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

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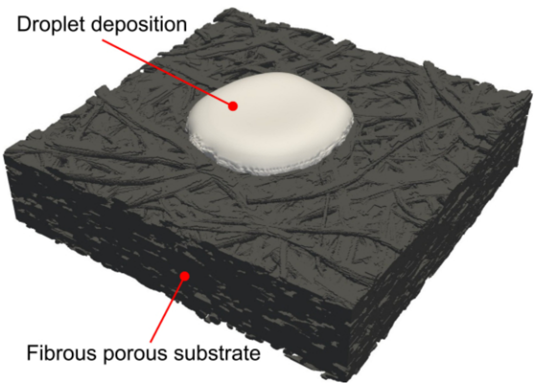
Plastic waste poses a major global environmental problem, because it degrades habitats, impedes natural processes, and can directly harm life on Earth. Cellulose fibre is a promising alternative to conventional petroleum-derived plastic for packaging applications [1]. Cellulose fibre packaging is sustainable, 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

References:

[1] A. Ahuja et al. (2024 *) Biomass Conversion and Biorefinery* , **14** , 13779.

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