead to behaviors beyond equilibrium statistical mechanics. Active matter physics has developed coarse-grained models to describe such systems, where energy injection at the microscopic scale drives emergent collective phases with complex structural and dynamical properties. A paradigmatic example is active Brownian particles (ABPs), spherical self-propelled units modeling systems such as bacteria or catalytic colloids. In two dimensions, ABPs exhibit crystalline and hexatic order at high density and low activity, while strong self-propulsion induces motility-induced phase separation (MIPS) even in the absence of attractive interactions [1].

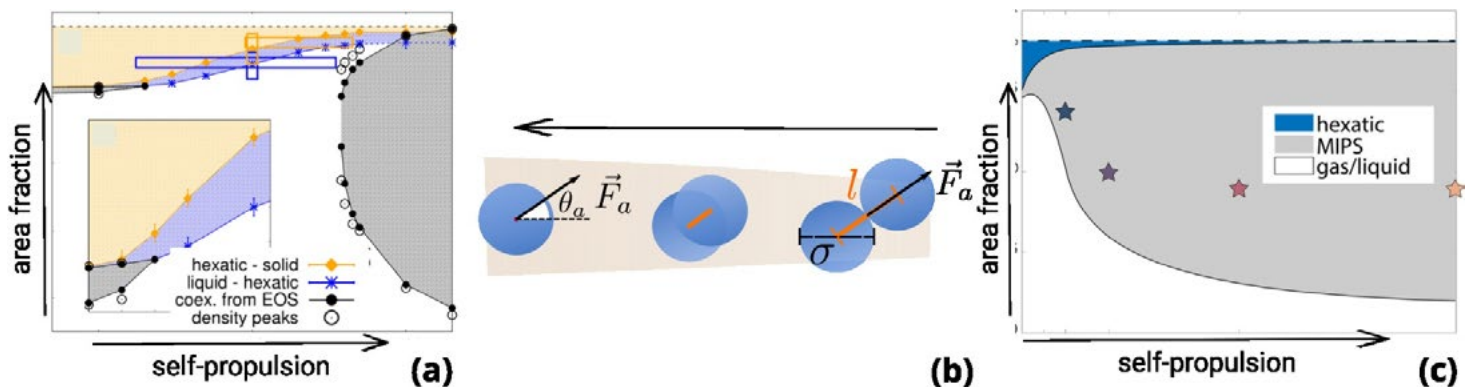
Introducing anisotropy qualitatively changes this picture. In active dumbbell systems, ordered phases evolve continuously with activity, and a coexistence region emerges, connecting the passive liquid-hexatic transition to the high-activity MIPS regime [2,3].

Here, we investigate how anisotropy reshapes this landscape using self-propelled dimers with tunable bond length. Through extensive numerical simulations, we map the state diagram as a function of packing fraction, activity, and anisotropy, bridging the behavior of spherical ABPs and elongated dumbbells.

Preliminary results reveal a rich phase behavior at intermediate dimer bond lengths [4], with the appearance of rotator and oriented crystals, besides to low-symmetry phases such as hexatic liquids and phases with quasi-long-range nematic order, whose properties are strongly influenced by the presence of topological defects, representing singular points in the order of the phase. Our research highlights how particle anisotropy provides a unifying control parameter that links classical phase transitions to active MIPS, offering new insight into the interplay of geometry, self-propulsion, and collective organization in determining phase transitions and materials properties in dense active matter systems.

Keywords:

Active Phase Transitions, Non-equilibrium Systems, Hexatic Liquids, State Diagrams, Coarse-grained Modeling



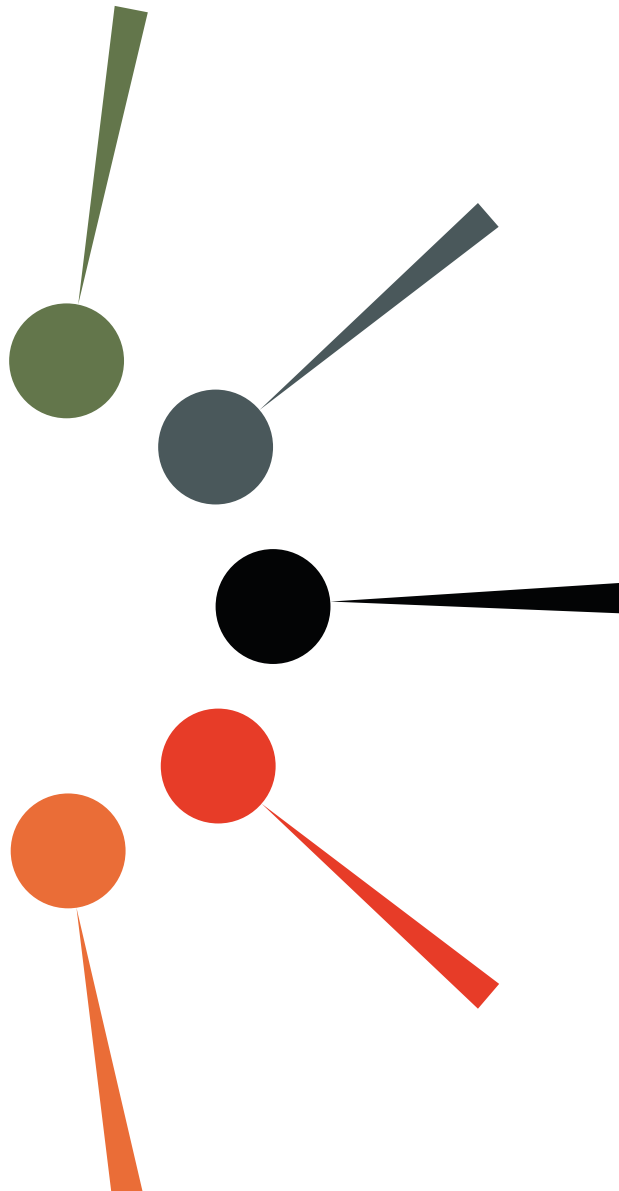
State diagrams of active Brownian particles (a) and active dumbbells (c). (b) Model of rigid dimers with variable bond length and a self-propelling force directed along the axis, interpolating smoothly between the limiting cases (a) and (c). Panels (a) and (c) are readapted from [1] and [3].

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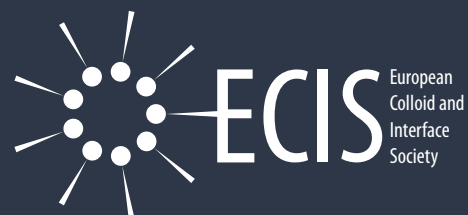
This research is funded by the MSCA-PF project 101283195.



Topic 7

Polymers, Polyelectrolytes,
Gels, Micro/Hydrogels, Glasses,
and Liquid Crystals

! POSTER



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ZnO-Containing Chitosan/Gelatin Coatings for Corrosion Protection of Stainless Steel

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Tssetska Radeva¹

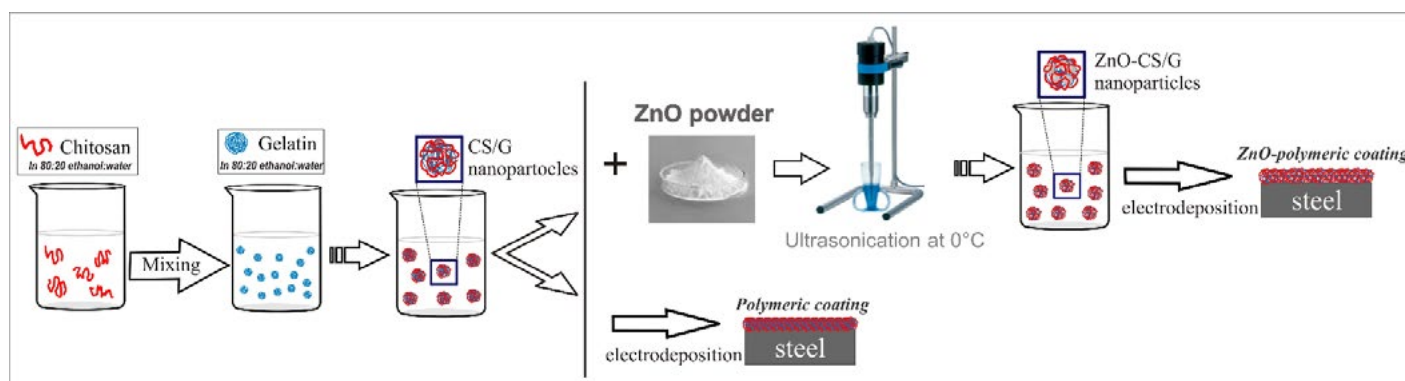
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Surface modification of stainless steel is an effective approach for improving its corrosion resistance in aggressive media. In the present study, ZnO-containing chitosan/gelatin coatings were deposited on stainless steel by electrophoretic deposition (EPD). The coatings were obtained from stable water–ethanol suspensions of nanoparticles formed through chitosan/gelatin complexation in the presence of ZnO. The use of a water–ethanol medium was intended to minimize undesirable water hydrolysis during the EPD process. Dynamic light scattering and electrophoretic measurements were employed to determine particle size and zeta potential. The morphology and elemental composition of the nanoparticles and the deposited coatings were characterized by scanning electron microscopy (SEM). The corrosion behavior of coated and uncoated stainless steel specimens was evaluated in PBS buffer (pH 7.4) by polarization resistance measurements over a period of 60 days. For comparison, ZnO-free chitosan/gelatin coatings were also studied. The results demonstrated that the incorporation of ZnO significantly improved the corrosion resistance of stainless steel compared with both the bare substrate and the ZnO-free coating.



Schematic illustration of the preparation of chitosan/gelatin and ZnO-containing chitosan/gelatin coatings on steel by electrophoretic deposition.

Acknowledgements:

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Eugenol Conjugation to PHEMA and PDMAPMA-b-PHEMA Enabling Nanoparticle Self-Assembly

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Amphiphilic polymers are promising platforms for nanoscale drug delivery due to their ability to self-assemble in aqueous media and encapsulate hydrophobic molecules. In this work, eugenol (4-allyl-2-methoxyphenol), a naturally derived compound with antioxidant, antimicrobial, and anti-inflammatory properties [1], was conjugated to polymers synthesized via RAFT polymerization [2], namely poly(2-hydroxyethyl methacrylate) (PHEMA) and the cationic block copolymer PDMAPMA₁₁₆-b-PHEMA₇₆. The functionalization was designed to impart intrinsic bioactivity and modulate amphiphilicity, promoting self-assembly in aqueous solution. The resulting nanostructures were used to encapsulate Coumarin-6 as a model hydrophobic compound [3] during the self-assembly process. The presence of the cationic PDMAPMA block significantly affected both encapsulation and antioxidant properties. In particular, the cationic copolymer showed lower encapsulation efficiency, likely due to the solvated charged groups promoting a more extended conformation and limiting the formation of compact hydrophobic domains. Conversely, this structure enhances the accessibility of eugenol moieties to DPPH radicals, resulting in higher antioxidant activity compared to PHEMA. Overall, this approach enables the development of multifunctional nanoplatfroms with self-assembly capability, colloidal stability, and intrinsic bioactivity for potential biomedical applications.

Keywords:

amphiphilic polymers; nanoparticles; eugenol; drug delivery; self-assembly

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Amphiphilic Polymer-peptide Nanostructures as Antimicrobial Systems

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Antimicrobial peptides (AMPs) are naturally occurring cationic amphiphilic molecules that have attracted increasing attention as potential alternatives to conventional antibiotics due to their broad-spectrum antimicrobial activity and their ability to disrupt microbial membranes through electrostatic and amphiphilic interactions.[1] Because they act at the membrane level, bacteria have a limited ability to develop resistance against them. However, their biomedical application is often limited by susceptibility to enzymatic degradation, possible cytotoxicity, and poor stability under physiological conditions. To overcome these limitations, significant efforts have focused on engineering AMP-derived systems and incorporating them into polymeric carriers to enhance stability and improve therapeutic performance.

Effective bacterial membrane disruption requires a balance between cationic and hydrophobic domains. While positively charged residues promote electrostatic interactions with negatively charged bacterial envelopes, hydrophobic segments facilitate insertion into lipid bilayers.

In this work, amphiphilic polymers were investigated as transport platforms for antimicrobial peptides. The strategy of polymer-peptide co-assembly in aqueous media was explored by appropriately tuning the amphiphilicity of the assembling components. The hybrid nanostructures were obtained via nanoprecipitation and characterized by dynamic light scattering under different conditions, including pH and presence of cosolvents. Poly(glycerol adipates) (PGA) and amphiphilic polydiacetylenes (PDA) will be explored as tunable amphiphilic systems. PGA is a degradable and bio-based polymer widely used for drug delivery.[2] Amphiphilic PDAs have stimuli-responsive optical properties and ability to form vesicles or micelles thanks to the presence of a polar head and hydrophobic alkyl chains.[3] Results showed how this strategy represents a promising approach for generating hybrid materials with potential applications in antimicrobial systems and biomaterials.

Keywords:

Antimicrobial peptides, Amphiphilic polymers, Hybrid nanostructures, Drug delivery, Antimicrobial materials

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Elucidating Iodine–Starch Interactions in Degradable Starch Microspheres

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Iodine-iodide-triiodide ($I_2-I^-I_3^-$) solution has historically been used as an antiseptic to prevent and treat various topical infections. However, its use is limited by issues such as irritation and staining, which can be prevented using new carrier strategies. This study investigates the loading of iodine into degradable starch microspheres (DSM), with particular focus on iodine–starch interactions and the resulting structural changes upon uptake. Iodine complexation was achieved using $I_2-I^-I_3^-$ solutions, yielding a characteristic purplish-red color within the DSM. Swelling and sedimentation analyses indicated a slight reduction in DSM density following iodine absorption, without compromising hydration capacity. A UV–Vis spectrophotometric method targeting the triiodide band at 352 nm enabled robust quantification of iodine by leveraging the equilibrium among iodine species. The iodine sorption profile showed a non-linear trend, with uptake increasing at higher concentrations, suggesting cooperative binding effects. Pre-organized I_3^- and I_2 molecules within starch helices, along with non-covalent interactions, enhance iodine retention. Small- and wide-angle X-ray scattering (SWAXS) analyses demonstrated iodine-induced ordering across multiple length scales, including a decrease in the dynamic correlation length and the emergence of characteristic peaks associated with iodine–amylose complexes. Overall, these findings provide insight into the physicochemical mechanisms governing iodine incorporation into DSM and highlight the structural consequences of loading, offering a framework for the design of starch-based carriers for controlled iodine release [1].

Keywords:

Starch microspheres, Iodine, Small- and wide-angle X-ray scattering (SWAXS)

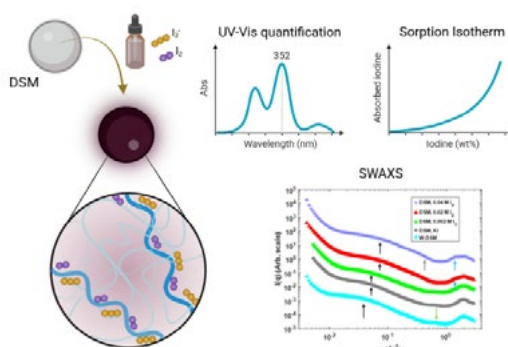


Figure 1. $I_2-I^-I_3^-$ incorporated into DSM induces a purplish-red color and enables UV–Vis detection at 352 nm, with concentration-dependent sorption and SWAXS patterns.

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Biocompatible Chitosan/Carboxymethyl Cellulose Nanofilms: Enhancing Surface and Optical Properties via Salt Annealing

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Polyelectrolyte multilayers (PEMs) are well-established surface coatings that can be built-up by alternately depositing positively and negatively charged polyelectrolytes onto a solid surface. These coatings are assembled from pairs of oppositely charged polyelectrolytes through electrostatic interactions or, when their molecular structures permit, hydrogen bonding. A key advantage of polyelectrolyte multilayers is their highly tunable properties, which can be tailored by adjusting adsorption conditions such as deposition time, polyelectrolyte concentration, ionic strength, as well as the type and concentration of added salt and pH. In recent years, we have developed advanced PEM strategies that offer strong potential for designing soft nanomaterials with finely tunable properties, allowing adaptation to the specific requirements of a wide range of applications, particularly in biomedicine and food science ^{1,2}. In this study ³, we prepared films from two biocompatible polysaccharides, chitosan and carboxymethyl cellulose. Such thin films, when prepared on model surfaces such as silicon or glass, change the optical properties of the surface. For this reason, we modified the films post-adsorption by immersing them in sodium chloride solution, a process known as salt annealing. By varying the salt concentration and duration of annealing, both surface and optical properties of the multilayer can be tuned and improved. The untreated films made the substrate reflect light more diffusely, leading to a clouded appearance of the surface. This effect was reduced via salt annealing, resulting in a film which does not affect the optical properties of the surface. In addition to the changes in optical properties, the wetting behaviour of the films was also studied. This study successfully correlates film roughness and the changes in the diffuse reflectance. Furthermore, as a proof of concept for application, the chitosan/carboxymethyl cellulose film was successfully prepared on a cherry tomato where salt annealing successfully diminished the influence of the film on its reflective properties.

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Synthesis and Characterization of Thermoresponsive Cationic Diblock Copolymers and Their Interaction with Bile Salts

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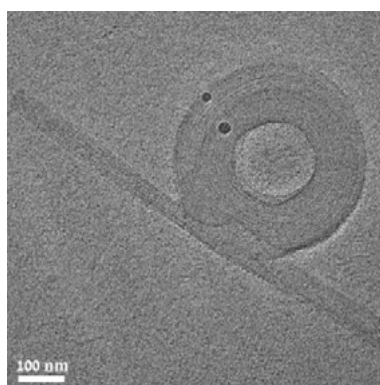
The number of applications for thermoresponsive polymers has expanded significantly within the biomedical field over the last few decades. Notable examples include their use for controlled-release formulations. Concurrently, cationic polymers have gathered some attention as drug carriers in gene or peptide therapy, and bile salt sequestrants used for bile acid related diseases and hypercholesterolemia.

Herein, a series of novel nonionic-cationic diblock copolymers were synthesized comprising one permanently charged cationic block, and one nonionic thermoresponsive block. The latter is a statistical copolymer of two temperature-sensitive monomers in relative proportions adjusted so that the endothermic phase transition of the polymer occurs at 38 °C as found by high-sensitivity differential scanning calorimetry measurements.

Dynamic light scattering and small-angle X-ray scattering measurements provided insight on the size of single polymer coil, and on the self-assembly behaviour at elevated temperature. Further research conducted on these block copolymers mixed with oppositely charged bile salt biosurfactants confirmed the retained capacity of the block copolymers to act as bile salt sequestrants. Moreover, cryogenic transmission electron microscopy revealed the capacity of certain mixtures to assemble into supramolecular structures with intricate, chiral internal structures with potential to act as drug carriers of chiral drugs.

Keywords:

Diblock copolymer, polyelectrolytes, thermoresponsive, bile salts, DLS, DSC, SAXS, cryo-TEM, supramolecular structure, self-assembly, drug delivery.



Cryogenic transmission electron microscopy image of block copolymer-bile salt complexes at 25 °C.

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Effect of Micro-phase Separated Structures on the Cryogenic Mechanical Properties of Thermosetting Resins

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Liquid oxygen (LOX) storage tanks in space launch vehicles serve as critical structural components while containing oxidizers at cryogenic temperatures (~ 90 K). Although traditionally manufactured from aluminum, these tanks face limitations in weight reduction due to high density. Carbon fiber-reinforced polymer composites are promising alternatives; however, their application is hindered by the inherent brittleness of polymers at cryogenic temperatures. While rubber particles are commonly added to improve toughness, they often lead to a significant decline in the glass transition temperature (T_g) and elastic modulus, alongside an undesirable increase in the coefficient of thermal expansion (CTE) due to their relatively large particle size. To overcome these challenges, this study proposes a strategy to refine the micro-phase separated structure of thermosetting resins. A silicone-based oil is introduced as a soft additive, and a silicone-modified epoxy resin is employed as a bifunctional polymer to act as an interfacial stabilizer, effectively reducing interfacial energy and minimizing the domain size of the dispersed phase. This structural refinement aims to significantly enhance the fracture toughness of the resin while minimizing the reduction in elastic modulus and the increase in CTE. We systematically evaluate the mechanical properties at both ambient and cryogenic temperatures as a function of the soft additive content and the resulting phase-separated morphology. Furthermore, the impact of these micro-structures on the cryogenic CTE is investigated to ensure structural reliability for aerospace applications.

Model-Independent Description of Multicomponent Adsorption from Affinity Spectrum Statistics

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Understanding adsorption in heterogeneous systems remains a central challenge, particularly for multicomponent mixtures. Equilibrium adsorption isotherms are commonly interpreted in terms of an underlying affinity spectrum, defined as the probability density function of adsorption free energies over the ensemble of adsorption sites. This framework provides a natural link between macroscopic adsorption behaviour and microscopic energetic heterogeneity.¹

In this work, we show that the macroscopic properties of adsorption are primarily governed by the main statistical features of the affinity spectrum, namely its mean values and covariance matrix. When these are fixed, different functional forms of the spectrum — including Gaussian, ellipsoidal, and Frumkin-type distributions — lead not only to very similar adsorption isotherms, but also to similar Conditional Affinity Spectra (CAS), i.e., the effective spectra obtained upon fixing the chemical potential of one component.²⁻⁴ This indicates that the detailed shape of the spectrum plays a secondary role, and that adsorption behaviour is controlled by a small set of statistical descriptors — a result that holds even when the functional forms differ substantially at the tails of the distribution, where direct experimental determination is least reliable.

This observation enables a unified and standardized description of heterogeneous and structurally disordered natural organic matter, largely independent of the specific isotherm model employed (e.g., NICA, Frumkin, Gaussian-based approaches), which can be viewed as alternative parameterizations of the same underlying statistical structure.

We focus on the Frumkin isotherm, showing that for any prescribed set of mean affinities and covariance matrix, there exists a unique corresponding set of parameters consistent with these constraints. This highlights that the Frumkin model can effectively capture system heterogeneity beyond its traditional interpretation in terms of intermolecular interactions.² In contrast to NICA (Non-Ideal Competitive Adsorption), this isotherm remains linear at low concentrations (i.e., satisfies the Henry limiting law) and clearly separates stoichiometric parameters from those describing heterogeneity.

Finally, we validate these results against Monte Carlo simulations and experimental data from model systems, establishing a statistically grounded and model-independent framework for multicomponent adsorption, with direct implications for trace element cycling by natural organic matter in changing ocean and soil environments.³

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Effects of swelling on the mechanical properties of alginate gels

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Alginate-based hydrogels represent a promising biomaterial for industrial and medical applications, such as the delivery of bioactive agents or macromolecular drugs [1]. However, during industrial processing the gels are exposed to mechanical stresses that may lead to deformation or fracture. These issues may become exacerbated by the swelling response of alginate gels in ionic solutions, common in biological contexts. Understanding the mechanical behavior of the gels is therefore essential to ensure process efficiency and to guarantee their integrity in real application environments.

In this study, we employ capillary micromechanics [2] to characterize the mechanical properties of alginate-based beads and capsules. The deformation of gels driven into a tapered capillary under constant pressure allow to measure their elastic moduli. We compare their response in ultrapure water with their properties along the swelling-deswelling curve by increasing the concentration of NaCl at fixed concentrations of CaCl₂. Performing serial dilution experiments, we then find different degrees of irreversibility, which we correlate with a loss of anisotropy present in the gels. By measuring the gelation dynamics, we explore the role of the manufacturing process in generating this structural anisotropy.

Keywords:

Alginate gels, mechanics, swelling, gelation

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Amphiphilic cyclodextrin microparticles versus post-emergence foliar herbicides

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Bentazon and mecoprop, two highly water soluble post-emergence foliar herbicides, pose a serious threat to the environment and human health. They are applied to a wide range of crops, such as soybeans, peanuts and corn, acting as photosynthesis inhibitors. Herein, mesoporous amine rich α - and β -cyclodextrin microparticles are proposed as highly efficient sorbent materials towards bentazon and mecoprop. The click-imine synthesis strategy involves amine-cyclodextrin derivatives with different arm lengths (0, 6 and 12, where 0 denotes an amination at C6 position) reacting with glutaraldehyde as crosslinker. The physical and chemical properties of the mesoporous polymers were determined using a wide range of techniques, including FTIR, TG, CHNO analysis, potentiometric and inclusion complex titration, SEM, nitrogen adsorption and DLS. The sorbent capability was investigated by sorption isotherm for bentazon and mecoprop separately and in mixtures, achieving removal yields of approximately 97% and $\geq 99\%$ for bentazon and mecoprop, respectively. Quantification was performed by HPLC-DAD developing a new analytical method with LOD and LOQ of 0.013 and 1 mg L⁻¹. Nonetheless, sorption kinetic analyses and molecular dynamics simulations will be carry out to gain a deeper understanding of the interaction mechanisms at the polymer-pesticide interface.

Keywords:

Herbicides, amphiphilic-cyclodextrin, mesoporous polymer, sorption, environmental sustainability

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Chitosan-based microgels: Elaboration of a model soft-colloid with controlled microstructure.

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Over the last two decades, bio-based soft colloids have received a lot of attention, especially polysaccharide-based microgels [2]. However, controlling their microstructure at different scales to evaluate systematically their rheological properties remains virtually unexplored. Nevertheless, their different architectures offer many bio-based alternatives to tailor the flow properties of the complex fluid [1]. In case of microgel, a free-defect structure, so-called “model”, means a homogenous crosslink density, without “loop” and free dangling chains, and a narrow distribution in size.

In this work, we aim to synthesize controlled chitosan-based soft colloids to investigate extensively their structure and their rheological properties in aqueous suspension. To do so, chitosan was chosen due to its versatility for chemical modification and as a semi-rigid biopolymer (persistence length from 8 nm [3]) which may provide a unique semi-rigid microgel.

Firstly, a strategy based on thiol-ene crosslinking chemistry [4] was optimised at macroscale to evaluate rheological properties of chitosan-based hydrogels prepared at different concentration. Then, the optimal synthesis conditions have been transferred at microscale in a water-in-oil emulsion, to produce chitosan-based microgels. Finally, their physical-chemical properties will be studied in water using rheology, scattering techniques and microscopy.

Keywords:

Microgels model, Chitosan, Thiol-ene, Soft-colloid

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Functional triblock terpolymers for vesicle self-assembly and decoration of polymer microgels towards membrane confinement

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By combining hydrogels or coacervates with amphiphiles, cell-like systems can be generated ^[1]. While the use of natural lipids offers the advantage of more closely mimicking biological membranes, the use of synthetic block co- and terpolymers provides greater flexibility in terms of membrane thickness, stability, and chemical modification. ^[2] On this account this work explores the synthesis of various triblock terpolymers, their self-assembly in aqueous solution, as well as their interaction with microgels to decorate their surface with a membrane for tailor-made transport.

Using various RAFT agents, triblock terpolymers are synthesized, consisting of a hydrophilic *N*-isopropylacrylamide (NIPAM) block, a hydrophobic hydroxypropyl acrylate (HPA) block, and cationic blocks of 4-vinylpyridine (pH-sensitive) or [2-(Methacryloyloxy)ethyl] trimethylammoniumchloride (TEMA). Both their molecular structure and PDI are investigated using ¹H, ¹³C and 2D HSQC NMR as well as SEC, and their self-assembly is examined using DLS at various pH values. These studies indicate the formation of self-assembled structures in a size range of approx. 260 nm or 650 nm, depending on the terpolymer used. The exact type of structure is currently being investigated via small-angle X-ray scattering.

Furthermore, we use a 4VP₁₀-HPA₇₀-NIPAAAM₄₀ terpolymer equipped with a thioxothiazolidine as a reactive end group, which allows for subsequently attaching various functional groups, e.g., fluorescein or adamantane. The first is used as a probe for further characterization of the terpolymer/ μ Gel assemblies, while the latter is employed to investigate the guided assembly of terpolymers on the microgel's surface by guest-host interactions between them and a β -cyclodextrine functionalization on the gels surface. To this end, hydrogels produced using droplet microfluidics in a cell-like size range of 50 μ m have been incubated with a library of triblock terpolymers in various compositions (hydrophobic block length fixed at about 50 % with a varying amount of ionic block length ranging from 9 – 19 %, at molar masses of about 12,000 – 18,000 g/mol depending on the terpolymer), and the resulting assemblies are examined using confocal microscopy. These studies indicate a strong influence of the different terpolymer structures on their self-assembly behaviour and furthermore hint towards significant interaction between the terpolymer assemblies and the μ gels, which will be explored in detail in further studies.

Keywords:

Triblock terpolymers, Self-assembly, Host-Guest interactions, Microgels

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Structure–Property Relationships of Waterborne Polyurethane–Anisotropic Titanate Nanotube Nanocomposites

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This study investigates the structure–property relationships of waterborne polyurethane (WPUD) systems in aqueous formulations, with emphasis on the role of anisotropic one-dimensional (1D) nanofillers. Inspired by assembled nanowire materials, where anisotropy governs macroscopic properties, anisotropic titanate nanotubes (TiNTs) were incorporated into WPUDs synthesized from a polycarbonate-based macro-diol, providing a model system to study the interplay between polymer architecture and nanoscale filler geometry.

Although WPUDs are environmentally (and health-) friendly due to low volatile organic compound (VOC) content, their mechanical and thermal performance is often limited. These limitations are closely related to the internal structure formed in aqueous environments, including phase separation and interparticle interactions. Introducing anisotropic nanofillers provides a pathway to tailor the morphology and the internal cohesion (structure–property relationships).

TiNTs, characterized by high aspect ratio and surface hydroxyl functionality, enable strong and directional interactions within the polymer matrix. A novel strategy was employed to incorporate unmodified TiNTs directly from aqueous dispersions into WPUDs without freeze-drying, preserving their fine 1D morphology and minimizing aggregation.

Nanocomposites containing 1–5 wt% TiNTs were prepared and characterized. Transmission electron microscopy confirmed uniform dispersion, while ash analysis confirmed the filler content. The structure of the nanocomposites was further investigated using solid-state NMR, X-ray diffraction (XRD), small- and wide-angle X-ray scattering (SAXS/WAXS), providing insight into filler–matrix interactions and micro-phase organization. Rheological measurements were performed to probe viscoelastic behavior and structural evolution in the aqueous state.

The incorporation of TiNTs influenced the microphase organization of the polyurethane matrix, promoting enhanced intermolecular interactions, particularly hydrogen bonding, and improved stress transfer. As a result, the nanocomposites exhibited increased mechanical performance and storage modulus. These findings highlight the critical role of anisotropic 1D nanofillers in controlling structure–property relationships in WPU systems and support the design of advanced, nature-friendly and bio-mimetic polyurethane nanocomposites.

Keywords:

Nanocomposite, waterborne polyurethane dispersions, titanate nanotube

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Molecular-Level Association Behavior of Cationic Linear and Dicephalic Surfactants with Polyelectrolytes at the Air/Solution Interface

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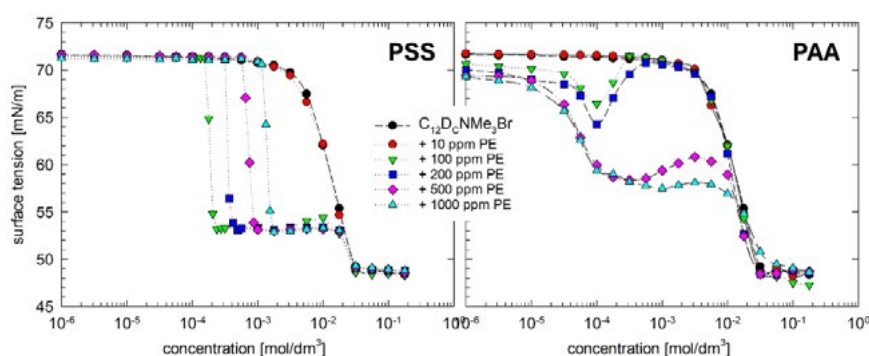
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We examined the interfacial properties of polyelectrolyte-surfactant complexes (PESCs) with linear and dicephalic cationic surfactants and anionic polymers PAA (Mw=100,000) and PSS (Mw=70,000). We compared complexes formed with 2-alkyl-N,N,N,N',N',N'-hexamethyl-propan-1,3-ammonium dibromides of varying alkyl chain lengths (C_n-DcNMe₃Br; n=10, 12, 14). Additionally, the interfacial behavior of PESCs made with dicephalic C12-DcNMe₃Br was compared with that of the classical linear surfactant, DTAB. According to [1], two types of surface tension dependence on surfactant concentration for PESCs can be observed. Type I shows a decrease in surface tension until the critical aggregation concentration (CAC), then a plateau until the critical micellization concentration (CMC). Type II shows an increase in surface tension, usually below CMC, reaching the surfactant solution's surface tension.

For both linear and dicephalic surfactants, similar behavior can be observed. For PECS with PSS, type I behavior, characterized by a very abrupt decrease in surface tension at CAC, is observed at polyelectrolyte concentrations above 50 ppm. Despite the lower surface activity of the dicephalic surfactant, CAC values are lower than those for DTAB, which may reflect stronger electrostatic binding. For PECS with PAA, type I dependence on surfactant concentration was observed at polyelectrolyte concentrations above 500 ppm. At lower concentrations, the type II shape of the surface tension dependence was observed. However, the onset of the surface tension increase was observed for much lower dicephalic surfactant concentrations than for linear surfactant. That seems counterintuitive, as interactions between double-charged surfactant and polyanion are stronger. On the other hand, examining the pH dependence of the surface tension as a function of surfactant concentration, we observed a transition from type II to type I behavior as we increased pH from 3 to 11, i.e., from weakly charged to fully charged PAA. We used molecular dynamics simulations for various surfactant-to-polymer ratios to correlate the interfacial behavior of PECS with the observed degree of surfactant binding and their morphology.

Keywords:

polyelectrolyte complexes, multicharged cationic surfactants, adsorption isotherm, MD simulations



The dependence of the surface tension on the C12-DcNMe₃Br concentration upon the addition of PSS and PAA and formation of PECS.

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Tailoring hydrophobic/hydrophilic binary polymer brushes: controlling grafting and chain length for tunable wetting properties

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Surface-grafted polymer systems can be designed to adapt dynamically to solvent environments, making them ideal for multifunctional interfaces. Exposure to solvents of different polarity can induce significant conformational and compositional changes within polymer layers, leading to tunable variations in surface properties such as wettability, adhesion, and morphology. [1, 2] In this context, binary polymer brushes (BPs), which are composed of two distinct polymer chains grafted onto the same substrate, represent a promising platform. [3] However, the performance and responsiveness of BPs critically depend on key structural parameters, notably the grafting density and the degree of polymerization of each constituent polymer. [4] In this contribution, we establish an alternative methodology for the synthesis of BPs using successive surface-initiated atom transfer radical polymerization (SI-ATRP). Unlike previous approaches, our method combines control over the grafting ratio, achieved from a two-component initiator monolayer on silicon substrates, with optimized polymerization conditions that enable tuning of the polymer chain length, allowing the preparation of BPs with tailored compositions. The monolayer consists of two mono(ethylene glycol) silanes: one bearing 2-bromoisobutyryl moieties that serve as SI-ATRP initiating sites (MeG-BiB), and the other carrying trifluoroacetate groups (MeG-TFA), which can be hydrolyzed and subsequently functionalized to anchor the second initiator through an acylation reaction. The polymerizations were based on the polarity-contrasting monomers *n*-Butyl methacrylate (BMA) and 2-hydroxyethyl methacrylate (HEMA) to prove the concept and to study the switching wetting properties. The influence of the grafting and polymer chain length ratios on the morphology and wettability upon interaction with solvents of different polarities was investigated. Precise control over these parameters resulted in changes in both surface topography and dynamic contact angle. Additionally, the results suggest that the phase separation (vertical or horizontal) can also be tuned depending on the specific solvent exposure.

Keywords:

Binary polymer brushes, wettability, switchable hydrophobic/hydrophilic polymer surfaces

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Probing molecular interactions between polymer and surface through hydrogel friction experiments

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Polymer dynamics near solid surfaces is of great importance for mechanics, adhesion, friction, and interfacial flows, as it sets the boundary conditions and the macroscopic response of polymer systems. However, directly obtaining the physical characteristics of polymer/substrate interaction from macroscopic experiments can be challenging. Indeed, the macroscopic response of interfaces may strongly couple molecular contributions from the interfaces with mechanical response from the bulk.

To isolate polymer/substrate interactions in gels, we develop specific friction experiments in which a spherical silica probe rotates and slides over swollen polymer networks often referred to as gels [1]. The set-up shown in the figure was designed to minimize bulk dissipative processes and allow homogeneous sliding at the interface.

In these systems, we demonstrated that measuring the velocity dependence of the friction force enables the determination of both the polymer/substrate interaction energy and the surface density of adsorption sites. The experimental results are analyzed using a theoretical model where energy dissipation at the sliding interface arises from sequences of polymer chain pinning, stretching, and desorption from the gel onto silica [1]. This study delves into dissipative mechanisms by tuning the physicochemistry of the interface, leveraging polyelectrolytes and neutral polymers. Experimental parameters—such as pH and salt concentration—are systematically adjusted to screen or enhance electrostatic interactions between the polymer and substrate. Additionally, we investigate the influence of polymer chain stiffness on frictional response. To achieve this, we engineer polymer brushes of controlled length at the hydrogel interface, enabling modulation of tribological properties.

Keywords:

Hydrogels, Tribology, Polyelectrolytes, Interface

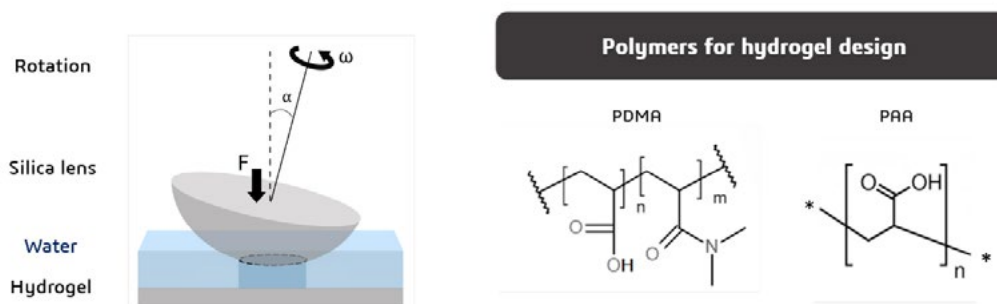


Figure 1 – Schematic of the experimental set-up with *in situ* contact visualization and the studied physicochemical conditions.

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Multi-Responsive Magnetic pNIPAM-Alginate Colloidal Hydrogels

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Smart hydrogels are hybrid materials capable of modifying their properties in response to external stimuli such as temperature, pH, magnetic fields, or electromagnetic radiation [1]. When embedded with functional nanoparticles, these materials can exhibit optical responses that emerge from the interfacial interplay between the chemical composition of the particles and their geometric arrangement — a fundamental coupling that poses challenges for rational design [2]. These characteristics make them of particular interest for active soft matter and remote actuation systems.

In this work, dual-network hydrogels with a polymeric composition of pNIPAM and alginate were designed, forming both Interpenetrating Polymer Networks (IPN) and Semi-Interpenetrating Polymer Networks (SIPN). The pNIPAM component confers thermos-responsiveness, while alginate enables fine tuning of the network elasticity. Magnetic microparticles were incorporated to introduce sensitivity to external magnetic fields. An optimized synthesis procedure was developed to ensure colloidal stability within both network architectures.

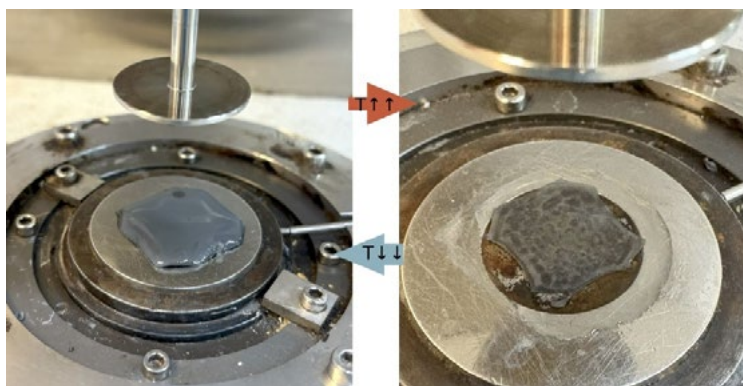
A full mechanical characterization was carried out, revealing that the application of a magnetic field and the variation of alginate cross-linking density drastically tune the viscoelastic properties of the hydrogel. ESEM imaging provided complementary structural insight, showing how these factors alter the internal pore morphology. These observations were consistent with swelling experiments, in which the hydrogels underwent a volume phase transition (VPT), expelling approximately 75% of their mass as the thermally collapsed pNIPAM network drove water release.

Electromagnetic simulations were conducted to investigate the infrared absorption behavior of the core-shell colloidal inclusions. By modeling a core-shell architecture — a 668 nm iron core with a 32–100 nm silica shell — we demonstrate a non-additive optical coupling between composition and geometry that produces highly selective absorption at 8 μm , sharper than that of either constituent material alone.

These results establish the multi-responsive character of the synthesized IPN and SIPN hydrogels, integrating thermal and magnetic actuation within a single soft matter platform. The combination of tunable mechanical properties characterized network topology, and optically engineered particle inclusions provides a basis for the rational design of colloidal hydrogels with programmable, stimulus-selective responses. Future work will explore the exploitation of these properties in targeted applications, including magnetically guided soft actuators.

Keywords:

Magnetism, Soft Matter, Nanoparticles



Example of swelling and de-swelling of the magnetic hydrogel.

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Linear and Non-Linear Interfacial Dilatational Rheology of Oligo(ethylene glycol)-Based Microgels at the Air–Water Interface.

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The interfacial mechanics of oligo(ethylene glycol) (OEG)-based microgels¹ adsorbed at the air–water interface were characterised by pendant drop tensiometry, combining linear and non-linear oscillatory dilatational protocols to resolve their viscoelastic response below and above the volume phase transition temperature (VPTT). Adsorbed layers were equilibrated at a constant surface area prior to imposing oscillatory area perturbations. In the linear regime, small-amplitude oscillations ($\Delta A/A_0 = 5\%$) were applied across a frequency range of 0.01–0.2 Hz, with harmonic analysis confirming the linearity of the response. Beyond this regime, large-amplitude oscillatory dilatation (LAOD) was employed to probe the non-linear mechanical response of the microgel-laden interfaces. Amplitude sweeps with stepwise increasing deformations ($\Delta A/A_0 = 5, 10, 20, 30\%$) were performed at a fixed frequency (0.02 Hz). The complete set of harmonic contributions was analysed via general stress decomposition (GSD)² to separate the intracycle stress into contributions arising from genuine interfacial network interactions and those stemming from surface density changes upon compression/expansion. This distinction is unique to dilatational deformation—as opposed to shear—since surface mass is not conserved during area oscillations. This framework, combining linear and non-linear harmonic analysis, provides a systematic basis for resolving differences in interfacial film strength, structuration, and deformation tolerance between the OEG-based microgel systems.

Keywords:

Pendant Drop Tensiometry, Oligo(ethylene glycol)-based Microgels, Interfacial Dilatational Rheology, Large-amplitude oscillatory dilatation (LAOD).

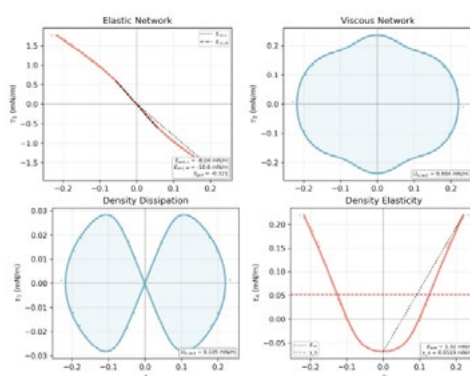


Figure: Representative GSD analysis under LAOD at the air–water interface. Total stress is decoupled into elastic and viscous network interactions (top), alongside density dissipation and density elasticity (bottom) arising from surface mass non-conservation.

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Coarse grain simulations of PEG hydrogels

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Cancer immunotherapy, which involves the utilization of T cells to enhance anti-tumor immunity, has demonstrated considerable potential. A significant challenge is to achieve effective expansion and activation of antigen-specific T cells in vitro. Polymeric hydrogels can be functionalized to recruit T cells and promote their expansion and activation. In this regard, hybrid hydrogels integrating synthetic polymers (e.g. polyethylene glycol, PEG) have attracted considerable attention due to their tunable mechanical properties, controllable degradation, and low cost. However, the majority of studies remain experimental relying on trial-and-error approaches, and the structure-property relationships of these hydrogels are unclear. As a “computational laboratory”, molecular simulation provides access to the real time molecular scale dynamics of materials’ link between microstructure and macroscopic performance. In this work, we consider a coarse grain (CG) implicit solvent model for molecular dynamics (MD) simulations of PEG polymers and hydrogels using the LAMMPS code. In this model, each CG bead represents a C-C-O unit. The force field includes Lennard-Jones interactions, along with bond, angle, and dihedral potentials with parameters adjusted to approximately fit the radius of gyration of PEG chains in implicit solvent. We consider the formation of hydrogels from different concentrations of a star-PEG melt (simulated explicitly by including a reaction step in the MD simulations), followed by equilibration and analysis of its structural and mechanical properties. This study aims to enhance the comprehension of the interactions between such polymers and T cells in molecular level, thereby providing fundamental data and theoretical support for designing PEG-based hydrogel systems for immunotherapeutic applications.

Keywords:

PEG-based hydrogel; Coarse grain models; Molecular dynamics simulations

Effect of crosslinker density on the dynamic and energetic properties of concentrated PNIPAM microgel solutions

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PNIPAM microgels are used as model systems for studying the properties of thermosensitive microgels. Their responsive behavior makes them ideal systems for the fabrication of smart materials with multiple commercial applications, which require an understanding of their dynamics and interactions. In this work, we have studied the effect of the crosslinker (BIS) density used in the synthesis of PNIPAM microgels on both their dynamics and interactions at room temperature (swollen state) as we increase the volume fraction of particles in the medium. Using Confocal Laser Scanning Microscopy, we have characterized: i) the dynamics of the system, determining the Mean Squared Displacement (MSD) as a function of time; ii) the interaction between particles, through the pair correlation function ($g(r)$). The results have showed that: i) depending on the crosslinking density, we could change the phase of the system; and ii) it is very important to establish a valid criterion for calculating the particle volume fraction (using complementary techniques such as static and dynamic light scattering) to make comparisons between microgels with different degrees of crosslinking.

Keywords:

PNIPAM microgels, thermosensitive microgels, crosslinking density, Mean Squared Displacement, pair correlation function, phase behavior

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Phase separation of poly(amic acid) : phase diagrams and kinetics followed by small-angle neutron scattering

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Poly(amic acids) (PAA) are interesting precursors of polyimides. The latter polymers, due to their excellent thermal, mechanical, and chemical properties, are extremely useful for applications such as porous membranes for gas separation and nanofiltration.^{1,2} We recently discovered that poly(amic acid) salts (Fig.1a) undergo liquid-liquid phase separation (PS) by adding salt (monovalent or divalent) and lowering temperature enough. PS is precisely a key process in making porous membranes³ through the formation of interconnected phases by spinodal-like PS for instance. In that case the polymer-rich phase is stabilized to form the porous membranes matrix. We combine rheological measurements, UV-visible spectroscopy and scattering techniques to investigate the solution behavior of poly(amic acid) salts (PAAS) across a range of conditions in the monophasic domain, including variations in ionic strength, polymer concentration and temperature. Specific viscosity measurements reveal a characteristic polyelectrolyte behavior, following Fuoss's law in salt-free solutions, switching to a neutral polymer-like scaling with added salt. Phase diagrams demonstrate an upper critical solution temperature UCST-type transition (Fig. 1b), characterized by reversible phase transition behavior induced by changes in ionic strength and temperature. To further elucidate the underlying mechanisms of PS, we have recently investigated the dynamics of phase separation using small-angle neutron scattering (SANS), by performing thermal quenches or ramps from the one-phase region to the two-phase one. The kinetics of growth can be followed in time through the evolution of the scattered intensity at low wavevectors (Fig.1c).

Keywords:

water-soluble poly(amic acid) salt, aqueous phase separation, membrane, phase diagram

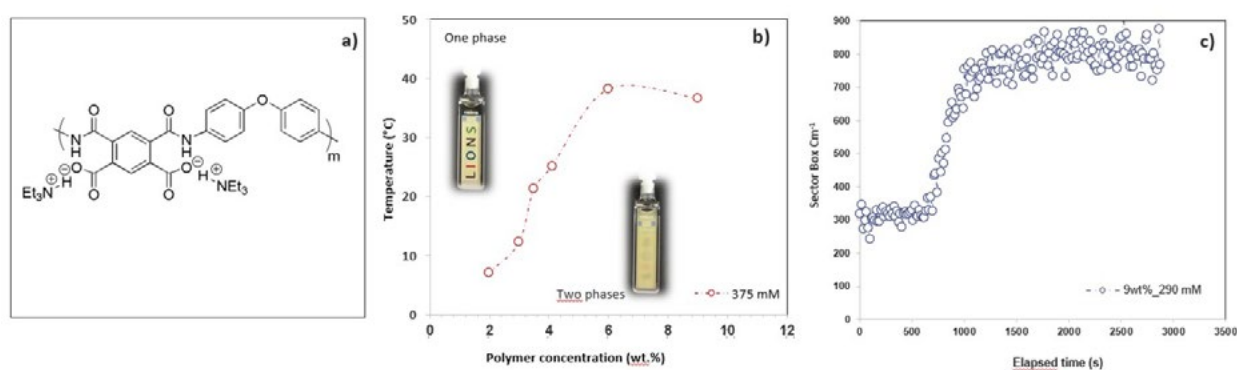


Figure 1. (a) Monomer chemical structure of water-soluble poly(amic acid) salt; (b) Phase diagram for poly(amic acid) salt solution at $C_s = 375 \text{ mM NaCl}$; and (c) Time evolution of average intensity from SANS data over a q range $0.001\text{--}0.002 \text{ \AA}^{-1}$ with a quench temperature from 40°C to 15°C

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PHYSIOCHEMICAL BEHAVIOR AND NETWORK MORPHOLOGY OF CHITOSAN: A MARTINI3 COARSE-GRAINED MOLECULAR DYNAMICS STUDY

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Chitosan-based hydrogels have emerged as advanced materials for wastewater remediation applications due to their high absorption capacity, biodegradability, and structural flexibility [1]. The presence of amine and hydroxyl groups in chitosan, as well as their distribution along the polymer chain, plays a crucial role in determining its solution behavior. Additionally, the network morphology and physicochemical properties of chitosan are influenced by factors such as the degree of acetylation, water/chitosan ratio, degree of polymerization, and pH [2]. Therefore, understanding and predicting the effects of these design parameters on morphology and physicochemical behavior in solution is key to developing tailored hydrogels for wastewater remediation.

In recent years, all-atom molecular dynamics studies have emerged as effective and accurate tools for studying such phenomena and their underlying molecular mechanisms. However, due to computational limitations, coarse-grained approaches, particularly those based on Martini 3 polysaccharide and carbohydrate force fields [3] have shown strong agreement with both experimental results and all-atom simulations, enabling the study of higher degree polymerization chains over longer timescales. In this work, Martini coarse-grained molecular dynamics simulations were employed to investigate the physicochemical behavior of chitosan in solution. This study analyzes the radius of gyration and persistence length of chitosan as functions of degree of polymerization, degree of acetylation, and amino group distribution. The results demonstrate a scaling behavior of the radius of gyration and persistent length with respect to degree of polymerization and acetylation, consistent with experimental findings. Furthermore, the study reveals a transition from rod-like chitosan oligomers to more flexible chain conformations in solution. Moreover, the network morphology was systematically examined for varying degrees of acetylation alongside the effect of pH on structural organization. The acetylation influence on the chain interactions, aggregation and swelling behavior and overall network architecture are studied for varying pH.

Keywords:

Chitosan, Deacetylation, Network morphology, Coarse Grain molecular dynamics

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Structural properties and electrical conductivity of electro-responsive polymer nanocomposites through coarse-grained Langevin dynamics.

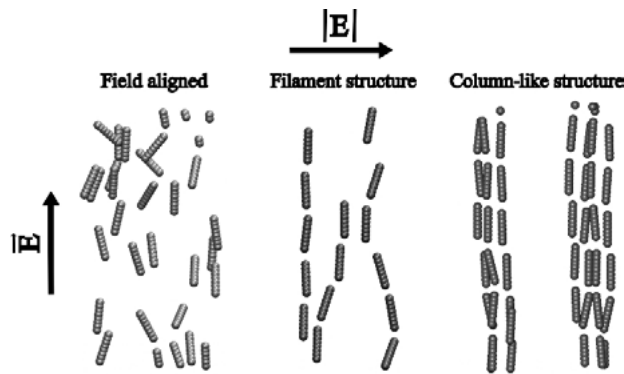
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Responsive polymer nanocomposites (PNCs) are a promising class of materials for designing smart systems. In this study, we employ coarse-grained Langevin dynamics to investigate the structural, and electrical properties of a PNC. This nanocomposite is constituted by polarizable nanorods (NRs) embedded within a polymer matrix under direct-current electric fields of varying amplitude. Our results show different structural motifs of the NRs depending on the amplitude of the applied field. At low field amplitudes, the NRs orient along the field direction, whereas at high amplitudes they self-assemble into percolating filaments and column-like structures. To compute the electrical conductivity of the system, we use both a resistor network model [1] and a theoretical model [2] for aligned and unaligned NRs. When comparing both models, the results show a disagreement in the computed electrical conductivity. This occurs because the theoretical model is incapable of accounting for the self-assembly of the NRs. To improve it and account for this self-assembly, we modify one of its parameters, which results in an electrical conductivity similar to that obtained with the resistor network. Therefore, our simulations results suggest that the structural motifs of the NRs directly affects the material's electrical conductivity, with an enhancement of around four orders of magnitude between low and high electric field amplitudes.



Self-assembled motifs at increasing amplitudes of the applied direct current electric field.

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Dynamic electrorheological response of nanorod polymer nanocomposites

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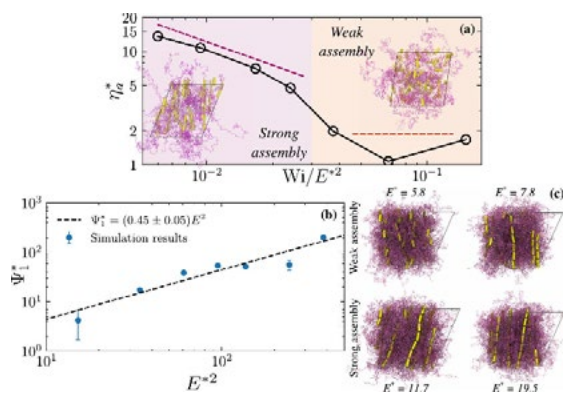
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Smart materials, such as responsive polymer nanocomposites, are a type of functional materials capable of dynamically altering their macroscopic properties in response to external environmental stimuli, such as temperature, electromagnetic fields, pH, or salt concentration. For our investigation, we utilize a coarse-grained model in Langevin dynamics to unveil the interplay between the dynamical and rheological properties of a polymer matrix embedded with nano-sized polarizable rods under different electric fields of constant amplitude. Firstly, we test the transport properties of metallic nanorods and organic nanodimers in polyethylene without an electric field [1]. Then we study the collective behavior of a crowded environment of nanorods under an applied electric field [2]. Lastly, we investigate the introduction of nanorods with a 6.7% weight percentage concentration into a polymer matrix susceptible to an electric field [3]. Our results show structural motifs that scale with increasing field amplitude, affecting the steady-state dynamical and rheological properties, as well as the transitory electro-orientation response times. The nanorods structural transition goes through three phases: at low-fields we observe individual orientation but no collective behavior, at medium range fields we report filament formation, and at high amplitudes they self-assemble into percolating columnar structures. Our simulations under shear flow suggest that the structural phases of the nanorods directly affect the material's rheological properties, acting as a thickening agent that is enhanced with increasing field amplitude. At the highest tested field, we report a 15-fold increase in viscosity compared to the zero-field viscosity.

Keywords:

Polymer nanocomposites, Coarse-grained simulations, Molecular Dynamics, Electrorheology, Smart materials, Self-assembly, Conductivity, Nanorods



Response of (a) the low-shear apparent viscosity, (b) first normal stress coefficient, and (c) 4 snapshots at different electric fields.

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Acknowledgements:

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Shouldn't it just be additive? Investigating how combined sugar and salt solutions influence a thermoresponsive polymer

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Osmolytes are a class of small organic molecules that influence the properties of macromolecules. First recognised for their function in osmotic pressure regulation in biological systems, they have since been identified as having a considerably wider role. Of particular note is their ability to denature and destabilise biomacromolecules. This destabilisation can occur via two paths: osmolytes interfere with the ability of the macromolecules to interact with, and be solvated by water molecules, or osmolytes interrupt hydrophobic interactions which are responsible for the formation of many biological structures. Sugars play many important roles in biological systems and, while it may not be their primary function, they also act as osmolytes. For example, glucose has been shown to destabilise synthetic macromolecules through osmolyte-type behaviour at elevated concentrations.¹ Specific ion effects which cannot be wholly explained by classical electrolyte theories, have also been found to significantly influence the properties of macromolecules. Traditionally, the variations observed between ions were attributed to their ability to “make” or “break” the structure of water. Upon further investigation it has been revealed that interfacial ion-partitioning plays a significant role in these specific ion effects where larger, less hydrated ions have an increased preference for interfacial regions.² These salt effects have been extensively investigated since they were first observed and generally follow a well-established series. We have previously shown that the concentration of an ion, and its position in this series, determines its ability to stabilise/destabilise macromolecules.³

As osmolytes and salts both play a significant role in a solution's ability to denature and destabilise biomacromolecules, their combined interactions (often present together in biological systems) are of particular interest in furthering our understanding. Herein, we investigate the combined effects of glucose and salts on the thermoresponse of Poly(*N*-isopropylacrylamide) (PNIPAM); a well characterised polymer that undergoes a temperature induced phase change at its lower critical solution temperature. Neutron reflectometry (NR) was employed to probe the internal structure and conformation of a PNIPAM brush while differential scanning calorimetry (DSC) examined the thermodynamic properties of free PNIPAM solutions (Fig. 1).

Keywords:

Osmolytes, Specific ion effects, PNIPAM, Neutron reflectometry, Differential scanning calorimetry

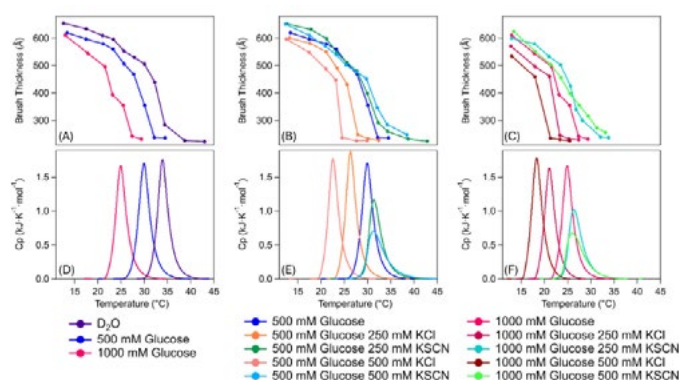


Figure 1. (A, B and C) PNIPAM brush thickness determined via NR and (D, E and F) specific heat capacity (C_p) of a PNIPAM solution measured with DSC as a function of glucose/salt concentration and temperature.

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Decoupling Charge and Screening: Small-Ion-Controlled Electrostatics in Random Copolymer Polyelectrolytes

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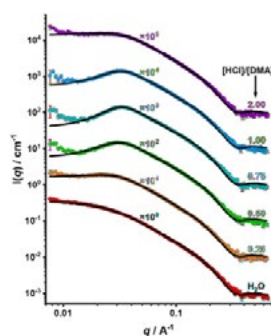
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Electrostatic screening fundamentally determines the conformation and interactions of polyelectrolytes, yet the relative contributions of polymer-bound charges and mobile small ions remain unresolved for weakly charged systems. Using synchrotron small-angle X-ray scattering (SAXS) combined with a rigorous modelling framework, we study the electrostatic behaviour of P(DMA-stat-PEGMA) copolymers with tunable charge density (dimethylaminoethyl methacrylate (DMA) and poly(ethylene glycol) methyl ether methacrylate (PEGMA)). The SAXS data are analysed using a Kratky–Porod worm-like chain (WLC) model that explicitly incorporates excluded-volume interactions and mimics electrostatic swelling, providing an accurate form factor for semi-flexible chains. To capture interchain electrostatics, we employ a PRISM-like (PRISM = polymer reference interaction site model) structure-factor expression derived from earlier Monte Carlo simulations, which links direct correlation functions to measurable scattering features and provides the second virial coefficient. By independently varying degree of protonation, ionic strength, and polymer concentration, we uncover a clear principle: electrostatic screening is governed predominately by mobile small ions (H^+ , Cl^- , K^+), not by the polymer macroions. Classical scaling emerges only when ionic strength is defined using small ions alone, both the persistence length and the second virial coefficient collapse onto an OSF-type (OSF = Odijk–Skolnick–Fixman) electrostatic stiffening law under this definition. Added salt softens the chains, protonation stiffens them, and the interchain structure peak shifts consistently with a single, unified scaling variable. Our results resolve a long-standing ambiguity in weak-polyelectrolyte physics and establish WLC-PRISM, grounded in Monte Carlo simulations, as a physically meaningful and experimentally validated framework for analysing electrostatic interactions in random copolymer polyelectrolytes.

Keywords:

Polyelectrolytes, Electrostatic screening, Small ions, SAXS, Worm-like chain (WLC) model, PRISM theory, Persistence length, Virial coefficient, OSF Theory



Synchrotron SAXS data recorded for 1.0% w/w aqueous solutions of PD8020:150 at various [HCl]/[DMA] molar ratios. All scattering data were fitted using the WLC-PRISM model. For clarity, curves are vertically shifted by an arbitrary factor, as indicated.

Influence of End Groups on the Aggregation of Polymers: A Neutron Scattering Study

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The solution structure of polymers strongly depends on concentration, solvent quality, and molecular weight. Beyond these parameters, chemically distinct end groups can significantly alter phase behavior, with effects strongly dependent on chain length. Previous studies have reported the formation of polymeric micelles in systems bearing hydrophobic end groups. [1] However, a systematic understanding of how micelle formation depends on molecular weight and concentration, particularly in the semi-dilute regime, remains incomplete. Moreover, the possibility that micelle formation is not the dominant state has received little attention.

We investigated the solution behavior and the occurrence of micelle-like structures in (semi)-dilute solutions. Hydrophobically end-functionalized PNIPAM homopolymers were synthesized via controlled reversible addition fragmentation transfer polymerization providing good control over molecular weight and dispersity. The end groups could be selectively cleaved via aminolysis, enabling direct comparison without altering backbone chemistry or molecular weight distribution. Dynamic light scattering (DLS) was used to characterize the dimensions of polymer coils and potential aggregates.

Cloud points in aqueous solution were determined via extinction spectroscopy (see Figure 1, left), providing access to macroscopic phase transitions. These measurements reveal a pronounced dependence on end-group functionality for polymers with molecular weights below 100 kDa, highlighting the increasing relevance of terminal groups at shorter chain lengths. Complementary to this, small-angle neutron scattering (SANS) was used to probe the nanoscale structure of the polymers in solution. From the SANS measurements we were able to determine the ratio between individual polymer chains and the micelles. Our studies demonstrated that a subdominant micelle formation occurs for samples with molecular weights below 100 kDa, indicating a coexistence of free chains and weakly associated micellar structures rather than complete micellization. The aggregation number of these micelles scales inversely with the molecular weight, further suggesting reduced end group association efficiency for longer chains. At low concentrations, these micelles exist as individual structures. Upon increasing the concentration micelles aggregate, leading to pronounced interparticle correlations and a distinct structure factor contribution in the scattering profile (see Figure 1, right).

These results demonstrate that terminal groups have a substantial impact on polymer solution behavior, particularly for shorter chains, and highlight how weak end-group association can drive concentration-dependent self-assembly in otherwise soluble homopolymers.

Keywords:

Small-Angle Neutron Scattering, Thermoresponsive Polymers, End Group Effects

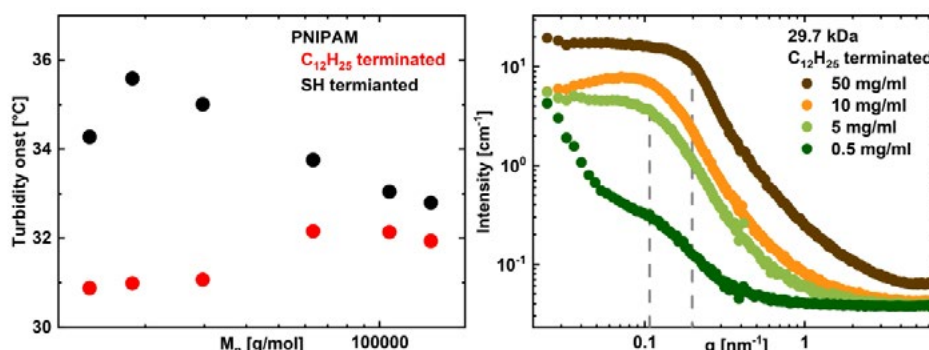


Figure 1: Left: Turbidity onset in dependence of molecular weight with (red) and without (black) hydrophobic end group. Right: Concentration dependent SANS profiles of PNIPAM homopolymers with hydrophobic end group.

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Stimulus-Driven Dynamics and Microrheology across the Soft-to-Hard Continuum of Responsive Colloids

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Responsive colloids are well-suited to investigate how external stimuli alter particle interactions, dynamics, and mechanical response. Here, we study two model systems spanning the soft-to-hard continuum: thermoresponsive poly(N-isopropylacrylamide) (PNIPAM) microgels with different crosslinking degrees, and electrorheological suspensions of anisotropic silica nanorods under applied electric fields. Using diffusing-wave spectroscopy (DWS), we track the stimulus-driven evolution of these systems through the intensity correlation function, the mean-squared displacement, and the viscoelastic moduli obtained by microrheology. For PNIPAM microgels, we examine how temperature and particle softness influence relaxation dynamics and mechanical response over a broad concentration range. For nanorod suspensions, we address how electric-field-induced organization affects particle dynamics and viscoelastic behavior. By comparing these two classes of responsive colloids within a common experimental framework, we aim to identify general links between the applied stimulus, particle-scale dynamics, and the resulting rheological response.

Keywords:

Responsive Colloids, Microgels, Microrheology, Light Scattering

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Charge Regulation of Dextran Sulphate Sodium Investigated with Membrane Osmometry

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Charges are important in soft matter and play, for instance, a key role in colloidal stabilization and in the flocculant properties of polyelectrolytes. The effective charge, however, is difficult to determine experimentally. The commonly used technique laser-Doppler electrophoresis, for example, is limited in use to dilute solutions: At higher polyelectrolyte concentrations, the effective charge changes due to charge regulation.

Here, membrane osmometry was employed to observe how the effective charge of dextran sulphate sodium (DSS) changes with ionic strength and polyelectrolyte concentration. Using a membrane osmometer, the effective charge was deduced from the osmotic pressure of a DSS solution in excess to that of a reservoir salt solution.

Our results demonstrate an increasing effective charge with increasing NaCl concentration or decreasing polyelectrolyte concentration. These results are in line with theory since increasing the NaCl concentration leads to stronger screening of dissociated groups on DSS. This reduces the driving force for counterions to re-associate [1]. Increasing DSS concentration results in decreasing distances between DSS molecules and, consequently, increasing double-layer repulsions between the polyelectrolytes. Re-association of counterions reduces the repulsion and lowers the effective charge of DSS [2].

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Self-Assembly and Phase Behavior in PAMAM G3 Dendrimer–DBSNa Complexes

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Electrostatic complexes of dendrimers and amphiphilic surfactants are promising building blocks for ordered mesophases in nanostructured soft materials. Here, we investigate the self-assembly behavior of sodium dodecylbenzenesulfonate (DBSNa) with PAMAM G3 dendrimer using small-angle X-ray scattering (SAXS) and Cryo-EM. By systematically varying the dendrimer charge state (d_p) and surfactant concentration (x_n), a structural phase diagram was established for the G3–DBSNa system. Over most of the composition window, the complexes exhibited conventional hexagonally packed cylindrical and lamellar phases, indicating that the self-assembled structure is highly sensitive to charge state and composition. Interestingly, at a very low dendrimer charge state ($d_p = 0.3$) and high DBSNa concentration ($x_n > 0.7$), an additional ordered phase was identified. SAXS revealed a superlattice structure with a characteristic d-spacing approximately twice that of the conventional hexagonally packed cylindrical phase, indicating the presence of cylindrical domains with different sizes. Cryo-EM provided complementary real-space evidence by showing side-view cylindrical features with characteristic spacings consistent with those derived from SAXS. These results show that the G3–DBSNa system can form not only conventional mesophases but also a distinct superlattice structure under specific charge and composition conditions, providing new insight into the hierarchical self-assembly of dendrimer–surfactant complexes.

Keywords:

dendrimer, surfactant, SAXS, Cryo-EM

Modeling Thermoresponsive Microgels: Linking Internal Architecture to Collective Behavior

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We introduce a coarse-grained theoretical and computational framework to describe the compression and assembly of thermoresponsive core-shell microgels in good solvent conditions [1]. The approach explicitly accounts for internal morphological heterogeneity by decomposing the particle free energy into core and shell contributions, each governed by a Flory-Rehner-type description with distinct elastic and swelling characteristics. Mechanical equilibrium between these regions is imposed to obtain a self-consistent description of particle size and internal restructuring. Interparticle interactions are represented through a size-dependent multi-Hertzian pair potential that captures the differential compressibility and mechanical response of the core and corona. Model parameters are calibrated against dynamic light scattering measurements of PNIPAM microgels across temperatures spanning the lower critical solution temperature, enabling a quantitative description of thermally induced swelling and collapse, including variations in core size. Monte Carlo simulations based on these effective interactions are used to investigate concentrated suspensions under compression, focusing on structural and thermodynamic properties such as size distribution, effective packing fraction, spatial correlations, and phase behavior. Our results demonstrate that particle softness, responsiveness, and internal heterogeneity collectively govern the organization and state behavior of dense microgel systems, providing a direct link between single-particle properties and emergent collective phenomena.

Keywords:

Microgels, polymers, colloidal suspensions, Flory-Rehner theory, Monte Carlo simulation

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Preparation and Application of Photo-Stimulated Multi-Responsive Gels

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Fluorescent gels with three-dimensional cross-linked networks and tunable luminescence represent an important class of smart materials. Herein, we develop a single light-triggered multi-responsive gel by incorporating photoacid generators (PAG), dual-state emission fluorophores (CP), and polyelectrolyte groups (NASS) into a polyacrylamide matrix. The gel exhibits simultaneous color, fluorescence, and volume responses upon light irradiation. The NASS-induced polyelectrolyte effect enables acid-triggered volume shrinkage, which is converted into non-contact photoresponsiveness by PAG. Benefiting from the photochromism of PAG, the gel changes from yellow to light pink under light. The dual-state emission fluorophores display distinct fluorescence behaviors: dispersion-state molecules undergo FRET with PAG, while aggregated-state molecules do not. Solvent exchange further modulates fluorescence responses: the gel in DMSO switches from yellow to blue fluorescence upon irradiation, whereas the hydrogel retains constant yellow fluorescence. This work demonstrates that the integration of PAG, dual-state fluorophores, and polyelectrolytes successfully endows the gel with light-induced multi-responsiveness, showing promising applications in biomimetic actuation and information encryption.

Keywords:

Multi-Responsive, Fluorescent gels

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Biopolymeric Hydrogels for the Co-Encapsulation of Phycocyanin and Albumin-bound Curcumin

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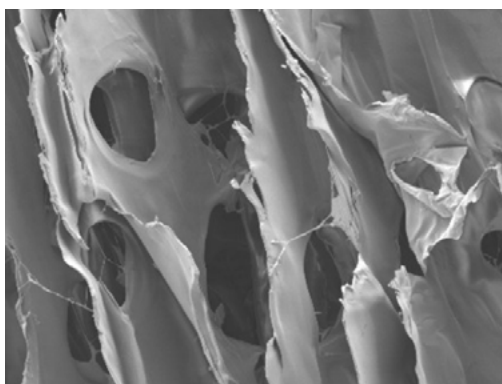
A significant challenge across various scientific and industrial fields remains the co-encapsulation of hydrophilic and hydrophobic compounds within a single delivery system. Towards this direction, the current study proposes an encapsulation strategy, according to which the simultaneous incorporation of both hydrophilic and hydrophobic biomolecules within a hydrogel matrix is enabled.

For this reason, in the present study, a hydrophilic hydrogel matrix is prepared to serve as the network on which the two compounds are co-encapsulated. Namely, the hydrophilic compound chosen is the cyanobacterial protein phycocyanin, extracted and purified by dry *Arthrospira maxima* biomass. The hydrophobic compound chosen is curcumin which has been previously bound to bovine serum albumin (BSA). This approach facilitates the indirect entrapment of hydrophobic molecules within the hydrophilic hydrogel network.

The structural and physicochemical properties of the resulting hydrogels are characterized using optical analysis, scanning electron microscopy (SEM) and confocal laser scanning microscopy (CLSM). Additionally, the antioxidant potential of the encapsulated biomolecules is evaluated to assess their functionality after the encapsulation. Furthermore, a cell viability assay confirmed the hydrogel's biocompatibility and lack of toxicity, demonstrating its suitability as a multifunctional biomaterial for biomedical and pharmaceutical applications.

Keywords:

antioxidants, biopolymers, hydrogels, structure, morphology



SEM image of the freeze-dried hydrogel containing both, phycocyanin and albumin-bound curcumin

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Exact model for conformational transitions in macromolecules under mechanical stretching

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Conformational transitions are central to explain the mechanical properties of macromolecules and biopolymers. However, standard polymer models such as the freely jointed chain and worm-like chain neglect internal conformational degrees of freedom, limiting their ability to capture force-induced structural changes.

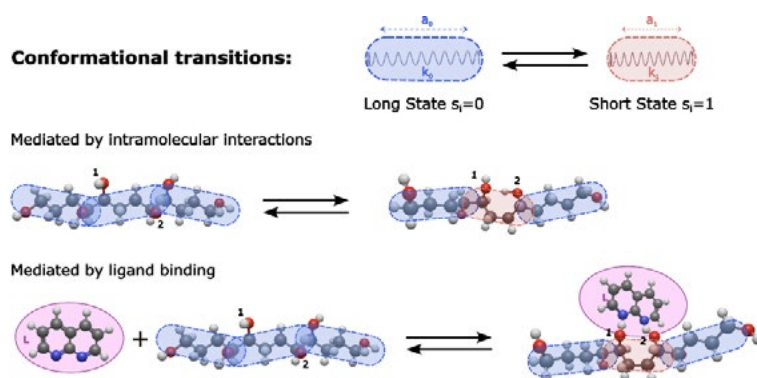
Here [1], we present an exact statistical-mechanical solution of a minimal two-state model within the elastic freely jointed chain (EFJC) framework [2]. Each segment can adopt two conformations with different Kuhn lengths and elastic constants, coupled through nearest-neighbor interactions that account for cooperativity (cf. Fig. 1). Using transfer-matrix methods, we obtain closed analytical expressions for the force–extension relation and state populations, ensuring thermodynamic consistency and avoiding the spurious phase transitions of mean-field approaches.

The model quantitatively reproduces experimental force-extension curves across different systems. Poly(ethylene glycol) displays non-cooperative behavior, hyaluronic acid exhibits a temperature-dependent transition with negative cooperativity, and DNA overstretching shows strong positive cooperativity. These results demonstrate that the framework captures a wide range of experimentally observed responses within a unified description.

We further identify the mechanisms underlying force-induced transitions, which arise from differences in Kuhn lengths, elastic constants, or their combination. The formalism can be extended to multistate systems, enabling the description of ligand–receptor interactions and competitive binding under mechanical load.

Keywords:

polymers, mechanical stretching, polymer theoretical modelling, single molecule experiments, AFM.



Two-state EFJC model: chain segments switch between conformations with different lengths and stiffness, including cooperative interactions.

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Acknowledgements:

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Design and synthesis of ionically cross-linked graphene oxide-reinforced hydrogel.

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Hydrogels have attracted significant attention due to their high water content, tuneable structure, and excellent biocompatibility, making them promising materials for biomedical engineering, tissue scaffolding, and environmental remediation. ¹ However, conventional hydrogels sometimes exhibit poor mechanical strength, limited structural stability, and restricted functional versatility, which constrain their use in demanding applications. One approach to overcome these limitations involves incorporating nanomaterials as reinforcing agents within hydrogel matrices. Among these, graphene oxide (GO) is particularly attractive due to its highly oxidized nature and high specific surface area. This provides a large and functional oxygen-rich interface that promotes strong interactions with polymer networks. Such interactions allow enhanced surface contact between the two components, further enhancing the hydrogel mechanical strength, elasticity and responsiveness, while maintain high water retention capabilities. However, achieving uniform dispersions of GO nanosheets within polymer matrices remains a significant challenge, despite being critical for fully optimising the mechanical and functional properties of hydrogels. ²

A powerful strategy to overcome this limitation, which has been partially explored in the context of nanocomposites, ³⁻⁵ is to exploit GO's acidic functional groups and pair them with hydrogels of complementary ionic character, allowing strong electrostatic interactions to form at their interface. These interactions are expected to significantly improve GO dispersion, enhance compatibility between organic and inorganic phases, and strengthen interfacial adhesion. ⁴ In addition, homopolar surface charges are anticipated to induce electrostatic repulsion, improving GO colloidal stability and enabling greater structural control in the resulting Nanoscale Ionic Hydrogels (NIHs). ⁶ Collectively, this approach is expected to yield GO-based NIHs with improved mechanical properties and enhanced performance, effectively moving beyond the concept of a traditional polymer matrix toward a single-phase hybrid system. ⁷

Herein, a GO-reinforced poly(2-hydroxyethyl methacrylate-co-2-(dimethylamino)ethyl methacrylate) (HEMA–DMAEMA) hydrogel is synthesised to maximise electrostatic interactions between the basic amine groups of the polymer network and the carboxylic acid functionalities of GO. To further enhance such interactions, GO nanosheets were pre-treated with succinic anhydride to introduce additional carboxylic acid groups at their edges (C-GO).

Preliminary results indicate improved dispersion of C-GO within the pre-polymer mixture, suggesting enhanced compatibility between DMAEMA monomers and C-GO sheets compared to standard GO. Ongoing spectroscopic characterisation will help elucidate and assess interfacial interactions (Infrared and Raman Spectroscopy), surface chemistry and chemical environment (X-Ray Photoelectron Spectroscopy), and nanoscale dispersion and morphology (Scanning Electron Microscopy). Moreover, rheological assessment will provide further insight into the system's structure-property relationships, allowing us to link this design approach to the resulting mechanical performance and network architecture of the hydrogel.

Keywords:

Hydrogels, Graphene oxide, Hybrid materials, Nanocomposites.

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Photoresponsiveness of lyotropic liquid crystals via precipitation-dissolution of an arylazopyrazole derivative

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Research on incorporating photoresponsive molecules into lyotropic liquid crystals (LLCs) for the optical control of their phase states is attracting attention due to their potential applications in drug delivery systems and other fields. Photostimulation offers high spatiotemporal flexibility, enabling versatile control of the liquid crystal phase through irradiation area and duration. However, conventional photoresponsive LLC systems face two major challenges. First, many photoresponsive molecules exhibit low thermal stability of one isomer, hindering precise control of the liquid crystal phase. Second, these systems often require a high concentration of photoresponsive molecules, which necessitates prolonged light irradiation. For rapid optical conversion, it is crucial to develop a system that functions with the addition of a small amount of dopant.

To address these issues, this study focused on an arylazopyrazole (AAP) derivative, an azobenzene analogue with high thermal stability of its *cis*-isomer. [1] Specifically, AAP-C10, which possesses an alkoxy group with a carbon chain length of 10, was synthesized. By doping a small amount of AAP-C10 into LLCs, photoresponsive liquid crystals were prepared, and their photoresponsiveness was evaluated. Upon UV irradiation of an AAP-C10-doped LLC, a shift in the SAXS pattern, indicating a change in the liquid crystal structure, was observed. Furthermore, when this UV-irradiated LLC was left in the dark at room temperature, almost no thermal back-isomerization from the *cis*- to the *trans*-isomer of AAP-C10 was observed, demonstrating the high thermal stability of these systems.

Keywords:

arylazopyrazole, lyotropic liquid crystals, photoresponsiveness

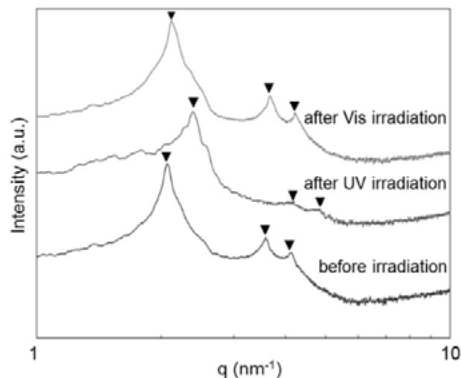


Fig.1. SAXS patterns of the hexagonal LLC doped with 1 wt% AAP-C10 before and after light irradiation.

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Preparation of Diblock Copolymer Nanoparticles by RAFT Dispersion Polymerization in Non-Polar Media and their use as Nanoreactors for the In Situ Synthesis of Silica or Titania

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Well-defined diblock copolymer nanoparticles are prepared via reversible addition-fragmentation chain transfer (RAFT) dispersion polymerization of 2-hydroxyethyl methacrylate (HEMA) in a poly(α -olefin) at 90 °C using a poly(lauryl methacrylate) (PLMA) precursor. This formulation produces a colloidal dispersion of spherical PLMA-PHEMA nanoparticles at 10% w/w solids. The nanoparticle cores can be swollen with 30% w/w aqueous HCl based on the PHEMA mass and then used as nanoreactors for the *in situ* synthesis of silica or titania using either tetraethyl orthosilicate (TEOS) or titanium *t*-butoxide, respectively. The nanoparticles are characterized by TEM, DLS and SAXS. The former technique indicates that core-swelling leads to a subtle change in copolymer morphology from pseudo-spherical to perfectly spherical nanoparticles. DLS and SAXS indicate the formation of near-monodisperse nanoparticles of 92-117 nm diameter with colloidal stability being retained after the nanoreactor syntheses. For the silicified nanoparticles, turbidimetry and SAXS studies suggest a reaction timescale of around 50 min at 25 °C. In this case, the final nanoparticle dispersion is highly transparent, whereas the corresponding titania-loaded nanoparticles form a highly turbid dispersion. Thermogravimetric analyses indicate silica and titania mass loadings of 17% and 21%, respectively. In both cases, the inorganic phase is amorphous rather than crystalline.

Keywords:

RAFT, PISA, Synthesis, Nanoreactor, Silica

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Agarose-mesoporous silica composite systems for controlled drug delivery

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Controlled drug delivery remains a major challenge in the design of advanced therapeutic systems, particularly due to the difficulty in achieving sustained and predictable release profiles. Among various carriers, mesoporous silica materials are highly valued for their large surface area, tunable pore size, and the possibility of functionalization. However, they are often associated with rapid burst release effect, which can lead to suboptimal therapeutic outcomes [1]. To overcome this limitation, the incorporation of such systems into hydrogel matrices has gained increasing attention, as hydrogels can introduce an additional diffusion barrier, enabling more control over drug release while offering high water content and biocompatibility [2,3].

In this study, mesoporous silica materials were synthesized via a sol-gel condensation approach based on the controlled hydrolysis and condensation of tetraethoxysilane as a silica precursor, and co-functionalized with various organic groups introduced during the synthesis. A comprehensive physicochemical characterization was performed using scanning electron microscopy (SEM), X-ray Photoelectron Spectroscopy (XPS), nitrogen adsorption-desorption measurements, and elemental analysis, confirming the successful synthesis and functionalization of the materials. The obtained materials were loaded with diclofenac sodium (DICL) as a model drug for further release tests. The burst effect was observed, indicating rapid desorption of DICL from the silica surface and limited control over the release kinetics. To address this, we proposed a composite delivery platform by incorporating drug-loaded mesoporous silica within an agarose hydrogel matrix. Rheological analysis confirmed the formation of mechanically stable hydrogel networks to limit the burst release effect, and providing a prolonged DICL release.

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Superlattice Formation and Mechanical Response of One-Component Polymer-Grafted Nanoparticle Assemblies: A Coarse-Grained Simulation Study

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Numerous studies have shown that the mechanical properties of systems composed of polymer-grafted nanoparticles (PGNPs) are strongly dependent on the self-assembled structures formed by these particles. In recent years, increasing attention has been directed toward the self-assembly of polymer-grafted nanocrystals, as polymer ligands exhibit significant conformational flexibility and versatile functional characteristics, enabling the formation of highly ordered and diverse superlattice structures. Previous research has identified grafting density, polymer chain length, and chain stiffness as key parameters governing self-assembled morphologies[1][2]. Although nanoparticle shape is also expected to play a crucial role in determining both superlattice structures and mechanical behavior, its specific influence has not yet been systematically elucidated.

To address this issue, we perform coarse-grained molecular dynamics simulations to investigate the effects of grafting density, polymer chain length, and nanoparticle shape on the formation of ordered superlattice structures (simple cubic phase) in one-component PGNP systems. Our results demonstrate that, even under identical grafting density and polymer length, distinct superlattice structures can be stabilized solely by variations in particle shape, emphasizing the critical role of particle anisotropy in determining equilibrium morphologies.

Furthermore, to obtain a comprehensive understanding of the relationship between structure and mechanical response, uniaxial tensile simulations are performed not only on well-ordered superlattices but also on various structures obtained under different conditions. The results reveal that particle rearrangements occur during deformation, indicating that the internal structure dynamically evolves under applied strain.

Keywords:

Polymer nanocomposite, Superlattice structures, Anisotropic interactions, Mechanical response, Molecular dynamics

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Extreme Thermodynamics: Coupling thermodynamic instabilities to mechanics in macroscopic polymer gels

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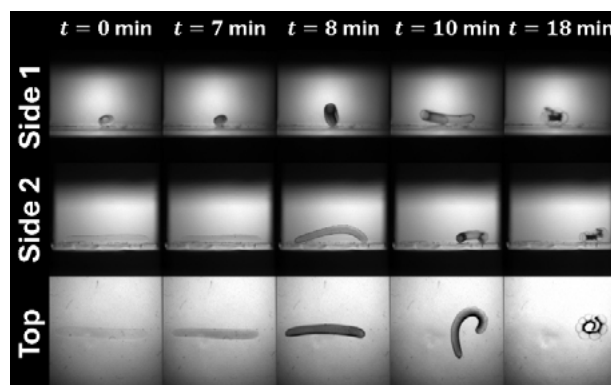
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Among thermoresponsive hydrogels, poly(N-isopropylacrylamide) (pNIPAM) gels are well known for their sharp volume-phase transition near $T \approx 32^\circ\text{C}$, at which they expel most of their solvent. Under slow, quasistatic heating, the gel shrinks affinely. The successive equilibrium states are defined by the condition that the chemical potential of the solvent inside the gel equals that in the surrounding bath. In contrast, a rapid temperature quench produces an effectively impermeable outer skin that fixes the total volume, preventing the solvent from equilibrating in and outside the gel. Instead, under this state of constrained equilibrium, phase separation between solvent-rich and solvent-poor regions occurs. For cylindrical gels, the simpler phase separation is axisymmetric: the outer region collapses while the interior remains swollen. Introducing a polarization vector to describe the solvent distribution reveals that axisymmetry is spontaneously broken, as this lowers the system's free energy. If the gel's centerline is initially curved, this polarization couples to the local curvature and tends to point opposite to the normal vector, thereby biasing the phase separation process and dictating how the gel bends. This coupling generates a feedback loop: curvature influences polarization, and polarization in turn drives further shape change. In S-shaped gels, where the curvature reverses sign, the discontinuity in the polarization vector is reconciled by a twist along the central section. Finally, we show that cylindrical gels of different diameters quenched above T exhibit distinct size- and temperature-dependent instabilities.

Keywords:

Hydrogels, Phase separation, Geometric evolution, Pattern formation



Evolution of a cylindrical hydrogel inside a bath under a rapid heating, imaged from three orthogonal directions. The hydrogel darkens as an impermeable skin forms, fixing its volume. Its geometry evolves, along with the solvent distribution, in a feedback loop. Finally, a 'bubble' pattern appears.

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Phase Behavior and Morphology of Biodegradable Poly(ϵ -caprolactone)/Propylene Carbonate Blends

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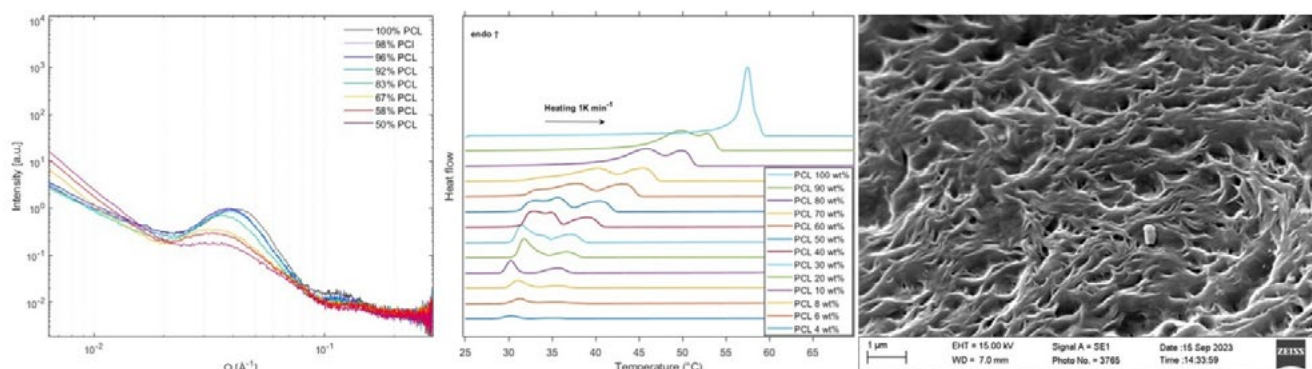
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Microplastic pollution is an increasing environmental concern, driving interest in biodegradable polymer materials as sustainable alternatives [1]. Porous polymers are of particular interest because their internal structure strongly influences degradation behaviour and potential functional performance [2,3]. In this work, the structure and morphology of poly(ϵ -caprolactone) (PCL)/propylene carbonate (PC) blends were studied by differential scanning calorimetry (DSC), simultaneous small- and wide-angle X-ray scattering (SAXS/WAXS), polarised light optical microscopy (PLOM), and scanning electron microscopy (SEM) imaging, using PCL as a model biodegradable semicrystalline polyester [4,5]. Across compositions, changes in melting and crystallization behaviour were observed, indicating that the addition of a solvent affects the crystallization of PCL and modifies the resulting structure. SEM imaging revealed the development of porous morphology, consistent with phase separation during cooling and crystallization, where polymer-rich and solvent-rich domains give rise to voids or sponge-like structure. An increase in polymer crystallinity, when normalized to the polymer fraction, was also observed with increasing PC content, suggesting that PC may enhance the ability of PCL chains to reorganize during crystallization and thus promote structural ordering within the polymer-rich phase. SAXS/WAXS measurements suggested composition-dependent changes in the scattering profile, with variations in the low- q region potentially associated with porosity development and shifts in the correlation peak position possibly reflecting lamellar reorganization [6]. The combined results suggest that the addition of PC strongly influences both the meso- and nanoscale morphology of PCL, leading to altered thermal response and the formation of heterogeneous porous structure.

Keywords:

biodegradable; porous; differential scanning calorimetry; polycaprolactone; propylene carbonate, small and wide-angle X-ray scattering.



SAXS profiles (left) and DSC heating thermograms (middle) reveal changes in nanoscale organization and melting behavior with increasing PC content. SEM imaging (right) shows the development of a porous, sponge-like structure..

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The development of self-assembled hyaluronic acid – transferrin colloidal particles for the formulation of hydrophobic vitamins

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The development of biocompatible drug delivery systems remains an important aspect of modern nanomedicine [1]. Polyelectrolyte complexes (PECs), formed through the spontaneous self-assembly of oppositely charged macromolecules, offer a versatile platform for this purpose. This research explores the development and characterization of a novel polyelectrolyte complex system, investigating the spontaneous self-assembly of oppositely charged macromolecules: the gross positively charged human apo-transferrin (Tr) protein and the negatively charged high-molecular-weight hyaluronic acid (HyA) polysaccharide. While PECs are increasingly recognized as promising candidates for controlled drug delivery, the specific interaction between Tr and HyA has remained unexplored in scientific literature until now. To provide a comprehensive understanding of this unique system, a multi-analytical investigation was carried out, with the physicochemical characterization of the PECs by dynamic light scattering, rheological measurements, ζ - and streaming potential studies. The morphology of the self-assembled particles was investigated with electron microscopy. The structural analysis of the PECs was carried out with CD- and IR-spectroscopy. Our experimental results underscore that the self-assembly mechanism is highly sensitive to the pH of the medium and the mass ratio of the components, proving that electrostatic interactions are crucial from the point of view of particle formation. We identified that a Tr/HyA mass ratio of 2:1 results in the formation of highly stable, negatively charged (ζ -potential -38 mV) colloidal particles with a well-defined diameter range of 240–260 nm at pH = 4.5. CD- and IR-spectroscopy experiments proved that the α -helix content (from 10.6% to 0.4%) of the protein decreases upon the interacting with the polysaccharide, confirming the unfolding of Tr. This unfolding process exposes the hydrophobic regions of the protein, which could enhance the encapsulation of different hydrophobic drugs. To prove this functional utility of these colloidal structures, the encapsulation of several hydrophobic drug molecules was carried out. The potential of the carrier as a drug delivery system was demonstrated with Vitamin D3 and K1, achieving encapsulation efficiency values higher than 60%. Notably, the nanoformulation increased the aqueous solubility of the vitamins almost threefold compared to the unformulated crystalline form. Dissolution studies in simulated physiological conditions showed a burst release mechanism with an almost complete release of the formulated vitamins within 30 minutes, whereas the pure drugs required 120 minutes to reach similar levels [2].

Keywords:

serum protein, polysaccharide, electrostatic interaction, encapsulation, hydrophobic vitamins

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Tailoring SIPN hydrogels: a road into targeted multiresponsive actuation

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Semi interpenetrated network (SIPN) hydrogels offer a promising pathway to overcome the mechanical weakness of conventional hydrogels while preserving their high water uptake and biocompatibility. In this work, we designed a SIPN system by combining linear chains of hydroxyethyl cellulose with a covalently cross-linked poly (acrylic acid co 2 hydroxyethyl methacrylate) network. The resulting material exhibited enhanced mechanical robustness together with high pH responsiveness, porosity and cytocompatibility. As proof of concept, we evaluated the SIPN hydrogel performance in the context of oral drug delivery, using doxycycline hyclate as a model compound. The hydrogels achieved 82% encapsulation efficiency and enabled a sustained release up to 89% of the loaded drug under conditions mimicking gastrointestinal pH. Ongoing work focuses on integrating magnetic nanoparticles to develop a multiresponsive platform capable of targeted drug delivery, while maintaining the biocompatibility of the system.

Keywords:

Hydrogel, actuator, drug delivery

Acknowledgements:

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Specific Counterion Interactions in Aqueous Polyelectrolyte Systems

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Polyelectrolytes are macromolecules with charged repeating units along with corresponding counterions that can dissociate in water. These counterions strongly influence the properties of polyelectrolyte aqueous solutions, from affecting the chain hydration to altering electrostatic interactions and transport characteristics such as ionic conductivity. Consequently, investigating the impact of different types of counterions on polyelectrolyte behaviour is essential.

In general, ions can be broadly classified into two groups based on their specific interactions with other charged moieties, as well as their affinity for water molecules [1]. Weakly hydrated ions - which interact better with ionic species and less with water molecules (e.g., SCN^-) - are referred to as Chaotropes, whereas strongly hydrated ions - which preferentially interact with water rather than ionic groups (e.g., F^-) - are classified as Kosmotropes. By incorporating these counterions with different affinities towards polyelectrolyte's ionic groups, the specific ion effect can be systematically studied by methods such as freezing point depression and ion-selective potentiometry.

Freezing point depression, as a well-established colligative property, can be a reliable tool to study the specific counterion effect of electrolyte and polyelectrolyte aqueous solutions [2]. Generally, the freezing point of water decreases upon the introduction of ions due to changes in the entropy of the solution by the ions' entropy of mixing. Polyelectrolytes on the other hand, affect freezing point depression in a more complex manner, as the presence of polymer chains introduces an additional configurational entropy contribution. In these systems, the extent of freezing point depression depends not only on ion concentration, but also on polymer characteristics and counterion chemistry [3]. These dependencies make freezing point measurements a valuable analysis for gaining insight into the specific ionic interactions in such systems.

Furthermore, electrochemical measurements can provide additional insight on the into the ion-specific behaviour of different counterions. One approach is the ion-selective potentiometry. In this method, by employing ion-selective electrodes that measure the activity a specific ion in a polyelectrolyte solution, the specific interactions between various counterions and ionic species along the polymer chains can be studied [4].

In this regard, we study the effect of various anions (such as F^- , I^- , SCN^-) on the freezing point behaviour of poly(2-(methacryloyloxy)ethyl trimethylammonium chloride) (pMETAC). Also, the ion-selective electrode potentiometry technique is implemented to further investigate the ion-ion specific interaction of tertiary ammonium groups and corresponding Chaotropic and Kosmotropic anions. To do so, the polyelectrolytes are first synthesized via the polymerization of 2-(methacryloyloxy)ethyl trimethylammonium chloride (METAC), followed by ion-exchange processes to obtain polyelectrolytes with the desired counterions.

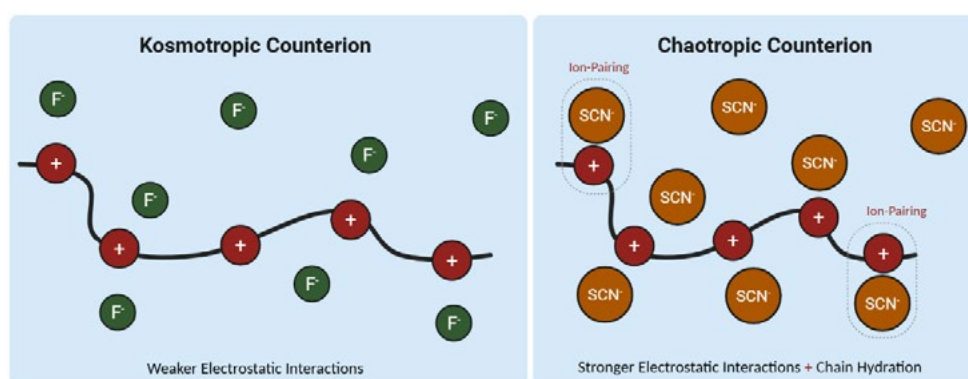


Fig.1 Different effect of kosmotropic and chaotropic counterions

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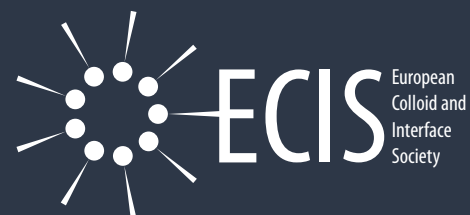
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Topic 8

Dynamics, Stability, Self-Assembly,
and Phase Behavior of Complex Fluids



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Studies on the amphiphilic block copolymer Soluplus® behaviour forming micelles to enhance drug solubility

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In the context of studying encapsulation systems using biocompatible polymers, the behaviour of Soluplus®, an amphiphilic block copolymer, has been explored. In aqueous solution, it undergoes self-assembly to form micelles, enabling the solubilization of molecules across a wide range of hydrophobicity. This is facilitated by the presence of vinyl caprolactam (a relatively hydrophilic monomer) in Soluplus's graft chain, which also enhances its interaction with more hydrophilic molecules. To better understand the micellar behaviour of this polymer, Soluplus aqueous solutions at a wide range of polymer concentrations (0.01 g/mL – 0.3 g/mL) were analysed using diffusion NMR (dNMR), small-angle X-ray scattering (SAXS), static (SLS) and dynamic light scattering (DLS), and viscosity measurements. These techniques were complemented by surface tension measurements to determine the polymer's critical micellar concentration (CMC). dNMR, SAXS, DLS, and SLS indicate that, at all tested concentrations, two forms of Soluplus micelles were detected, with hydrodynamic radii of 3 nm and 26 nm [1].

The large micelles are spherical in shape with a core-shell structure while the small objects are less ordered but, at room temperature, accounts for 60–70 %wt of the total. SLS at variable temperature (T) demonstrate that the increase in T shifts the equilibrium towards the large spherical micelles. Interestingly, the formation of large particles occurs three orders of magnitude above the CMC determined from surface tension measurements. Instead of the traditional cooperative micellization process, we propose a thermally activated isodesmic self-assembly of the small aggregates into core-shell micelles.

As next step, the aim is to investigate the application of these micelles as a drug delivery system. Preliminary results on the use of Soluplus® micelles to encapsulate the anti-cancer drug doxorubicin will be also presented.

Keywords:

diffusion-NMR, static light scattering, amphiphilic block copolymer

References:

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Multi-scale Molecular Simulations of Polymer - Ion Pair Amphiphile Complexes

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Ion pair amphiphiles (IPAs), molecular complexes of oppositely charged surfactants, can serve as cost-effective phospholipid analogs for drug delivery. While IPA vesicles exhibit tunable phase behavior, their practical application is often limited by low colloidal stability and complex co-assembly mechanisms with therapeutic payloads. In this study, we integrated coarse-grained molecular dynamics (CG-MD) simulations with refined theoretical models to systematically investigate the structural modulation and stabilization of IPA-based carriers. Our results demonstrate that the colloidal stability of IPA vesicles can be significantly enhanced through polymer incorporation. We identified that polymer charge density, chain length, and rigidity are the primary determinants of vesicle-vesicle interactions; specifically, stiffer and longer polymers promote efficient bridging effects, which can be harnessed to control vesicle fusion kinetics and morphology. Furthermore, our simulations reveal that using explicit charge models is crucial for accurately capturing the realistic self-assembly transitions from micelles to bilayers driven by molecular geometry and IPA cross-interactions. Extending our framework to biopolymer-IPA complexes, we examined the interaction mechanisms of Hyaluronic Acid (HA) and Ribonucleic Acid (RNA). We found that while HA adsorption is sensitive to specific functional group orientations, RNA binding is primarily driven by long-range electrostatic attraction and stabilized by hydrogen bonding between IPA headgroups and RNA nucleobases. Notably, steric hindrance limits the involvement of the RNA backbone in these interactions. Overall, this work provides a comprehensive design framework for engineering robust, polymer-stabilized IPA platforms capable of efficiently delivering diverse biopolymeric therapeutics.

Acknowledgements:

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Monte Carlo simulations of aggregate-structure transitions of hexagonal plate-like hematite particles in a quasi-two-dimensional system

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Monte Carlo simulations were performed for a quasi-two-dimensional dispersion of hexagonal plate-like hematite particles to investigate aggregate-structure transitions and their internal structures. The analysis was limited to a quasi-two-dimensional model in which particle centers were confined to a plane, a single magnetic moment was fixed at the particle center, and Néel relaxation was not included. A hexagonal prism model was introduced with an explicit contact test for polyhedral particles, and two in-plane magnetization models were considered by assigning the magnetic moment along either the opposite-vertex direction or the opposite-edge-midpoint direction of the hexagonal plate. Without an external magnetic field (Fig.1 (a)), strong magnetic particle-particle interactions led to the formation of column-like clusters, where particle axes were aligned and neighboring magnetic moments tended to arrange in an antiparallel manner. Under a magnetic field applied perpendicular to the plane (Fig.1 (b)), these column-like clusters collapsed and the number of isolated particles increased. For particles with the same volume and material, increasing the aspect ratio shifted the onset of the rapid increase in the order parameters to weaker interaction conditions, indicating that particles with larger aspect ratios form aggregates more easily. This trend was almost independent of the magnetization model in the examined conditions. In addition, the parameter sweep (mainly for aspect ratios of 3 or larger) was chosen within a range where equilibration was practically achievable in the present MC framework. These results suggest that, within the present model assumptions and parameter range, aggregate-structure transitions are governed mainly by the magnetic interaction strength, the applied field strength, and the particle aspect ratio, rather than by the difference between the two magnetization models.

Keywords:

Hexagonal plate-like particle, Shape anisotropy, Magnetization model, Aggregate structures, Monte Carlo simulation

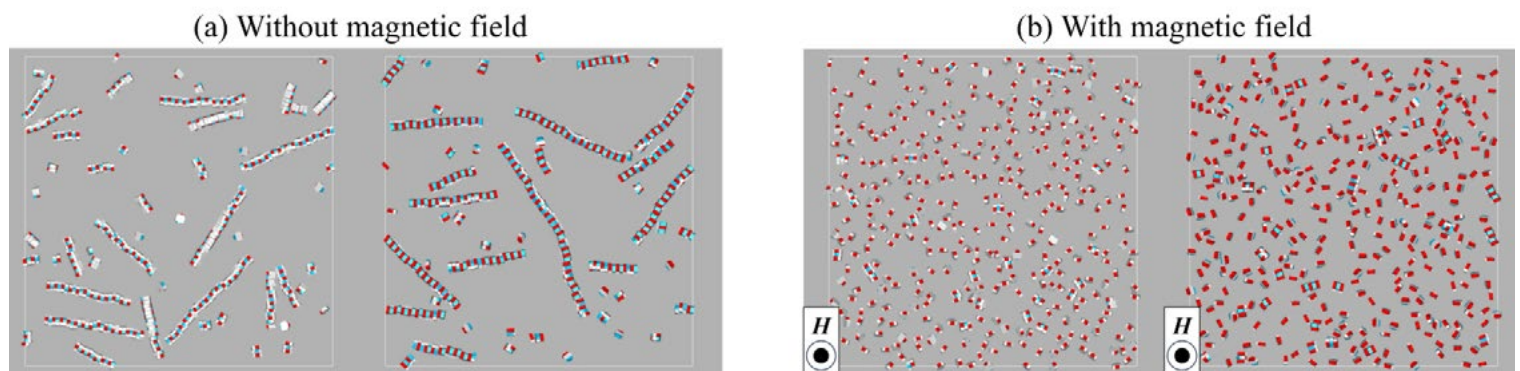


Fig.1 Aggregate-structure transitions of hexagonal plate-like hematite particles

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The authors would like to gratefully acknowledge the use of computational resources provided by the Centro de Supercomputación de Galicia (CESGA), Galicia, Spain.

Fluorination-Dependent Structural Changes in Butanols from MD Simulations and X-ray Scattering

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Fluorinated alcohols are attractive model systems for probing how fluorination, a key structural motif of environmentally persistent per- and polyfluoroalkyl substances (PFAS), reshapes intermolecular organization and dynamics in the liquid state. Here, we examine a series of fluorinated butanols to determine how the degree and pattern of fluorination influence their liquid structure and dynamics. Molecular dynamics (MD) simulations were performed using the OPLS-AA force field, while small- and wide-angle X-ray scattering (SWAXS) experiments were carried out for the investigated compounds. Theoretical scattering intensities were calculated from the simulation results using the complemented system approach for direct comparison with the experimental data [1-3]. As shown in Fig. 1, the resulting calculated SWAXS intensities are in good agreement with the experimental data, supporting the validity of the employed molecular models. Increasing fluorination leads to a shift of the main scattering peak towards lower q values, indicating an increase in characteristic correlation lengths associated with the polyfluoroalkyl segments. Partial scattering contributions show that this feature arises primarily from correlations between fluorinated hydrophobic moieties. Radial and spatial distribution functions reveal that fluorination affects the hydrogen bond network, particularly when substitution occurs near the hydroxyl group. Intramolecular conformational analysis indicates reduced molecular flexibility with increasing fluorination. The dynamic properties obtained from MD simulations reflect the combined influence of hydrogen bond strength and conformational preferences. Overall, the results reveal that fluorination reshapes liquid butanol structure and dynamics, primarily through changes in hydrophobic correlations, hydrogen-bond organization, and conformational constraints, providing insight into structure–property relationships relevant to PFAS-related systems.

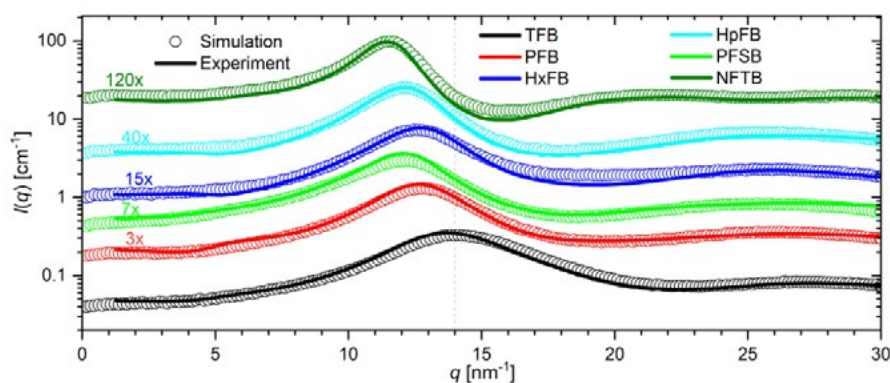


Fig.1. Experimental and calculated SWAXS curves for studied fluorinated butanols.

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Acknowledgements:

We acknowledge the support from the Slovenian Research Agency (research core funding no. P1-0201 and project no. N1-0483 “Ionic Liquids and Nanoclays in Aqueous PFAS Removal”) and from the Hungarian National Research, Development and Innovation Office (project no. SNN152145).

SYNCHRONIZATION IN MULTI-INJECTOR DROPLET GENERATION DEVICES FOR THE SCALE PRODUCTION OF EMULSIONS

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We investigate collective dynamics in a parallel droplet-generation system designed for the scalable production of monodisperse chitosan gels. These gels are used as containers for liquid diets of biological control insects in intensive agriculture [1, 2]. The device consists of a 19-injector array arranged in a honeycomb geometry, where droplets are formed by flow-driven injection and subsequently polymerized under UV light. While parallelization increases throughput, hydrodynamic interactions between injectors introduce coupling that can lead to synchronization of droplet formation, potentially affecting size uniformity and stability.

We perform time-resolved measurements of droplet creation and detachment events across the injector array and analyze the temporal correlations between injectors. We quantify pairwise synchronization using event-based metrics and construct synchronization matrices and networks. To distinguish genuine coupling from coincidental alignment due to similar dripping rates, we compare the experimental data against interval-preserving surrogate datasets. This analysis reveals statistically significant synchronization regimes that depend on the imposed flow rate.

We observe the emergence of partially synchronized clusters across the injector array, indicating hydrodynamic coupling mediated by shared flow and pressure fluctuations. These results show that multi-injector droplet generators behave as systems of coupled oscillators, where collective dynamics can be tuned through control parameters such as flow rate and geometry.

Our findings provide insight into collective effects in microfluidic soft matter systems and offer guidelines for the design of scalable droplet-based fabrication devices.

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Modelling steric finite size effects in the electric double layer of electrolytes and ionic liquids at electrode surfaces

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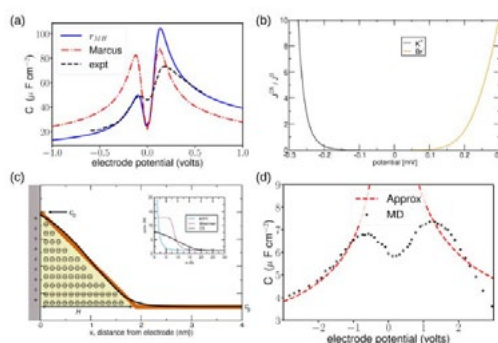
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DLVO theory was constructed to describe interactions between charged surfaces with relatively low surface potentials, 5-50 mV, or 0.2-2 kT in thermal energy. But electrochemical systems typically involve potentials 0.3-3V, or 10-100 kT. At such potentials it is indispensable to include steric forces due to finite ion size in theoretical models [1]. In modified Poisson-Boltzmann modelling steric effects introduce a concentration cap to counterion adsorption profiles, the effect of which is to introduce a maximum in the electrode capacitance as electrode potential increases [2], see Figure 1a. The steric effect starts to dominate when the electrode potential reaches 200 mV relative to bulk solution. The same is true in nonequilibrium systems where electric current is flowing: Poisson-Nernst-Planck (drift-diffusion) models must be modified to include the steric force, and the corresponding steric flux exceeds the diffusion flux (both arising from concentration gradients, distinct from drift current due to the electric field) when the potential exceeds 0.2V, see Figure 1b.

In conventional low-potential conditions the counterion adsorption profile (electric double layer) follows an exponential profile. Curiously, under steric conditions above 200 mV, we observe an approximately linear profile, Figure 1c, when applying the well-regarded Carnahan-Starling model of the steric force. The steric concentration cap is not reached until much higher potentials above 4V. The approximation of a linear profile enables construction of a semianalytical model [3], which might be used in place of the Grahame equation to relate surface potential to surface charge. Combined with a Clausius-Mossotti description of the permittivity of the electric double layer, this approximation may be successfully applied to both aqueous electrolytes, Fig.1b, and ionic liquids Fig.1d, the region of validity being the steric regime above 200 mV. The theory will be useful for understanding electrocatalysis in ionic liquids, and improving electrodes for energy storage or electroosmosis.

Keywords:

electrochemical surface, steric force, finite ion size, electrolyte theory



(a) Capacitance of Ag in 0.1M NaF, exp (black), semianal. approximation, various ion radii (red, blue) (b) Ratio of steric to diffusion flux at various potentials. (c) Linear counterion steric concentration profile. (d) Capacitance in EMIM-TFSI ionic liquid, MD (black) and semianal. approx (red).

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Thermal stabilization of enzymes in lipidic mesophases governed by phase structure and transitions

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Lipidic mesophases (LMPs) provide nanoconfined environments with tunable structure and dynamics, offering a promising platform for controlling biomolecular stability. [1-3] While their structural versatility is well established, the relationship between mesophase architecture and enzyme stability at elevated temperatures remains insufficiently understood.

Here, we employ Dimodan-based LMP as a model system and investigate its structural stability and impact on enzyme denaturation. Small-angle X-ray scattering (SAXS) confirms that these mesophases maintain well-defined internal structures over a broad temperature range. Upon incorporation of enzymes into the LMP, we observe a significant increase in denaturation temperature compared to bulk buffer conditions.

Further analysis reveals that enzyme stability is strongly coupled to the mesophase structure and its phase transitions. In particular, the highly viscous bicontinuous cubic phase (Ia3d) enhances enzyme thermal stability, whereas transition to the more fluid hexagonal phase leads to rapid unfolding. Differential scanning calorimetry (DSC) demonstrates that enzyme denaturation coincides with these structural transitions. In addition, aggregation processes commonly observed in bulk aqueous systems are effectively suppressed within the LMP environment.

These findings suggest that LMPs stabilize enzymes through mechanical confinement. Our results highlight the critical role of mesophase symmetry and viscosity in regulating enzyme stability and provide a general strategy for designing soft nanoconfined systems for high temperature biocatalysis.

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We also thank Prof. Florian Seebeck for granting us access to the UV-Vis spectrometer, and Dr. Thomas Weber for his assistance with the SAXS measurements.

Kinetic control of a nucleophilic reaction in reverse wormlike micelles by modulating alkane chain length

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Reverse wormlike micelles (RWMs) are soft confinement model systems that act as anisotropic nanoreactors, providing a versatile platform to investigate how confinement influences the efficiency of chemical reactions in aqueous media [1]. Among these, nucleophilic addition reactions remain largely unexplored despite their relevance to a wide range of chemical and biological processes, including enzyme-catalyzed hydrolysis [2]. As a proof of concept, this work investigates the influence of the structure of RWMs composed of lecithin, water, and different linear alkanes (octane, C8; nonane, C9; decane, C10; and undecane, C11), at a fixed water-to-surfactant molar ratio (W_0), on the kinetics of the nucleophilic addition of hydroxide ions to crystal violet. The nanoreactor structure was characterized by rheology and small-angle X-ray scattering (SAXS), while the reaction kinetics were monitored *in situ* by UV-Vis spectroscopy during ammonia gas permeation.

The results demonstrate that the reaction proceeds significantly faster in RWMs than in bulk aqueous solution [3], highlighting the role of confinement in enhancing the reaction rate. Rheological and SAXS analyses showed that the reaction does not compromise the structural integrity of the RWMs, although systems with narrower aqueous channels (ACs) exhibit greater changes in their viscoelastic response (Figure 1A). Kinetic measurements revealed that increasing the alkane chain length progressively decreases the reaction rate, following the order $C8 > C9 > C10 > C11$ (Figure 1B). This behavior reflects the combined effects of ammonia diffusion through the continuous alkane phase and the degree of confinement imposed by the nanoreactors. Overall, these findings demonstrate that the structure of RWMs [4] can be tailored to modulate nucleophilic reactions under confined conditions, providing new insights into the rational design of self-assembled nanoreactors for confined chemical processes.

Keywords:

Anisotropic nanoreactors, Reverse wormlike micelles, Soft confinement, Nucleophilic reaction

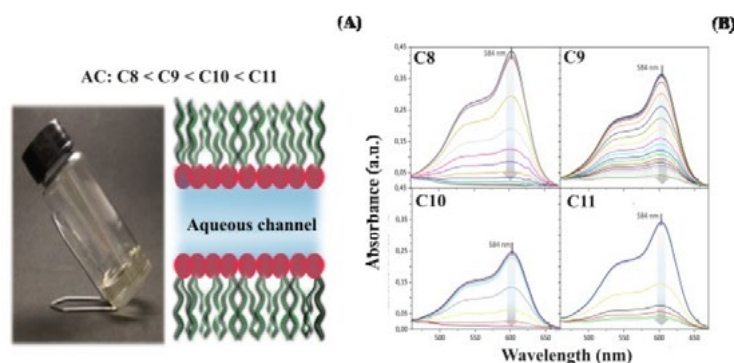


Figure 1. (A) Schematic representation of the aqueous channel (AC) in reverse wormlike micelles (RWLMs), illustrating the order of the aqueous channel diameter ($C8 < C9 < C10 < C11$). (B) Crystal violet reaction kinetics monitored by UV-Vis spectroscopy for the four alkanes over 290 min.

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Influence of viscoelasticity-induced sheet formation on shear thickening of concentrated suspensions

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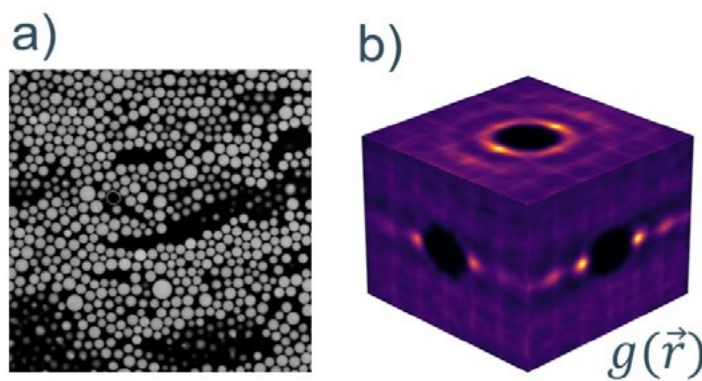
Semi-dilute polymer solutions exhibit viscoelastic properties such as shear thinning and normal stress differences under shear flow. These viscoelastic stresses can assemble suspended particles into string-like and, at higher concentrations, sheet-like structures in dilute and semi-dilute suspensions [1]. The resulting structures can be tuned by the applied flow protocol [2]. Here, we investigate whether these viscoelastic forces can be used to control the rheology and microstructure of concentrated particle suspensions. Concentrated suspensions in Newtonian media typically exhibit shear thickening due to hydrocluster formation and frictional contacts, a problematic property that can lead to clogging in industrial processes. By dispersing particles in a viscoelastic medium instead, we aim to harness viscoelastic structuring effects to modify this shear thickening behavior.

We disperse silica particles in glycerol-based viscoelastic polymer solutions to create refractive-index-matched viscoelastic model suspensions with varying degrees of elasticity. Rheological measurements show that the shear thickening behavior differs significantly from suspensions in Newtonian media. To identify the microstructural origin of this rheological change, we use 3D confocal microscopy with a mounted shear cell. This setup allows direct visualization across the full gap height and, using computer vision, enables quantification of the suspension microstructure after shear. This approach allows comparison with previous experiments in Newtonian media [3].

In viscoelastic media, particles organize into sheet-like structures aligned with the flow direction, in contrast to the structures observed in Newtonian suspensions. These sheet-like structures reduce particle collisions and hinder hydrocluster formation, which explains the observed changes in shear thickening. Our results show that viscoelastic stresses provide a route to control microstructure and flow behavior in concentrated suspensions.

Keywords:

Suspension Rheology, Viscoelasticity, Shear Thickening, Computer Vision, Self Assembly



a) Confocal microscopy image of particles ($d = 7$ micron) that have organized into sheets in a viscoelastic liquid after subjected to shear flow b) The 3D-pair correlation function $g(\vec{r})$ demonstrates the anisotropy

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Quantitative description of the surface tension minimum in a two-component surfactant system

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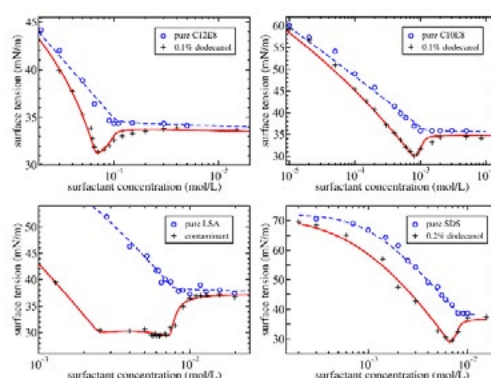
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The Gibbs adsorption equation is the thermodynamic cornerstone for the description and understanding of the surface tension in a surfactant solution. It relates the decrease in surface tension to an increased surfactant adsorption. In the early 1940's, it therefore puzzled researchers to sometimes observe a *minimum* in the surface tension for certain surfactant solutions, which seemed to indicate surfactant desorption (even depletion) according to the Gibbs adsorption equation. It is now understood that the minimum is related to contamination of the surfactant (notably by dodecanol) and its occurrence has since then been studied extensively in experiments [1-3]. Still, the precise role of the (tiny amount of) contaminant present is not well understood and a quantitative description and understanding of the minimum in the experimental surface tension is lacking. It is our aim to provide such a quantitative description. Our theoretical analysis is based on a Statistical Thermodynamic treatment of the Langmuir model for a surfactant mixture combined with the mass action model adapted to describe the formation of mixed micelles [4]. A new Statistical Thermodynamic expression for the surface tension is derived and used to compare with a number of surface tension experiments for both ionic and non-ionic surfactant systems [4].

Keywords:

Surfactant, Surface Tension, Langmuir model, Mass Action model, Micelle Formation, Surfactant Mixture



Surface tension as a function of surfactant concentration for a (contaminated) solution of (a) C12E8, (b) C10E8, (c) LSA, (d) SDS. Open symbols are experimental results by Lin et al. [1], McBain and Vinograd [2] and Elworthy and Mysels [3]. The solid lines are the theoretical results [4].

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Toward the True Shape of Supramolecular Structures by Contactless Drying

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Understanding the intrinsic structure of supramolecular aggregates during drying remains challenging, as conventional approaches often introduce external constraints that distort the final morphology. Sessile droplets are affected by substrate interactions such as contact line pinning and capillary flows, while pendant droplets, although substrate-free, still experience asymmetric boundary conditions and gravity-induced distortions. As a result, the observed structures frequently reflect method-specific artifacts rather than the true aggregate morphology. To overcome these limitations, acoustic levitation provides a contactless drying environment, minimizing substrate-induced effects and enabling a more symmetric evaporation process. However, strong acoustic streaming and enhanced convective transport can significantly alter evaporation kinetics, potentially influencing structure formation. A critical assessment of these competing effects is therefore required.

We compare sessile, pendant, and acoustically levitated droplets using aqueous silica nanoparticle suspensions (Aerosil 90 and Aerosil 300, differing in specific surface area and resulting aggregate morphology) as model systems. Evaporation kinetics were evaluated within a Maxwell-type framework. This approach assumes the steady evaporation of a droplet as the evaporation rate is governed solely by vapor diffusion in the surrounding gas.

While the initial evaporation phase can be described by this approach for the three methods during the late phase of drying, clear, method-dependent differences in the aggregation of the particles were observed. Sessile droplets exhibit pronounced substrate-induced inhomogeneities and often characteristic ring-like deposits, whereas pendant droplets, although substrate-free, remain influenced by gravity and the presence of a supporting capillary, leading to deviations from spherical symmetry. In contrast, acoustic levitation enables drying in a contactless and geometrically unconstrained environment, allowing for a more intrinsic evolution of aggregate structures.

Furthermore, particle-specific morphologies are resolved under levitated conditions. Aerosil 90 forms collapsed, shell-like structures, whereas Aerosil 300 yields more compact and spherical aggregates. This indicates that, in the absence of substrate interactions, the final morphology is governed primarily by particle properties rather than external constraints.

Overall, these results indicate that acoustic levitation provides improved access to the intrinsic shape of supramolecular aggregates. At the same time, it offers a controlled environment in which transport-induced effects can be assessed without the superposition of substrate induced effects inherent to sessile or pendant geometries.

Keywords:

Drying, Droplets, acoustic levitation, silica particle

Worms, droplets, and vesicles: manipulating self-assembly pathways of betaine surfactants with additives

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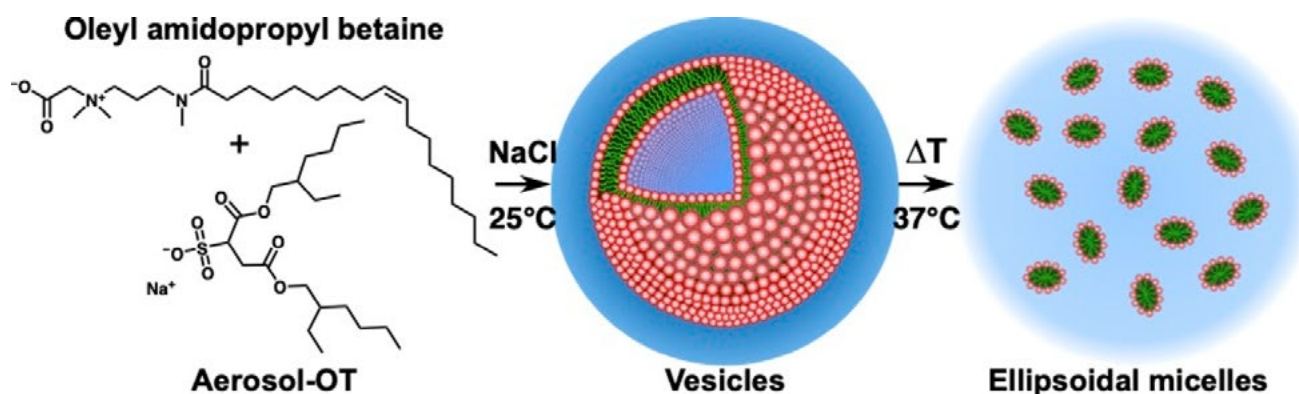
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Zwitterionic betaine surfactants are found to exhibit highly tunable self-assembly behaviour, offering a versatile platform for controlling structure and function in complex fluids. Here, we showcase how simple additives - varying from small organic molecules to salts and co-surfactants - alter self-assembly pathways in aqueous oleyl amidopropyl betaine systems. Resultant structures vary from wormlike micelles, to microemulsions, vesicles and more. Small-angle neutron scattering, including contrast variation with selective deuteration, is used extensively to resolve structural evolution and additive partitioning across length scales, and uncover the key interactions in play.

Keywords:

Surfactants, self-assembly control, additives, small-angle neutron scattering.



Schematic of the aqueous vesicle assembly of two well-known surfactants, and their thermal response at physiological temperature.

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Effect of pH on hydration-driven phase transitions in lipids.

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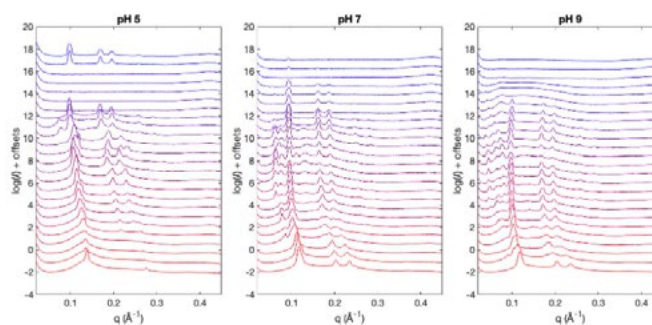
The role of pH is important to the effective design of drug delivery systems, particularly in biological environments where local pH gradients can strongly influence material behaviour. This is especially relevant for lipid-based formulations, where phospholipids are widely used due to their biocompatibility and although generally considered zwitterionic and insensitive to pH, may still exhibit pH-dependent effects. Previous works support this, demonstrating that hydration can drive lipid redistribution and the formation of different structural layers in lipid depots [1], as well as pH-dependent structural changes in lipid nanocarriers [2]. Here, we extend this concept to investigate how pH further affects hydration-driven lipid phase changes and transport processes.

In this study, small-angle X-ray scattering (SAXS) was used to probe hydration-driven structural transitions with spatial and temporal resolution. A capillary-based setup, in which lipids were at the bottom with excess buffers on top, created a hydration gradient, enabling spatially resolved measurements from the aqueous phase across the interface and into the lipid bulk, while measurements at defined hydration times captured the evolution of phase behaviour.

Our results show pH-dependent differences in hydration behaviour and structural reorganization across the lipid systems, characterized by the emergence and coexistence of multiple liquid crystalline phases, including hexagonal, several cubic, and intermediate structures. These observations highlight a complex, spatially heterogeneous phase behaviour that evolves over timescales of days and weeks along with hydration gradients. Together, these findings highlight the need to account for pH-dependent effects in phase distribution, lipid rearrangement, and transport processes in lipid-based delivery systems.

Keywords:

lipid phase behaviour, water diffusion, pH effect, hydration gradient, SAXS



SAXS profiles of SPC/Span80 50/50 weight ratio at different pH (5,7,9) after 1 week of hydration.

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Evaluation of emulsion stability prepared by the required HLB method under quasi micro gravity created by Clinostat

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Since Griffin proposed the HLB theory in 1949, the HLB number has been widely used in industry as an indicator of the surfactant properties. When a surfactant emulsifies an oil and water, its HLB number not only determine the type of emulsions but also influence on the stability of the emulsion. The appropriate HLB number of the surfactant should be tuned considering the properties of the emulsified oil which are commonly expressed as “required HLB number (rHLB)”. Fine emulsions are formed when the surfactant passes through a phase state of higher interfacial activity in the emulsification process. In other words, the phase behaviour in the surfactant system can be roughly predicted from the HLB and rHLB numbers.

In this study, we have investigated the stability of O/W emulsions in surfactants/oil/water systems with different HLB and rHLB numbers, particularly utilizing the microgravity condition. Our previous results demonstrated that quasi-microgravity remarkably suppressed creaming as well as Ostwald ripening, so it can be expected that the microgravity experiments would reveal the significance of the surfactant HLB number.

The O/W emulsions were prepared in the POE sorbitan stearate (HLB14.9)/glyceryl stearate (HLB4.0)/liquid paraffine/water system. The weight fractions of the mixed surfactants and oil in the system were fixed at 0.04 and 0.40, respectively. The appearances and droplet sizes between these emulsions were apparently same just after emulsification, but phase separation and droplet growth depended on the surfactant HLB number. The droplet growth with time was observed even for the emulsion with the HLB number matched to rHLB (~10) in terrestrial gravity (1G), while the droplet size remained constant in micro-gravity (0.03G, Figure), suggesting that the surfactants inhibited coalescence and/or coagulation. In our presentation, the emulsion stability under different HLB conditions will be shown and discussed based on interfacial properties.

In this study, we include additional factors of PIT by changing the temperature at which we can expect phase changes. Our objective is to explore the effect of microgravity with temperature changes to predict emulsion stability.

Keywords:

Emulsion stability, HLB number, Quasi-microgravity

Non-equilibrium (thermo)dynamics of colloids under mobile piston compression

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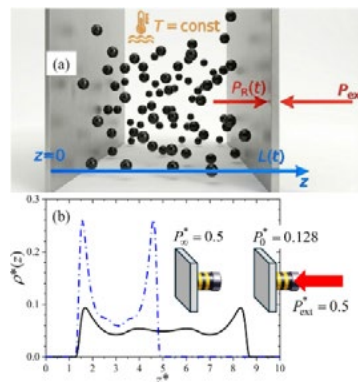
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We investigate the non-equilibrium compression of a confined colloidal fluid driven by a mobile boundary within dynamical density functional theory [1]. The system consist of a hard-sphere fluid confined between two parallel walls, one of which acts as an overdamped piston subjected to a sudden increase in external pressure. The piston motion is characterized by a mobility parameter K . By varying K over several orders of magnitude, we identify a crossover from quasi-static compression to a diffusion-limited strongly driven regime. For small K , the system evolves through near-equilibrium states and the total injected work attains its minimal value, equal to the equilibrium free-energy difference. In contrast, for large K , the piston rapidly adjusts and the dynamics becomes controlled by the intrinsic diffusive relaxation of the confined colloidal fluid, leading to universal saturation behavior of the piston trajectory, pressure-position relation, particle currents, and center-of-mass velocity. In this regime, the total injected work and entropy production are bounded, reflecting fundamental constraints imposed by diffusive transport. We find that the maximum injected power scales linearly with K , while the entropy-production peak exhibits a crossover from quadratic growth to saturation. The corresponding peak times display distinct $1/K$ asymptotic regimes separated by an intermediate crossover. The entropy change of the thermal bath is computed explicitly and shown to interpolate between the reversible limit, where it exactly compensates the configurational entropy loss of the fluid, and a strongly driven regime dominated by irreversible dissipation. Finally, the time evolution of the configurational entropy and the external potential energy reveals a dynamical decoupling between geometric confinement and structural relaxation, including transient non-monotonic behavior in the high-mobility regime. These results provide a quantitative thermodynamic characterization of boundary-driven compression and uncover generic non-equilibrium features governed by a single mobility parameter.

Keywords:

non-equilibrium thermodynamics, hard spheres, entropy production, dynamical density functional theory, overdamped piston



Schematic illustration of a hard-sphere fluid confined between two parallel walls. The right boundary is an overdamped mobile piston subjected to an externally imposed pressure

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Structural Interplay in Block Copolymer-Bile Salt Complexes: From Globules to Ribbons

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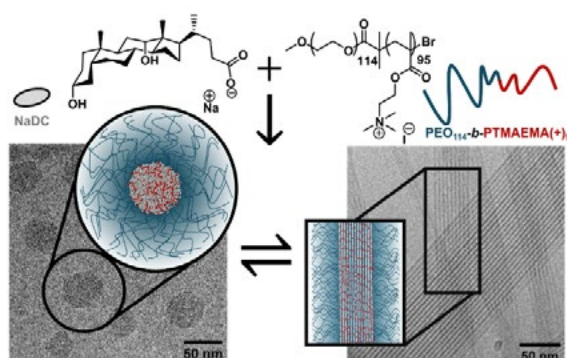
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The supramolecular structures resulting from the complexation between the neutral–cationic block copolymer poly(ethylene oxide) –*block*– poly(2-(trimethylammonium)ethyl methacrylate iodide) (PEO114 –*b*– PTMAEMAI95) and the bile salt sodium deoxycholate (NaDC) were investigated by dynamic light scattering, small-angle X-ray scattering, cryogenic transmission electron microscopy and proton NMR techniques.[1] Complexes were produced using different preparation protocols: the direct mixing of the pure solutions of block copolymer and bile salt, containing their respective simple counterions, and the dispersion in water of a freeze-dried complex salt, free of simple counterions. While the direct mixing protocol produced a mixture of ordered ribbon-like aggregates and globular particles with disordered cores, the complex salt protocol yielded exclusively ordered “ribbons”. The globular particles resembled classical spherical “complex coacervate core micelles” with a core of anionic deoxycholate micelles complexed with cationic PTMAEMA(+) blocks, the core radius being limited by the PTMAEMA contour length, and a shell composed of neutral PEO blocks. The drastically different ribbon morphology was found to result from (1) the organization of DC anions into hexagonally packed helices in the core and (2) the limitations on the ribbon thickness imposed by the lengths of the copolymer blocks. By varying temperature and sample treatments, it was found that the ordered ribbon morphology represents the equilibrium structure at 25 °C, while the globular morphology is favored at 50 °C. The results suggest strategies to design the morphology and tune the dimensions of aqueous block copolymer–bile salt aggregates.



Supramolecular structures controlled by the delicate balance between the bile salt self-assembly and the geometric characteristics of the block copolymer.

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Buffer-Dependent Self-Assembly and Multiscale Structure of POPC Vesicles Revealed by SAXS and WAXS

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Lamellarity and structure of lipid vesicles arise from an interplay between interfacial forces and preparation conditions. Here, the influence of buffer system (Tris, sodium phosphate, HEPES), concentration (10–100 mM), and extrusion pore size (30 and 50 nm) on POPC vesicle self-assembly is investigated.

Small-angle X-ray scattering (SAXS) reveals pronounced differences in lamellarity. Vesicles in sodium phosphate buffer show coexistence of uni- and multilamellar populations, consistent with the competition between hydration repulsion and attractive interbilayer forces controlling bilayer stacking [1,2]. In contrast, low-concentration Tris yields predominantly unilamellar vesicles, whereas HEPES promotes multilamellar structures, suggesting specific buffer–membrane interactions. Membrane thickness decreases from ~38 Å to ~34 Å with increasing concentration, consistent with electrostatic screening and changes in headgroup orientation [1–3].

Dynamic light scattering (DLS) shows that vesicle size depends strongly on buffer conditions for 50 nm extrusion, while this dependence is reduced for 30 nm pores, highlighting the interplay between chemical environment and geometric confinement. This agrees with established extrusion methods [4,5] and recent findings that incomplete bilayer separation can preserve multilamellar structures [6]. Cryo-TEM confirms the SAXS results, showing mixed lamellarity in sodium phosphate buffer and predominantly unilamellar vesicles in low-concentration Tris. Wide-angle X-ray scattering (WAXS) probes lipid packing and headgroup organization, linking molecular structure to vesicle morphology.

Overall, buffer composition and extrusion conditions determine vesicle self-assembly across length scales and provide a framework for preparing biomimetic membranes with a high fraction of unilamellar vesicles.

Keywords:

lipid vesicles, self-assembly, lamellarity, SAXS, bilayer structure, buffer effects.

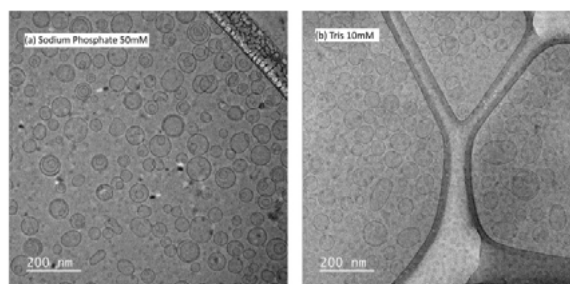


Figure 1: Cryo-TEM micrographs of POPC vesicles extruded through 50 nm membranes. (a) Sodium phosphate buffer (50 mM) showing coexistence of unilamellar and multilamellar vesicles. (b) Tris buffer (10 mM) showing predominantly unilamellar vesicles.

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Structure of Nanoions in Water-Alcohol Mixtures: Partial Structure Factors and SAXS Predictions

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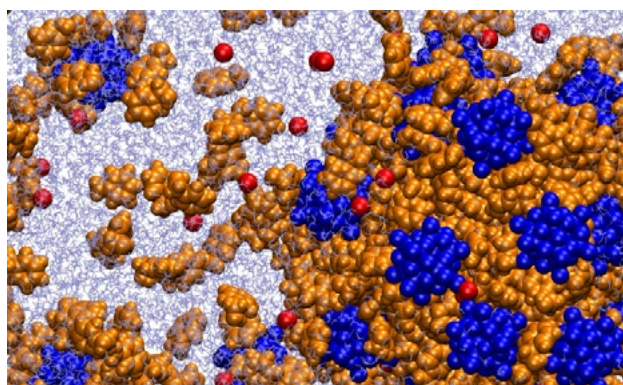
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Understanding the structural organization of ionic polyoxometallates (POMs) in water-alcohol mixtures remains challenging. Experimentally it is difficult to access and resolve the molecular-level correlations that give rise to complex solution structures. This difficulty is compounded by the intrinsic structural complexity of a water-alcohol mixtures themselves, within which the nanoscale organization of POMs occurs. Moreover, the thermodynamic origin of the superchaotropic[1] behavior exhibited by these nanoions is still not fully understood at the molecular level.

To address these issues, we perform all-atom molecular dynamics simulations of keggin ions ($\text{Na}_3[\text{PW}_{12}\text{O}_{40}]$) in water and benzyl alcohol. We analyze the resulting colloidal structures in real space, as illustrated in the figure below. In addition, we compute partial structure factors from the simulations to probe the molecular-level organization of these ionic solutions. These structure factors enable the prediction of small angle X-ray scattering (SAXS) spectra, thereby providing a direct link to experimental observables. This approach not only yields quantitative scattering predictions but also offers detailed insight into the underlying molecular structures governing these complex systems.

Keywords:

Polyoxometalates, Keggin ions, Superchaotropy, Water-Alcohol Mixtures, Molecular Dynamics Simulation, Scattering, Colloids



Solution of keggin ions and sodium ions in water and benzyl alcohol. Blue: $[\text{PW}_{12}\text{O}_{40}]^{3-}$, Red: Na^+ , Orange: Benzyl Alcohol, Purple lines: Water.

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Bulk and Interfacial Self-Assembly of Surfactants in Deep Eutectic Solvents

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Deep eutectic solvents (DES) are biocompatible molecular mixtures similar to ionic liquids with unique properties, including stabilisation of biomolecules, tunable viscosity and nanostructural organisation. DES are formed by hydrogen bonding between hydrogen bond donor and acceptor components, offer promising alternatives to volatile organic solvents in pharmaceutical and cosmetic formulations.^{1,2} Understanding surfactant behaviour in these complex fluids is key to advancing their application.^{3,4} This study investigates the bulk and interfacial self-assembly of two anionic surfactants – sodium lauroyl sarcosinate (SLS) and cocamidopropyl betaine (CAPB) in two DES systems – 1:2 choline chloride:glycerol (ChCl:Gly) and 1:1:1 choline chloride:glycerol:urea (ChCl:Gly:U). We present recent results from neutron reflectometry (NR) on INTER at ISIS, and small-angle neutron scattering (SANS) on LARMOR at ISIS, investigating the bulk and interfacial self-assembly of SLS and CAPB across a range of concentrations (below, at, or above the critical micelle concentration (CMC)). The surface tension was determined using hanging drop tensiometry to determine the CMC. These results provide insight into the molecular drivers of surfactant assembly in DES and highlight differences in the interfacial architecture and efficiency of structurally distinct surfactants. This study lays the groundwork for rational design of DES-based emulsions and delivery systems where interfacial control is critical.

Keywords:

Deep eutectic solvents, surfactants, self-assembly, neutron scattering, interfacial adsorption

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Assembly of tubes in the stretching-dominated limit

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The self-assembly of tubular structures is a fundamental process in both biological systems and nanotechnology, necessitating theoretical models to understand and control its outcomes. In this study, we investigate tubule assembly using Classical Nucleation Theory (CNT) and an elastic model within the stretching-dominated regime [1]. We identify the conditions under which tubules form from free subunits in solution and explore the potential formation pathways. Our analysis reveals that two dimensionless parameters govern the assembly and polymorphism of tubules: the Föppl-von Karman number, which quantifies the balance between stress and bending, and a parameter which measures the relative importance of bending versus line tension. Tubule formation initiates with the spontaneous emergence of a curved square patch, followed by two distinct mechanisms: (i) curvature fluctuations, dominant in systems with high line tension, and (ii) aspect-ratio fluctuations, prevalent in systems with high bending modulus. Using non-equilibrium thermodynamics, we characterize the kinetics of tubule formation and determine the conditions influencing the final radii distribution of the assembled tubules, which may deviate from thermodynamic equilibrium. This work provides a framework for optimizing tubule assembly efficiency and controlling their structural properties, offering insights for applications in nanotechnology and materials science.

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Self-Assembled Vesicles of Emissive Surfactants in Water: Structural Characterization and Photophysical Insights

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Controlling the emission color of organic compounds is an important strategy for applications such as OLEDs. Intermolecular orientation plays a crucial role in determining the emission properties. In the crystalline state, emissive behavior is governed by intermolecular interactions, mainly originating from π -electron interactions of chromophores; consequently, molecular orientations are restricted to the most stable configurations, resulting in limited structural diversity.

In contrast, molecular assemblies in aqueous media can exhibit diverse supramolecular structures arising from complex intermolecular interactions. Hydrophobic interactions play a central role in the self-assembly of amphiphiles into micelles and vesicles, driven by the entropic stabilization of water molecules. Therefore, self-assembly in aqueous solutions is expected to produce molecular orientations and emission behaviors that are not accessible in the crystalline state[1].

In this study, we synthesized new emissive amphiphiles bearing an aminostilbazolium skeleton and two hydrophobic alkyl chains. Aminostilbazolium derivatives exhibit distinct emission color changes depending on their local environment due to their charge-transfer character, suggesting the possibility of substantial color tuning through control of molecular orientation.

These molecules formed vesicle-like structures in aqueous solution (TEM image shown in Figure 1). The particle size and bilayer structure were characterized by DLS and SAXS. Considering the electrostatic interactions between neighboring molecules, bilayer structures are not typically formed by conventional dyes under crystalline conditions. Finally, distinct emission behaviors were observed in highly diluted solution, vesicular assemblies, and the neat state.

Keywords:

self-assembly, vesicle, SAXS, Fluorescence

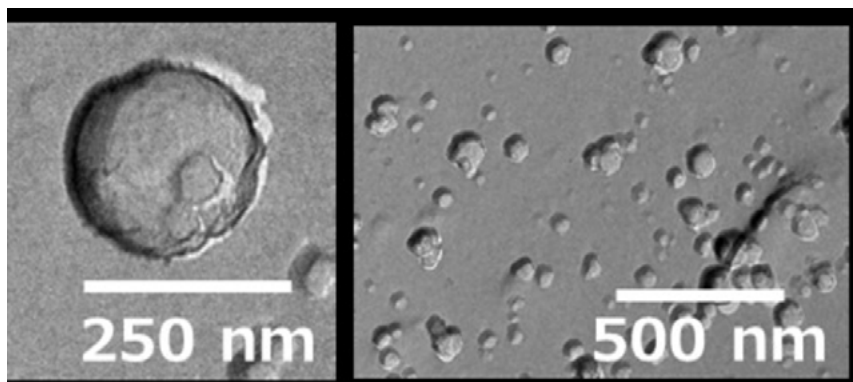


Figure 1. TEM images for self-assembly of the amphiphilic Aminostilbazolium derivatives.

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Composition-Independent Prediction of Self-Assembled Structures in Multicomponent Systems Using Machine Learning

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Predicting self-assembled structures from molecular structures is a central challenge in the design of functional soft materials, especially in multicomponent systems, where nonlinear mixing effects make rational design difficult. In this study, we developed a machine-learning framework to predict self-assembled structures in multicomponent surfactant systems directly from molecular information.

To generate training data, dissipative particle dynamics (DPD) simulations were performed using amphiphilic molecular models, and surfactant systems containing one to five components were constructed. The critical packing parameter (CPP)[1] was used as a descriptor of the resulting self-assembled structures because it showed a clear correspondence with the observed morphologies.

Several model architectures were compared to identify a suitable approach for multicomponent prediction. When the training and test data contained the same number of components, models that treated each component separately showed higher accuracy than those that handled all components together. Among them, graph-based models, which represent molecules as networks of atoms and bonds, performed particularly well, indicating that such representations are effective for capturing structural features relevant to self-assembly.

We then evaluated generalization across different numbers of components. Models trained on one- to four-component systems were successfully extended to five-component systems. Among the tested approaches, models that use graph-based learning both to extract structural features of each molecule and to explicitly represent interactions between components showed the strongest generalization ability. These models maintained high accuracy for five-component systems even when they contained molecular species not included in the training data, and achieved an R^2 of approximately 0.8 even when trained only on two-component systems. These results suggest that interaction patterns learned from simple mixtures can be transferred to more complex multicomponent systems.

Overall, this study demonstrates that machine learning combined with coarse-grained simulation enables accurate prediction of self-assembled structures in multicomponent systems with substantial generalization across composition space. The proposed framework provides a promising strategy for the data-efficient design of complex soft materials.

Keywords:

Machine learning, Self-assembly, Molecular simulation, Multicomponent systems

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Preparation of colloidal clusters via controlled hydrothermal carbonisation of polystyrene particles

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The controlled assembly of colloidal particles into finite clusters with well-defined geometries remains a key challenge in the design of hierarchical materials. In this work, we introduce a scalable strategy for generating dense clusters of cross-linked polystyrene nanoparticles via microwave-assisted hydrothermal carbonization (HTC) with glucose as the carbon precursor.

The approach exploits the dynamic interplay between carbon shell formation and particle destabilization during HTC. We show that the formation of acidic by-products leads to a decrease in pH and a concomitant increase in solution conductivity, progressively screening electrostatic repulsion and promoting particle aggregation. By systematically varying reaction parameters—including temperature, duration, initial pH, particle concentration, and stirring—we identify the key factors governing both carbon-coating kinetics and cluster-formation pathways.

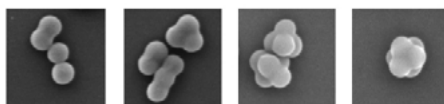
Statistical modeling reveals that temperature, reaction time, and particle concentration strongly influence final conductivity and pH, which in turn control particle stability and aggregation regimes. The transition from diffusion-limited to reaction-limited aggregation enables tuning between open aggregates and compact, close-packed clusters, including dimers, trimers, and higher-order structures. Importantly, cross-linked particles prevent reshaping, allowing direct observation of cluster configurations formed during assembly.

We demonstrate that clustering can be finely controlled by balancing destabilization and surface re-stabilization induced by carbon deposition. Conditions such as moderate initial pH (~ 6.3) and controlled stirring favor the formation of monodisperse, discrete clusters, while higher temperatures, longer durations, and reduced stirring promote larger aggregates.

This work establishes hydrothermal carbonization as a versatile route to engineer colloidal clusters from simple isotropic building blocks, providing a tunable platform for fabricating colloidal “molecules” with potential applications in materials science and nanotechnology.

Keywords:

Self-assembly, clusters, carbonization, polystyrene colloids



SEM images of clusters prepared by hydrothermal carbonization of polystyrene particles

MODELING ADSORPTION ON BIOMIMETIC SURFACES FOR THE DEVELOPMENT OF ENVIRONMENTALLY FRIENDLY POLYMER COATINGS

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Adsorption of polymers on heterogeneous, biologically inspired surfaces is a multiscale problem that links molecular design with macroscopic function. We developed a computational framework based on coarse-grained molecular dynamics to study how polymer architecture, chain length, and concentration controlled the formation and stability of polymer coatings on complex substrates. The model substrate was a digital replica of the fatty F-layer that protects human hair, obtained from high-resolution microscopy data[1]. Two representative polymers were examined: a linear flexible chain that illustrates emerging bio-based candidates for cosmetic applications, and a stiff comb-like cationic polyelectrolyte typical of current high-performance films. Equilibrium simulations showed that increasing bulk concentration always enhanced adsorption, yet architectural differences strongly affected film morphology. The branched polyelectrolyte built thicker and more uniform layers, whereas the linear polymer reproduced the surface heterogeneity of the substrate. A slab-wise density analysis quantified this partial coverage and highlighted regions where the film was locally depleted or enriched. To probe mechanical resistance, we subjected the adsorbed layers to linear shear flow. Tracking the fraction of adsorbed chains in time revealed that even weak shear induced partial desorption, while strong shear accelerated this process. For both polymer types, longer chains conferred greater resistance, but the comb-like architecture remained more stable overall[2].

We then extended the study to interfacial friction. Symmetrical substrates, each coated with identical polymer films taken from the adsorption runs, were compressed to selected separations and then slid past one another. By varying polymer architecture, chain length, inter-layer distance, and sliding velocity, we aimed to map the kinetic friction coefficient and relate it to film morphology.

The methodology introduced here provides transferable tools for exploring adsorption-desorption and friction phenomena in polymer systems, offering quantitative guidelines for designing sustainable coatings that operate reliably under realistic conditions.

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Acknowledgements:

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The Role of Precipitation Environment on Asphaltene Physicochemical Properties

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Asphaltene precipitation poses a significant challenge in deep-water offshore production [1], particularly within the complex thermodynamic environments of pre-salt reservoirs. Standard methods (e.g., ASTM D6560) typically characterize asphaltenes under atmospheric reflux, which may not accurately reflect the fractional selectivity of the precipitating medium. Variations in pressure and temperature during extraction can alter the purity and the physicochemical nature of the resulting solids, especially regarding the co-precipitation of waxes. This study investigates the impact of the precipitation environment by comparing asphaltenes obtained by two methods using n-pentane: a standard condition (AC51: 1 bar, 40 °C) and a pressurized condition (AC55: 5 bar, 60 °C). The resulting fractions were characterized using Gel Permeation Chromatography (GPC), Differential Scanning Calorimetry (DSC), and Fourier-transform Infrared Spectroscopy (FTIR). Colloidal stability was assessed through the Asphaltene Solubility Class Index (ASCI) using n-heptane/toluene mixtures (0 to 100%, in 5% increments), complemented by optical microscopy of the critical precipitation tubes. Distinct morphological differences were observed: AC51 exhibited a wet and easily agglomerated appearance, whereas AC55 appeared glassy and dry, resembling thin foils. DSC analysis revealed a significant peak around 90 °C for AC51 (both in crystallization and melting curves), likely associated with co-precipitated crystalline waxes [2]. In contrast, AC55 showed no such peaks, suggesting the pressurized extraction yielded a higher-purity asphaltene fraction. GPC analysis yielded similar molecular weights for both samples (2455 g/mol for AC51 and 2582 g/mol for AC55). While these values exceed those reported by the Mullins model (600–800 g/mol) [1], they remain within the ranges found in broader literature [3]. FTIR spectra revealed a distinct band at 3400 cm⁻¹ in AC55, attributed to -OH groups, indicating higher polarity compared to AC51. Regarding stability, the ASCI for AC51 could not be determined as no visible precipitation occurred even at 100% n-heptane. This enhanced stability is likely due to the presence of co-precipitated waxes, as identified by DSC, which may act as stabilizers in solution. Conversely, AC55 exhibited an ASCI of 14 (70% n-heptane), confirming its instability. Optical microscopy confirmed that while AC51 contained dispersed aggregates not visible to the naked eye, AC55 showed significant agglomeration starting at 65% n-heptane, preceding the visible precipitation tube. The results demonstrate that the precipitation environment significantly changes asphaltene purity and stability. Moderate pressure and temperature effectively minimized wax contamination, resulting in a more polar and unstable asphaltene fraction, probably providing a more accurate representation of the solids' behavior in pressurized production systems.

Keywords:

Colloidal stability, Aggregation, Asphaltene.

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Acknowledgements:

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Bio-Based Surfactant–Polymer Assemblies for Agrochemical Active Ingredient Release: A Molecular Dynamics Study

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In agrochemical applications, the controlled and targeted release of active ingredients is essential to improve efficacy while minimizing environmental impact. Smart surfactants are emerging as key formulation components because they can respond to external stimuli and trigger the release of active ingredients only under specific environmental conditions. In this work, we investigate the encapsulation of poorly water-soluble active ingredients using mixtures of bio-based smart surfactants and polymers, which self-assemble into mixed aggregates capable of stabilizing hydrophobic compounds in aqueous environments.

Using computational modeling based on Molecular Dynamics, we study how aggregate structure, stability, and compatibility with the encapsulated active ingredient vary as a function of external parameters such as pH and salinity. By linking environmental changes to aggregate stability and disassembly, this work provides mechanistic insight into stimuli-responsive release mechanisms, demonstrating how active ingredients can be released autonomously in response to environmental conditions encountered in agricultural soils. The results support the rational design of smart surfactant–polymer delivery systems aligned with safe-and-sustainable-by-design principles for next-generation agrochemical formulations.

Keywords:

Safe and sustainable by design, molecular dynamics simulations, bio-based surfactants, agrochemical, encapsulation, stimuli-responsive release

References:

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Microscopic and rheological origins of phase separation in Aqueous Biphasic Systems

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Liquid-liquid extraction is a process widely used in the separation of substances. More specifically, for the separation of metals in recycling. Traditionally, systems composed of an aqueous and an organic phase are used, but these exhibit carcinogenic properties. It is in this context that aqueous biphasic systems have begun to attract attention due to their lower toxicity. The ionic liquid tributyltetradecylphosphonium chloride ([P44414]Cl), mixed with an inorganic salt (NaCl) and water, belongs to this family of mixtures. This system, which is initially monophasic when composed of ionic liquid and water, becomes biphasic when a sufficiently large amount of salt is added [1]. Furthermore, it displays a Lower Critical Separation Temperature (LCST). Understanding self-organisation and the fundamental mechanisms of phase separation is of paramount importance for extraction applications. We therefore propose to combine small-angle neutron scattering (SANS) measurements with rheological measurements for different compositions. In the absence of salt, the ionic liquid organises itself as a nanosuspension of spherical ionic liquid objects in water, which reverses at high concentrations of ionic liquid, forming water-based hard spheres in ionic liquid.

We also show that the addition of salt induces a change in the composition of the objects as well as their shape, leading to a non-linear evolution of viscosity.

Understanding the mechanisms of metal ion diffusion is also important in the context of metal separation. We are also studying the diffusion of metal ions within each phase independently of the biphasic system, as well as the impact of the liquid-liquid interface on this phenomenon.

Keywords:

Aqueous Biphasic System, Small Angle Neutron Scattering, Rheology, Phase separation

References:

[1] Schaeffer. PCCP. 2019

Stoichiometry-Driven Magnetic Frustration in Triangular Lattice Complexes

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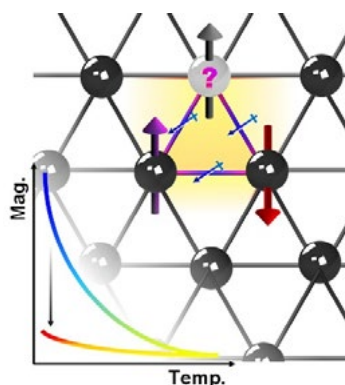
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Frustrated magnetic states rely on topological frustration. Here, we combine topological and Coulombic shielding to ensure magnetic spins remain uncoupled through stoichiometry-directed self assembly. Precise tuning of reactant ratios and solvent environment governs the crystallization of Eu-based formate systems, yielding triangular lattices with distinct metal vertex motifs: mono-nuclear $[\text{Eu}(\text{O}_2\text{CH})_3]_n$ (1) and di-nuclear $[\text{Eu}(\mu\text{-OCHO})(\text{OH})(\text{O}_2\text{CH})_2]_2$ (2). In both systems, assembly results in dipolar ordering of formate ligands, adopting head-to-tail or pairwise antiparallel configurations depending on stoichiometry. These arrangements define lattice organization and local electrostatic environment. In (1), cooperative dipole alignment enhances Coulombic shielding at the metal centers, suppressing magnetic coupling and yielding a non-magnetizable Eu^{2+} state. In contrast, antiparallel dipole pairing in (2) produces a net-zero dipolar field, enabling paramagnetic behavior. We validate this electrostatic control using homologous Gd and Sm analogues. This establishes a tunable route via directed self assembly to programmable spin isolation with potential application in quantum information processing.

Keywords:

Self assembly, Lanthanide-Based Triangular Lattice Frameworks, Qudits, Spin Frustration, Quantum Spin Liquids (QSL)



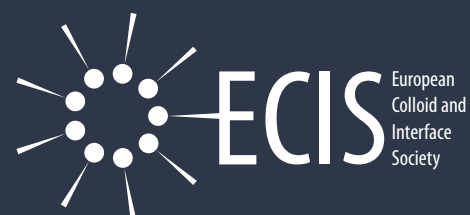
Frustrated magnetic states. Schematic of triangular lattice in spin liquids with unpaired dipoles leads to frustrated magnetization.

Topic 9

Individual and Collective Behaviors
of Colloids under External Fields



! POSTER



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Light-Driven Aggregation of Microparticles via Negative Thermophoresis

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The coupling between electrokinetic phenomena and thermal gradients offers a largely unexplored route to control collective behavior in particle-based systems. When suspended particles strongly absorb light, localized heating at the particle level can generate self-induced temperature gradients in the surrounding electrolyte, giving rise to thermophoretic interactions that are absent under uniform thermal conditions.

Here we demonstrate a laser-driven aggregation process in aqueous suspensions of hybrid polystyrene–magnetite microparticles, governed by electrokinetically mediated uphill (negative) thermophoresis arising from particle-induced thermal gradients. Upon laser irradiation, light absorption by individual magnetic microparticles leads to localized heating of the electrolyte solution, producing temperature gradients that drive neighboring particles toward the irradiated region and result in the formation of a dense and dynamic aggregate.

The aggregation process is fully reversible and can be switched on and off by controlling the laser irradiation. By quantifying the cluster growth dynamics, we show that the strength of the effective attraction is strongly modulated by the electrolyte concentration. Increasing salt concentration progressively weakens the aggregation and eventually suppresses it, consistent with a reduction of the Soret coefficient at high ionic strength due to electrokinetic screening effects.

Beyond reversible aggregation, we identify a regime in which laser-induced thermophoretic forces drive the system toward a well-defined steady-state cluster size. These results highlight the central role of particle absorption and electrolyte-mediated thermophoresis in shaping nonequilibrium assembly pathways, and clearly distinguish the observed behavior from conventional optical trapping or equilibrium assembly mechanisms.

Keywords:

Thermophoresis, aggregation, optofluidics

Acknowledgements:

Acknowledgements: The authors thank financial support from Grant PID2024.161166NB.I00 funded by MICIU/AEI/10.13039/501100011033/FEDER/UE, from Grant PRE2022-2-101943 funded by MICIU/AEI/10.13039/501100011033 and by FSE+ (A.C.), and from Ministerio de Universidades (Spain) and Universidad de Granada under the FPU grant FPU21/02569 (M.I.). I.M.N thanks financial support from the program Becas de Iniciación a la Investigación para Estudiantes de Grado. Universidad de Granada-Banco Santander del Plan Propio de Investigación de la Universidad de Granada.

3D Monte Carlo Simulations of Structural Regime Change in Magnetic Janus Particle Aggregates

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Magnetic particle suspensions have actively been studied in research fields such as fluid engineering, colloid and surface engineering, biomedical engineering and environmental resource engineering. In these applications, it is necessary to develop an accurate method for controlling the internal structure of particle aggregates using an external magnetic field. Recently, many researchers have focused on suspensions composed of spherical Janus particles whose hemispheres are covered by magnetic materials ^{1,2}. For magnetic Janus particles, it is predicted that the internal structure of their aggregates differs from that of conventional magnetic particles. From this background, in the present study, we investigated the transition of aggregate structures in a suspension of magnetic Janus particles under a uniform magnetic field. Three-dimensional Monte Carlo simulations were carried out in order to investigate the dependence of the transition of aggregate structures on various factors, such as the magnetic interaction between particles, an applied magnetic field and the distance between the magnetic moment and the particle centre. Here, we employ a particle model ² in which the magnetic moment is radially shifted with respect to the particle centre. The main results obtained here are summarized as follows. For Janus particles whose magnetic moments are near their centre, long chain-like clusters tend to be formed in a system when the magnetic particle-particle interaction is sufficiently strong. In the case of strong magnetic interactions, an increase in the distance between the magnetic moment and the particle centre leads to a transition in aggregate structures from chain-like clusters to cluster units consisting of 2 to 5 particles. With increasing the strength of the magnetic field, chain-like clusters have a strong tendency to be formed aligned in the direction of an applied magnetic field. For Janus particles with magnetic moments near their surface, those in chain-like clusters tend to arrange so that their magnetic caps are close to each other. From these results, we demonstrate that the strength of magnetic interaction between particles, the applied magnetic field strength, and the position of the magnetic moment strongly influence the internal structure of particle aggregates and the orientation of magnetic caps in Janus particle assemblies. It may be important that these results provide valuable guidance for designing highly functional particle systems.

Keywords:

Magnetic Janus particle, Monte Carlo simulation, Aggregate structure, Uniform magnetic field, Thermodynamic equilibrium

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Acknowledgements:

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Memory effects in the orientational dynamics in nanoparticle suspensions

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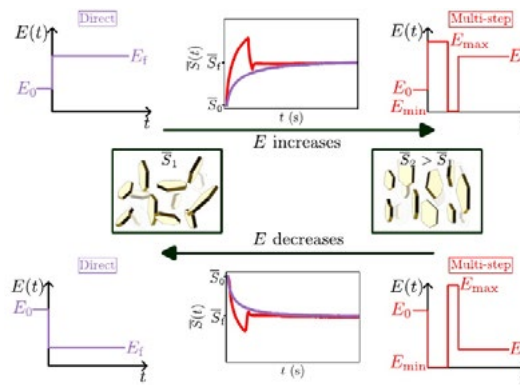
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The relaxation of stochastic systems after sudden perturbations is constrained by speed limits and often reveals memory effects that hinder attempts to accelerate their dynamics [1]. Here we demonstrate Kovacs-type [2] nonmonotonic relaxation in the electro-orientation of non-spherical nanoparticles and show how this memory effect limits simple acceleration protocols. Experimentally, the orientational dynamics is monitored optically through field-induced birefringence, which is proportional to the nematic order parameter [3]. When an AC electric field is first set to an extreme value until the birefringence reaches its target and is then switched to the target field (matched two-step protocol), the relaxation exhibits a characteristic Kovacs shoulder. We interpret this behavior within a theoretical framework based on the Smoluchowski equation for the orientational probability density. In the high-frequency AC regime, orientational relaxation is governed by induced dipoles, and the observed memory effect originates from polydispersity, which generates a spectrum of rotational diffusion coefficients and hence multiscale relaxation. Building on this insight, we design protocols that mitigate the detrimental effect of memory by sequentially suppressing the slowest active relaxation mode. Experiments on nanoparticle suspensions with different properties confirm these mechanisms, and we demonstrate substantial reductions in relaxation time compared with single quenches and matched two-step protocols with NaMt suspensions. More broadly, these results illustrate how memory effects emerge when many degrees of freedom are steered with a single control parameter and provide an experimentally accessible strategy for controlling multiscale stochastic dynamics [4].

Keywords:

Electric birefringence, Electro-orientation, Memory effects, Nonequilibrium dynamics, Stochastic dynamics



Schematic representation of the experimental system in a poorly aligned (left) and a strongly aligned (right) configuration. Upper and lower panels are the applied electric field protocols and the birefringence response.

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Acknowledgements:

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Negative and positive Zeta Potential controls: reliable Zeta potential values for electrophoretic mobility and streaming potential. The importance of standards.

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Nanoparticles are known to have an extraordinarily large specific surface area, meaning that their surface properties govern their colloidal properties and general behavior. Therefore, it is essential to determine the surface properties for the technical application of particles where adhesive surface effects play a role.

Experimentally, Zeta potential is the most accessible primary measure for determining the properties of a colloidal surface. Since the stability of charged particles against agglomeration is driven by electrostatic repulsive forces, it can be described as a function of the Zeta potential.(1)

Particle surface characteristics and charge play an important role in the particle's physical state, stability in different media, agglomeration tendencies, and interaction with biological systems. Zeta potential measurement provides an indirect measure of the net charge and as a tool to compare batch-to-batch consistency. (2)

The Zeta potential is greatly influenced by the fundamental properties of the surrounding medium, such as pH and ionic strength. Additionally, different Zeta potential determination methods cause different particle accelerations, resulting in different forces acting on the electric double layer surrounding the particle. Therefore, reliable and stable Zeta potential controls are essential to define the Zeta potential independently of the method and allow for the reasonable interpretation of the experimental results. (1)

Considering this, we have developed stable Zeta Potential Controls formulated on basis of surface-modified polystyrene particles that are either positively or negatively charged. These products are designed for the reproducible validation of Zeta potential. Thanks to a free of charged surfactants formulation, which is buffered against CO₂ intake, a significant reduction in background noise and a stable physicochemical environment could be achieved. The particle concentration has been adjusted to ensure suitability for most common experimental setups, with a defined electrophoretic mobility value, a shelf life is 12–18 months from and room temperature storage.

1)Zeta Potential Controls Applied Microspheres Product Brochure.
<https://www.applied-microspheres.com/products/zeta-potential-controls>

2)Clogston JD, Vermilya A. Measuring Zeta Potential of Nanoparticles: Version 1.2. 2020 Apr. In: National Cancer Institute's Nanotechnology Characterization Laboratory Assay Cascade Protocols [Internet]. Bethesda (MD): National Cancer Institute (US); 2005 May 1–. NCL Method PCC-2. PMID: 39013058. **Measuring Zeta Potential of Nanoparticles: Version 1.2** Jeffrey D. Clogston , Alison Vermilya

Keywords:

Zeta Potential, Standards, Nanoparticles, Surface Properties, Colloidal Properties

References:

1)Zeta Potential Controls Applied Microspheres Product Brochure.
<https://www.applied-microspheres.com/products/zeta-potential-controls>

2)Clogston JD, Vermilya A. Measuring Zeta Potential of Nanoparticles: Version 1.2. 2020 Apr. In: National Cancer Institute's Nanotechnology Characterization Laboratory Assay Cascade Protocols [Internet]. Bethesda (MD): National Cancer Institute (US); 2005 May 1–. NCL Method PCC-2. PMID: 39013058. **Measuring Zeta Potential of Nanoparticles: Version 1.2** Jeffrey D. Clogston , Alison Vermilya

How Magnetically Induced Convection Reshapes DLS Signals

¹José López-Molina, ²Guillermo Lorite-Méndez, ²Schon Fusco, ²Miguel Ángel Rodríguez-Valverde, ²María Tirado-Miranda

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Dynamic light scattering (DLS) is straightforward to interpret when particle motion is purely diffusive, or when a single linear drift adds the familiar oscillatory signature to the correlation function. Here we show that weak-gradient magnetophoresis can quickly drive the system beyond this simple picture. By combining Particle Image Velocimetry (PIV) with three-dimensional DLS in dilute dispersions of superparamagnetic polystyrene particles, we resolve how magnetically induced flow changes both the particle dynamics and the meaning of the DLS signal. In the early stage after magnet placement, motion near the scattering volume remains sufficiently coherent for DLS oscillations to appear, enabling the extraction of a characteristic drift velocity. As the flow develops into a convective pattern with a narrow jet and recirculating vortices, however, the oscillations vanish even though advective effects remain strong. Particles still cross the scattering volume and contribute to decorrelation, but the local velocity field is no longer described by a single direction or magnitude. Our results identify a clear breakdown of simple drift-based DLS analysis and show that convective transport can strongly bias magnetophoretic measurements under weak field gradients.

Acknowledgements:

We thank PID2023-147135OB-I00, supported by MICIU/AEI/10.13039/501100011033 and by “FEDER, EU for the funding of this project and grant PID2022-136540NB-I00 funded by MCIN/AEI/10.13039/501100011033 and ERDF A way of making Europe.

Design and implementation of a cell for water deionization using Shock Electrodialysis

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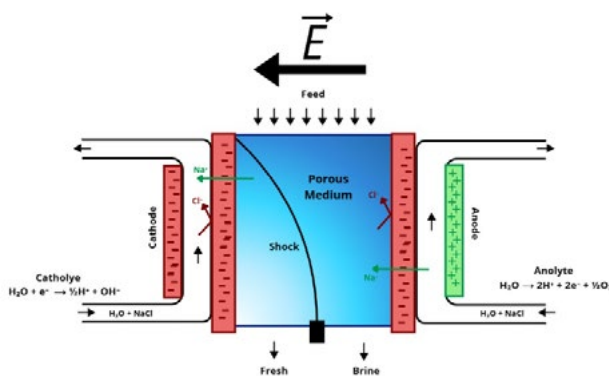
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When an electrolyte and oppositely charged solid surfaces, such as electrodes, are immersed, the ions migrate towards them, respectively. This forms an electric double layer (EDL), and capacitive deionization (CDI) can occur if these ions are removed using a low-intensity electric field [1]. One way to address this issue is to increase the strength of the electric field and add a component that allows for ionic selectivity, such as an ionic membrane [2], thereby achieving concentration polarization (CP). This phenomenon is generated by spatial differences in the ionic transport number, which limit the current to the diffusion of species that cannot pass through. It has been proven that using a weakly charged porous medium (acting as a leaky membrane) can intensify CP due to over-limiting currents (OLC) within the EDL of the medium, producing Shock-Electrodialysis (SED) [3]. Consequently, a large quantity of low-concentration water can be recovered from a high-concentration feed, enabling efficient water purification.

This research aims to design a cell capable of distinguishing between the various ionic kinetics discussed above and of operating at a scale suitable for societal use.

Keywords:

Capacitive deionization (CDI), Concentration Polarization (CP), Over-limiting Current (OLC), Shock-Electrodialysis (SED)



Schematic diagram of a cell containing porous material in which a shock wave forms, separating two regions with vastly different concentrations from a common solution

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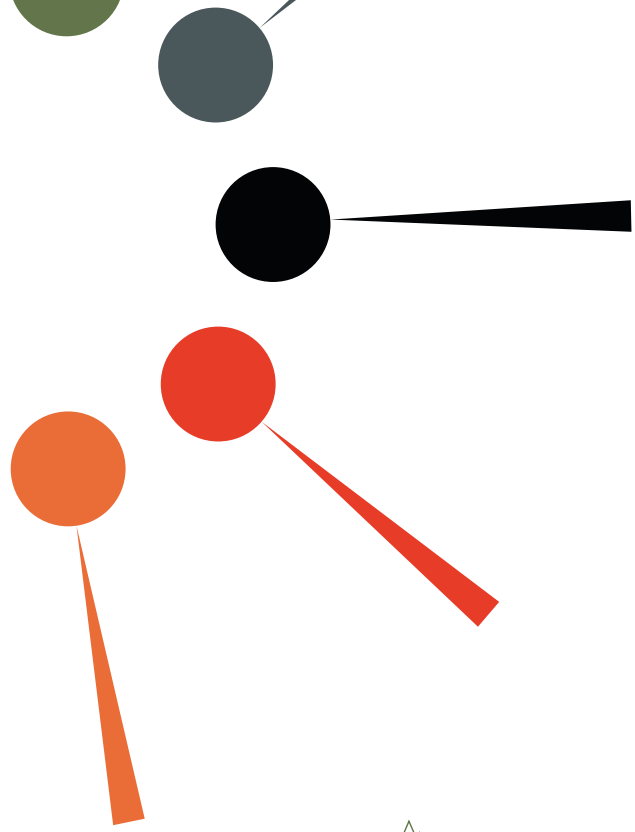
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Financial support of this investigation PID2023-151881OB-I00 funded by MICIU/AEI/10.13039/501100011033/ and FEDER, UE. J.J.A.S. acknowledges Beca-Colaboracion25/26 (ref. 25CO1/006150) funding by Ministerio de Educación, Formación Profesional y Deportes (España)

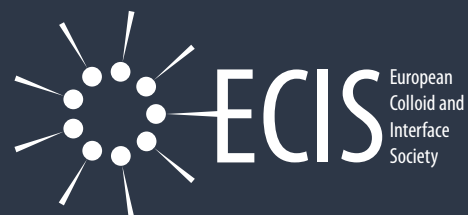
J.A.L.P. acknowledges FPU2023 (ref. FPU23/03086) funding by Ministerio de Ciencia, Innovación y Universidades (España)

Special Sessions 1

Machine Learning and AI-Based
Methods for Colloids and Interfaces



! POSTER



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Democratizing Digital Twins: Hybrid Modeling Approach for Cosmetic Process Innovation

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Background & Objective: In the evolving landscape of cosmetic manufacturing, the ability to accurately predict product quality across different production scales is a critical lever for agility and innovation. Traditional "black-box" Machine Learning (ML) models often require vast datasets and struggle with extrapolation. This work presents a "Hybrid Modeling" approach—combining first-principles mechanistic models with data-driven AI solutions—to create a robust predictive framework for L'Oréal's manufacturing processes. Another objective of this work is also to demonstrate how chemists and process engineers (Subject Matter Experts) can collaborate with digital specialists to build models rooted in physical reality rather than pure data correlation.

Methodology: The study explores the potential of hybrid modeling for manufacturing process predictions, beginning with initial **simple formulations** and extending to complex emulsion formula. This research was conducted in partnership with **BaseTwo**, a specialist in hybrid modeling for manufacturing processes. By integrating physico-chemical principles—such as Population Balance Equations (PBE) with empirical data, we developed below workflow to predict product quality attributes as a function of process parameters:

Step 1: Manufacturing experimental batches followed by Physico-chemical characterization (Particle Size Distribution (PSD), Rheology) of product quality.

Step 2: Building the model using a training dataset

Step 3: Evaluating model performance on "unseen" conditions (data points excluded from model construction) and comparing predictive results with experimental outcomes.

Step 4: Depending on predictive accuracy, performing further iterations by either incorporating additional data or fine-tuning the mechanistic equations using the initial training dataset.

Final Step: Model validation once the targeted accuracy thresholds are achieved.

Results: Initial results demonstrated that the hybrid modeling approach accurately predicts PSD for both simple and complex emulsions across various manufacturing scales, even under unseen conditions. A second study focused on fine-tuning these models, enabling a transition from PSD to robust rheology predictions by introducing the physico-chemical "Packing Factor" parameter.

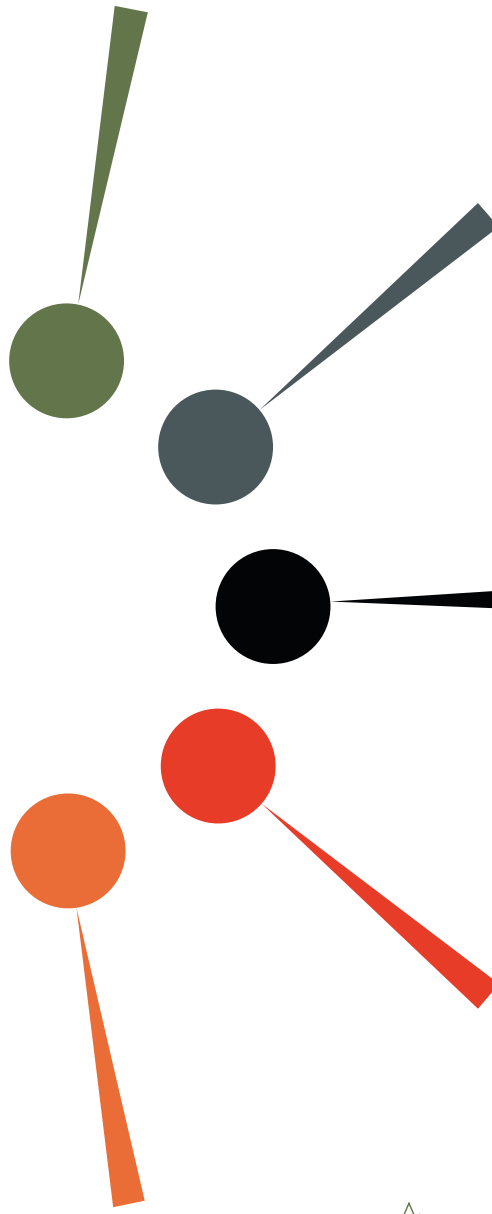
Conclusion & Impact: This collaboration between L'Oréal and BaseTwo AI demonstrates that hybrid models provide a "decoded" and deployable solution for lab researchers. By leveraging previously solved parameters, we can achieve predictive scale-up without additional data, directly accelerating the transition from lab to production. Future work will focus on scaling this collaborative framework at bigger scales and other cosmetic sectors to establish a new standard for inclusive process digitalization.

Keywords:

Hybrid Modeling, Digital Twin, Cosmetic Process Engineering, Emulsions, Scale-up Optimization, Physics-Informed Machine Learning

References:

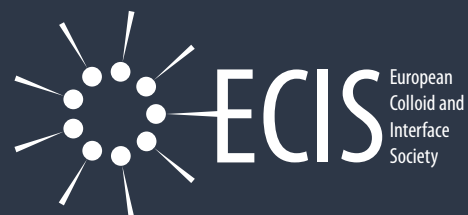
A review and perspective on hybrid modeling methodologies" by Artur M. Schweidtmann, Dongda Zhang, and Moritz von Stosch, published in Digital Chemical Engineering in 2024

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Special Sessions 2

Scattering, Imaging, and Other
Analytical Techniques Applied
to Colloids and Interfaces

! POSTER



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Solution SAXS Reveals Glycation-Dependent Structural Expansion and Early Aggregation in Human Serum Albumin

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Human serum albumin (HSA) is a major transport protein and an important short-term glycemic marker. Under hyperglycemic conditions, reducing sugars can non-enzymatically glycate HSA, altering its conformation, microenvironment, and aggregation behavior. To clarify these glycation-induced changes, we established an integrated analytical platform to separate and characterize fructose-glycated HSA prepared over 1-5 weeks.

An integrated BAC-SEC (Boronate Affinity Column-Size Exclusion Column) platform coupled with MALS(Multi-Angle Light Scattering), DLS(Dynamic Light Scattering), RI(refractive index), UV-Vis(Ultraviolet-visible spectroscopy), and synchrotron SAXS(Small-Angle X-ray Scattering) was used to characterize fructose-glycated HSA. SEC/MALS-DLS/RI revealed progressive formation of dimers, oligomers, and aggregates, with increased hydrodynamic radius and molecular weight during glycation. BAC-SEC separated monomeric glycate HSA into low-, medium-, and high-glycation populations. HPLC-UV showed glycation-dependent microenvironmental changes, including greater Trp exposure and tertiary loosening. SAXS further demonstrated glycation-induced structural expansion, with R_g increasing by about 2% in LGA and 10% in MGA within 3 weeks, together with subtle conformational heterogeneity.

Overall, the BAC-SEC/MALS-DLS/RI and SAXS-UV/RI platforms successfully differentiate glycate HSA by glycation degree and aggregation state, while revealing progressive size expansion and structural perturbation caused by fructose-induced glycation. These results provide a solution-based framework for evaluating how glycation alters albumin structure and support future studies of ligand or drug-binding behavior in diabetic conditions.

Keywords:

glycate HSA, SAXS, Boronate Affinity Column

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Acknowledgements:

13A biological small- and wide-angle X-ray scattering (SWAXS) beamline at the Taiwan Photon Source (TPS)

Characterization of Drug Delivery Nanoparticles by Light Transmission Spectroscopy (LTS)

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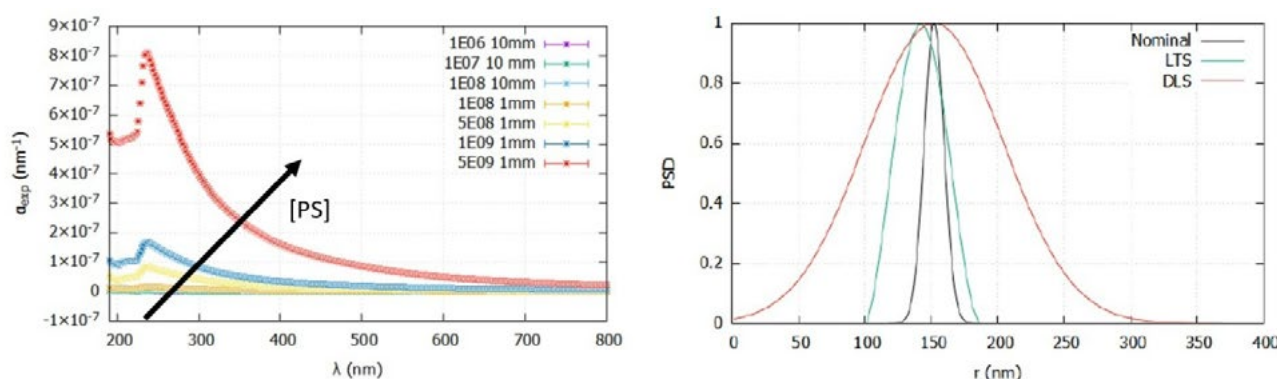
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In recent years, nanostructured drug delivery systems based on soft colloidal particles have attracted increasing interest due to their tunable properties, biocompatibility, and ability to improve drug stability and delivery efficiency. Among them, polymeric microgels, based on poly(N-isopropylacrylamide) (pNIPAM), are responsive colloids capable of entrap and release active molecules thanks to their stimuli-responsive reversible swelling and deswelling [1]. Solid polymeric nanoparticles based on Chitosan, derived from a non-toxic and biocompatible polysaccharide, represent another versatile drug delivery platform due to their mucoadhesive properties allowing sustained drug release through adhesion to biological membranes [2]. Soft lipid vesicles known as liposomes, consisting of a phospholipid bilayer and an aqueous core, also enables the efficient encapsulation and delivery of drugs or genetic material [3]. The characterization of such systems is commonly performed using scattering techniques, which provide particle size distributions (PSDs) but often lack access to absolute concentration. In detail, the hydrodynamic size obtained by Dynamic Light Scattering (DLS) differs from the true geometrical size, while complementary methods such as Small-Angle X-ray Scattering (SAXS) and Small-Angle Neutron Scattering (SANS) provide structural information.

Light Transmission Spectroscopy (LTS) is here presented as a powerful alternative to the above characterization techniques, enabling the simultaneous determination of both PSD and absolute particle concentration of colloidal dispersions[4]. LTS is based on the measurement of the wavelength-dependent extinction spectrum of a polychromatic light beam transmitted through the sample. The attenuation of light, arising from both scattering and absorption, is governed by the Beer–Lambert law and modelled using Mie scattering theory. By analysing the spectral dependence of the transmitted light and solving the associated inverse problem, LTS provides the number-based PSD and the average size. First, monodisperse polystyrene particles are employed as model systems to validate the methodology. Then LTS is applied to different soft nanostructured colloids used for drug delivery, to determine their particle concentration and the effect of the preparation protocol on the concentration of the final suspension.

Keywords:

Drug delivery, Light Scattering, Microgels, Liposomes, Chitosan, LTS, PSD, Absolute Concentration



Extinction spectra of PS nanoparticles (radius = 150 nm) at different concentrations and their corresponding particle size distributions (PSD) obtained by LTS, compared to DLS and the nominal size.

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Structural characterization by scattering and spectroscopic methods of mixed micelles of Pluronic F127 and miltefosine

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Poloxamers, commonly known as Pluronic[®], are amphiphilic linear block copolymers that self-assemble into micelles in aqueous solutions. Due to their biocompatibility and physicochemical properties, they are widely used in pharmacy for drug delivery applications. Herein, we investigate the properties of Pluronic F127 as a nanocarrier for Miltefosine (MF), an amphiphilic, alkylphospholipid used as an antiparasitic drug. A full structural characterization of the aggregates has been carried out at physiological pH, using small-angle neutron scattering (SANS) and dynamic light scattering (DLS), combined with proton 1D and 2D nuclear magnetic resonance (NMR) spectroscopy, to determine the precise location of the drug. DLS results indicate the co-assembly of both surfactants into mixed micelles, which remain stable over a wide range of temperatures and exhibit a single size distribution with an intermediate hydrodynamic radius compared to the individual surfactants. NMR results indicate that both the hydrophobic and hydrophilic domains of the drug interact primarily with the hydrophobic PPO core of the F127 micelles, suggesting that the MF is preferentially localized within the micelle core. The structural properties of the aggregates depend on the proportions of drug and carrier. When MF is in excess, SANS shows that the structure of the mixed micelles resemble MF ones, characterized by their reduced size, a dehydrated core, and a lower F127 aggregation number, whereas they become similar to pure F127 micelles as the concentration of the poloxamer increases. Overall, this work demonstrates that F127–MF mixed micelles provide a versatile and tunable colloidal system by an adequate control of composition and temperature, with potential applications for the treatment of parasitic pathologies.

Keywords:

Polymeric micelles, Pluronic, miltefosine, SANS

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Measurements and theory of ion relaxation times near electrified surfaces using frequency-modulated surface acoustic waves

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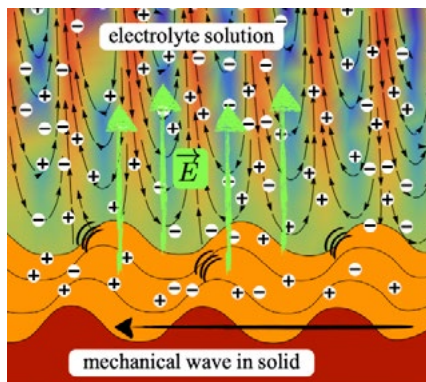
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We show recent theory and measurements of the dynamical behaviour of an electrified glass surface in electrolyte. We use MHz-level frequency-modulated surface acoustic waves (SAWs) to study the dynamics of an array of ions and ion mixtures in the electrical double layer (EDL) that appears at the electrified glass/solution interface. The SAW travels in the flat solid, and the EDL exists in the electrolyte solution; both phenomena are entangled through a field effect, a mechanical evanescent wave, which is invoked in the solution by the SAW [1] and vibrates ions in the EDL [2, 3]. The excited EDL leaks a measurable electrical field to the bulk of the electrolyte solution. This is a new MHz-level spectroscopy for studying ion relaxation times near isolated electrified surfaces.

Electrical double layers (EDLs) are nanometer-thick clouds of ions that appear at the charged interface between a substrate and an electrolyte solution and determine its electrical properties. Ions diffuse and migrate through the thickness of an EDL within micro- to nano-seconds: These are ion-specific limiting-times for charging and discharging the EDL and are known as the EDL relaxation-times. They are a product of the EDL structure and the ion size and charge. An ion relaxation-time similar to the SAW periodic time results in an ion electro-mechanical resonance, which maximises ion vibration and the leakage of the electrical field, introducing a peak in the measured voltage spectrum. The spectrum of the electrical field leakage identifies the interaction between the SAW and different ions, elucidate ion relaxation times in the EDL and hence the intrinsic rate of the EDL charge and discharge by specific ions, and gives a glimpse into the dynamical behaviour of EDLs.

Keywords:

electrical double layer, relaxation times, spectroscopy, surface acoustic waves



An illustration of a surface acoustic wave destabilising ions near an electrified surface to result in the emission of an electrical field into the bulk of electrolyte solution

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Spatial Distribution and Optical Response of Gold Nanoparticles within thermosensitive Polymer Brushes

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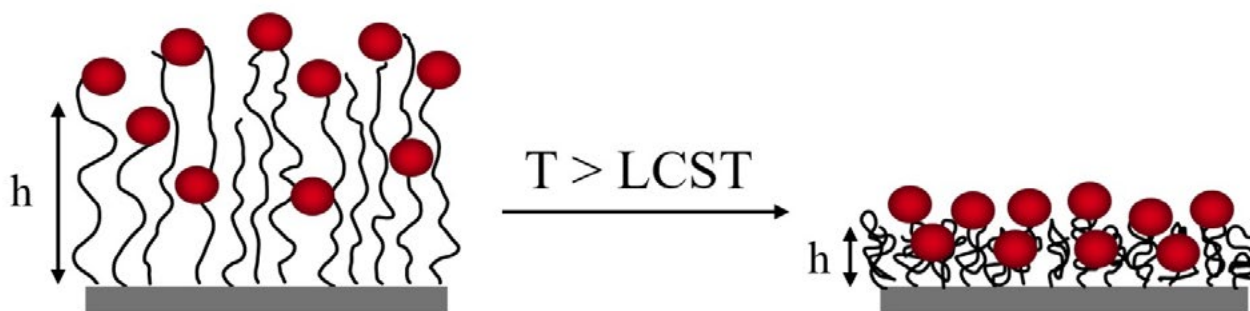
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Metal/polymer nanocomposites are versatile hybrid materials and find use in many fields such as photonics, biomedical engineering and catalysis. A promising realization of this type of hybrid material is the controlled self-assembly of gold nanoparticles (AuNPs) inside a polymer brush, which induces color changes upon exposure to environmental changes ultimately enabling sensor applications.

Polymer brushes serve as a matrix for the immobilization of AuNPs. Particle uptake into the brush matrix is affected by several parameters such as brush thickness, particle size and the grafting density [1,2]. Uptake of nanoparticles has proven to be highest at intermediate grafting densities [3]. In the present study thermoresponsive Poly(*N*-Isopropylacrylamide) (PNIPAM) brushes with varying grafting densities are synthesized directly from a silicon substrate by a controlled radical polymerization (SI-ARGET ATRP). Nanocomposite materials are fabricated by dip-coating polymer brushes into a AuNP suspension. The topography of the nanocomposite coatings is characterized by atomic force microscopy, the vertical particle distribution is investigated by neutron and X-ray reflectometry, and optical properties are characterized by in situ spectroscopic ellipsometry. This study reveals the grafting density-dependent penetration of particles into the brush, where particle uptake is found to scale with the inverse of grafting density. The relation between particle distribution and temperature-induced structural changes will be presented. As an outlook, the usage of AuNPs within polymer brushes as hotspots for local photothermal heating will also be discussed.

Keywords:

Polymer Brush, PNIPAM, Gold Nanoparticles, Neutron Reflectometry, Spectroscopic Ellipsometry



Sketch of Gold Nanoparticles within a swollen PNIPAM brush (left) and a collapsed PNIPAM brush (right). Changing polymer brush solvation by external stimuli allows to tune the particle proximity, which modulates the optical properties.

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Feature-guided SANS analysis to map micellar phase space

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Surfactants self-assemble into a rich variety of micellar structures governed by molecular interactions, solvent conditions and even external stimuli. As a result, identifying micelle structure is still heavily dependent on trial-and-error approaches, with significant cost and risk associated with custom synthesis and formulation. Small-angle neutron scattering provides detailed insight about nanostructure, and with increasing popularity of high-throughput, fluidic approaches to generate large datasets, the bottleneck shifts from measurement to analysis. Within a few hours, hundreds of scattering patterns can be acquired to map micelle structure to surfactant composition and identify synergistic interactions that drive micellar transitions.

In this work we utilise a feature-guided algorithm that exploits changes in low- q gradients, to determine which model parameters should be adjusted. Since micellar transitions are smooth, the initial parameters for one composition is closely related to next, constraining the fitting algorithm and enabling rapid analysis of detailed phase maps. This approach facilitates the generalisation of models and enhances the accessibility and the utility of these information-rich experiments. We exploit this methodology to investigate self-assembly as a result of hydrogen bonding interactions [1] .

Keywords:

Small-angle neutron scattering, Self-assembly, Phase mapping, Feature-guided fitting

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Forming Kinetically-trapped Liquid Crystalline Spherical Nanoparticles during Polymerization-induced Self-assembly

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Liquid crystalline nanoparticles (LC NPs) have attracted considerable attention due to their anisotropic structures. However, the fabrication of LC NPs has typically been constrained by challenges in mass production and precise morphology and size distribution controls. Polymerization-induced self-assembly (PISA), a scalable and efficient technique, enables nanoparticle synthesis with diverse morphologies at high solids. Although the kinetic trapping associated with PISA typically limits morphological transitions of nanoparticles, it can be utilized to fabricate specific nano-objects. Herein, kinetically-trapped poly(2-(dimethylamino)ethyl methacrylate) –poly(6-((4-cyano-4'-biphenyl)oxy)hexyl methacrylate) (PDMA-PMA6CB) diblock copolymer LC NPs were synthesized using the LC polymer PMA6CB as the core-forming block. Small-angle X-ray scattering (SAXS) verified the straight PMA6CB main-chain conformation in PDMA–PMA6CB spherical micelles, exhibiting birefringence as lyotropic liquid crystal behavior in spherical particle formation under polarized optical microscopy (POM). To adjust birefringence, benzyl methacrylate (BzMA) was introduced to produce PDMA-PMA6CB-PBzMA triblock copolymer nanoparticles. The resulting nanoparticles exhibited reduced or absent birefringence, likely resulting from disrupted PMA6CB block radial orientation in spherical micelle cores, evidenced by SAXS. Further investigation of the morphological transitions of PDMA-P(MA6CB-co-BzMA) statistical copolymer nanoparticles elucidated kinetic trapping effects during nanoparticle formation. This study presents an efficient method to prepare LC NPs, offering valuable insights into the core-forming block control.

Keywords:

Polymerization-induced self-assembly; Liquid crystalline nanoparticles; Kinetic trapping; Small-angle X-ray scattering

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Nucleation of semiconductor material from solution onto templated SAMs

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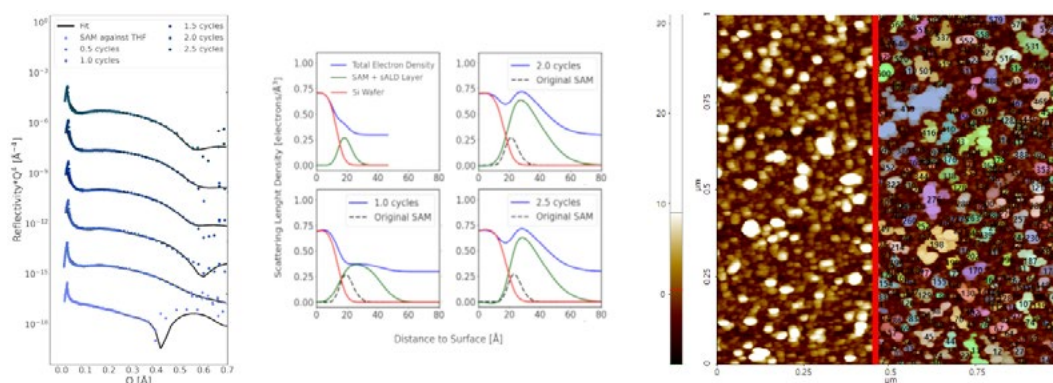
Solution based atomic layer deposition (sALD) is an emerging technology that aims to transfer high vacuum atomic layer deposition (ALD) into a wet chemical environment. The technique aims to enable large scale processes for printing of functional materials. It has been used to successfully create layers of antimony selenide [1], perovskites[2] and perovskite solar cells[3].

The nucleation process of precursors in the first cycles of an sALD procedure and the resulting layer structure plays an integral part in the final quality of the produced layers.[4] An in-situ study of the nucleation of SnS₂ from the precursors tetrakis(dimethylamido) tin(IV) (TDMASn) and H₂S at the interface of a self-assembled monolayer (SAM) of (3-Mercaptopropyl)trimethoxysilan (MPTMS) from tetrahydrofuran (THF) revealed an island growth mechanism. This was attributed to the mismatch in density of thiol groups on the surface of a dense MPTMS SAM and the density of sulfur atoms in crystalline SnS₂, favoring the growth in islands instead of continuous layers.[5]

Therefore SAMs with different thiol densities were prepared by using mixes of functionalized and non-functionalized, long-chained organic phosphonic acids. Combining XRR with atomic force microscopy (AFM) a correlation of nucleation site density and the structure of the produced layers was found.

Keywords:

x-ray reflectometry, xrr, self assembled monolayer, SAM, atomic layer deposition, ALD, AFM, atomic force microscopy, nucleation, semiconductor



XRR data and model fits (left) and resulting electron density profiles (EDPs) of the SAM and sALD layers (middle). Shown are in-situ data of 2 sALD cycles. AFM data evaluated with grain analysis(right) of the sample after coating shows island growth with densities comparable to XRR.

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Controlled Nucleation and Growth of 2D SnS₂ via Solution Atomic Layer Deposition on Functionalized Surfaces

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Atomic layer deposition (ALD) is an established vapor-phase technique that utilizes sequential, self-limiting surface reactions to achieve sub-nanometer thickness control. By pulsing precursors individually, the process ensures the growth of high-quality, uniform 2D films [1]. Transitioning to solution-based ALD (sALD) offers significant advantages, including scalability, atmospheric pressure processing, and a broader precursor library, yet the fundamental precursor-surface interactions in solvents remain poorly understood [2].

As the initial cycles of sALD dictate final film quality and crystallinity, self-assembled monolayers (SAMs) are employed as templates to precisely control the density of nucleation sites. Previous *i n-situ* XRR investigations of SnS₂ growth on (3-mercaptopropyl)trimethoxysilane (MPTMS) SAMs revealed non-ideal island growth, linked to the distribution of thiol groups present at the SAM surface [3]. This necessitates optimization which might become possible by using phosphonic acid-based SAMs on AlO_x/Si as it offers a wider range of available SAM molecules and longer alkyl chains available for purchase to provide a more ordered template for controlled nucleation.

We investigate nucleation behaviour of 2D SnS₂ on thiol terminated SAMs on AlO_x/Si substrates after 10 sALD cycles. To control nucleation site density, we mixed 12-mercaptododecylphosphonic acid (SH-C12PA) with decylphosphonic acid (C10PA) spacers. By varying the SH-C12PA molar fractions at 100%, 5%, 1%, 0.2% and 0%, we systematically increased the average intermolecular distance of the functional –SH groups. The evolution of the SnS₂ films after 10 sALD cycles is characterized using X-ray reflectometry and atomic force microscopy. The primary objectives are to evaluate SAM homogeneity across different dilution systems and to tune the available SnS₂ nucleation sites on the functionalized surfaces. These insights into interfacial wetting behavior clarify how surface site density governs the transition between island and layer-by-layer growth, providing a pathway to defect-free 2D semiconductor fabrication.

Keywords:

X-ray reflectometry, SnS₂, Solution atomic layer deposition, Self-assembled monolayers

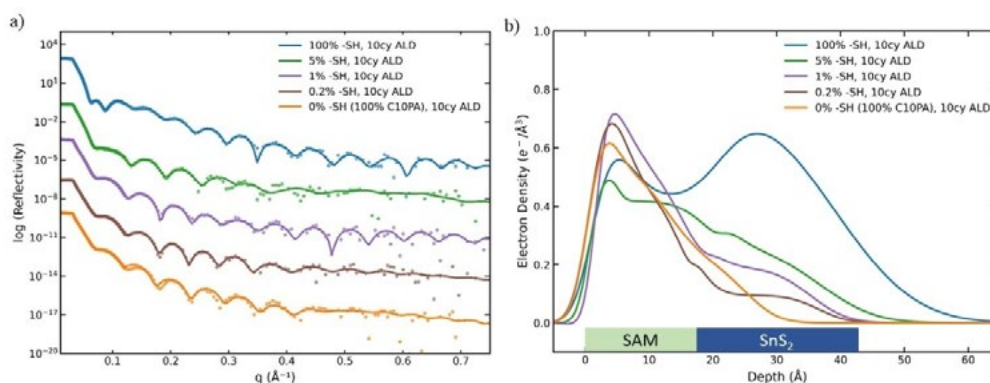


Figure 1: a) Ex-situ XRR data (dots) and fits (lines) of SnS₂ after 10 sALD cycles on AlO_x/Si with varying thiol-densities SAM. b) Electron density profiles of SnS₂ and SAMs derived from a).

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Understanding Particle Adsorption at the Oil/Water Interface in Light-Responsive Pickering Emulsions and Real-Time Formation under In Situ Ultrasound

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Light-responsive Pickering emulsions offer a route to externally controlled destabilisation through light-induced changes in particle wettability [1]. However, their response is often highly sensitive to formulation, and the relationship between particle-scale interfacial behaviour and macroscopic emulsion stability remains unclear.

Here, we investigate adsorption and organisation of azobenzene-functionalised silica particles at the oil–water interface. By systematically varying particle loading, surface functionalisation, photoswitch structure, and oil phase, we identify key parameters governing interfacial packing and adsorption energy. Langmuir trough measurements combined with neutron reflectometry are used to resolve structural changes at planar interfaces under irradiation, distinguishing lateral rearrangement from out-of-plane redistribution. These results are correlated with bulk emulsion behaviour characterised by optical microscopy and droplet size analysis [2–4].

In parallel, we present a newly developed sample environment at the ISIS Neutron and Muon Source that enables real-time emulsion formation under in situ ultrasound and controlled light irradiation on small-angle neutron scattering beamlines. The system integrates a tip sonicator with a sealed neutron-compatible cell and multi-wavelength LED illumination, allowing emulsification and external perturbation directly within the neutron beam. Preliminary measurements demonstrate the capability to follow structural evolution during emulsification and provide direct comparison with conventional ex situ preparation.

This combined approach links interfacial structure to bulk emulsion response and establishes new opportunities for studying dynamic emulsion formation under external stimuli.

Keywords:

Pickering emulsions, light-responsive particles, particle adsorption, oil–water interface, neutron reflectometry, small-angle neutron scattering

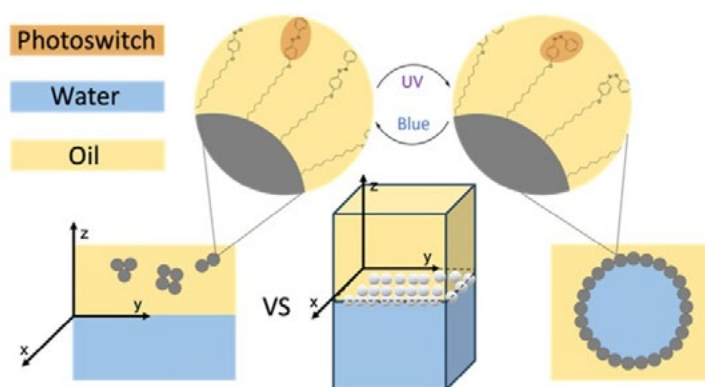


Figure 1: Light-induced changes in particle wettability at the oil/water interface.

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Nano-ions as Superchaotropic Fluorescence Quenchers: A Model for Protein-Surface Interactions.

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The low charge density of superchaotropic anions like polyoxometalates (POMs), giant POMs (Mo_{154} , Mo_{132}), and inorganic boron clusters ($\text{B}_{12}\text{X}_{12}^{2-}$; X=H, Br, I) renders them distinct hydration properties.¹ Despite a growing interest, its effect on optical properties^{2,3} and peptide dynamics remains poorly understood. Herein, we report a systematic investigation of the effect of structurally diverse nanometric-sized inorganic clusters on the fluorescence properties of N-acetyl-L-tryptophanamide (NATA).⁴ Initially, tryptophan was chosen as the fluorophore; however, certain POMs, most notably ammonium metatungstate hydrate (AMTH), at higher concentrations produce anomalous distortions in its excitation spectra rather than the expected fluorescence quenching. Such a distortion was indicative of a direct chemical interaction between the POM and the fluorophore rather than a purely photophysical mechanism. To overcome this complication, we have chosen NATA, the protected analogue of tryptophan. Steady-state, time-resolved fluorescence measurements, coupled with SAXS, reveal a novel quenching mechanism that cannot be attributed solely to energy transfer. The quenching efficiency was found to be a complex interplay of the size and charge density of the nano-ions, with Mo_{154} and Mo_{132} exhibiting the strongest quenching behaviour consistent with their giant size⁵ and surface charge distributions while, smaller POMs (HPW, HSiW, AMTH, $\text{K}_8\text{SiW}_{11}\text{O}_{39}$) at equimolar concentrations acted as comparatively mild quenchers. Strikingly, rather than quenching, boron clusters at equivalent concentrations to other nano-ions were found to support the fluorescence enhancement of NATA. Our results thus demonstrate a contrasting effect on the photophysics of NATA, subject to nano-ions, which is yet to be rationalized.

Keywords:

Superchaotropic, Giant POMs, Boron Clusters, Fluorescence, SAXS.

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Effect of post-synthesis surface modification on the SERS activity of silver nanoparticles

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Silver nanoparticles (AgNPs) are widely investigated due to their unique plasmonic properties that enable a broad range of applications in chemical sensing, spectroscopy, and nanomaterials engineering.[1,2] Among these, their use as substrates for surface-enhanced Raman scattering spectroscopy (SERS) is particularly important, as AgNPs can provide strong Raman signal enhancement through localized surface plasmon resonances.[3]

In this study, colloidal silver nanoparticles prepared by chemical reduction were examined with a focus on how post-synthesis treatment and surface environment influence their physicochemical properties and SERS performance. Surface modification was explored through controlled washing procedures as well as through adsorption of polymeric species at the nanoparticle surface. These strategies enable the investigation of how variations in surface composition, residual ionic species, and interfacial interactions influence nanoparticle behavior. The physicochemical properties of the resulting colloidal systems were characterized using dynamic and electrophoretic light scattering to evaluate particle size, electrokinetic potential and colloidal stability. The SERS activity of the AgNPs was investigated using the model molecule 1,2-bis(4-pyridyl)ethylene (BPE). Particular attention was paid to adsorption phenomena and adsorption-induced changes at the nanoparticle surface, and their influence on Raman signal enhancement. These observations highlight the importance of surface chemistry in determining the performance of silver-based SERS substrates.

Overall, this work emphasizes the role of controlled post-synthesis treatment and adsorption investigation, including the possible involvement of polymer-mediated surface interactions, in the development of tunable and reproducible AgNP systems for SERS and related analytical applications.

Keywords:

silver nanoparticles, SERS spectroscopy, surface modification, adsorption, BPE

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Characterisation of non-spherical particles in suspension using Depolarised DLS

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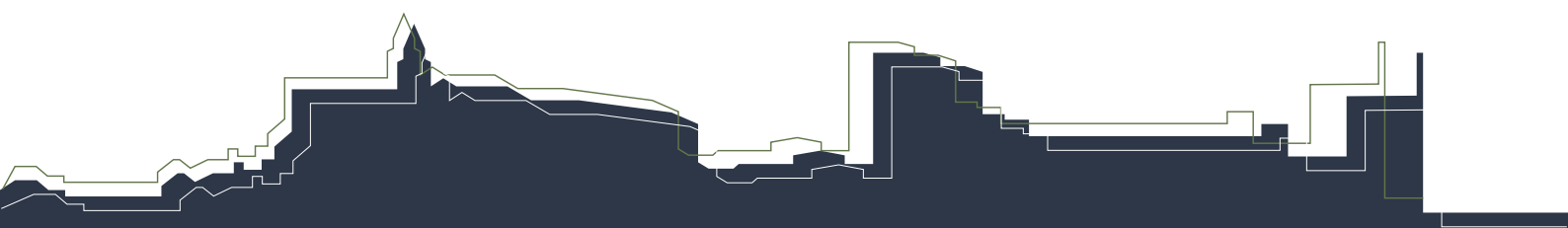
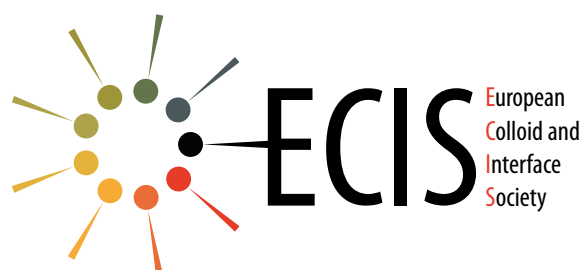
Non-spherical nanoparticles (eg cubic, tetrahedral or rod shaped) are important for a wide range of applications, with some advantages over spherical particles. In addition, some particles (such as nanodiamonds) have irregular shapes making them difficult to characterise by traditional techniques.

Many applications of nanoparticles require suspension in aqueous solutions (for example biological media). However, many traditional characterisation techniques (such as electron microscopy) require samples to be in a dry state. While these methods enable the determination of the core size of (hard) particles, they do not enable characterisation of their effective size in suspension, including the effect of surface stabilizers, or changes to particle size as a result of protein corona formation in biological media.

In this paper we will present advanced methods for the characterisation of non-spherical particles using depolarised dynamic light scattering and illustrate with a range of regular and irregular shaped particles, including particles with complex stabilising layers and protein coronae. The advantages and disadvantages of the technique will be discussed.

Keywords:

DLS, Nanorods, Non-spherical particles, Colloids, Protein Corona



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