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

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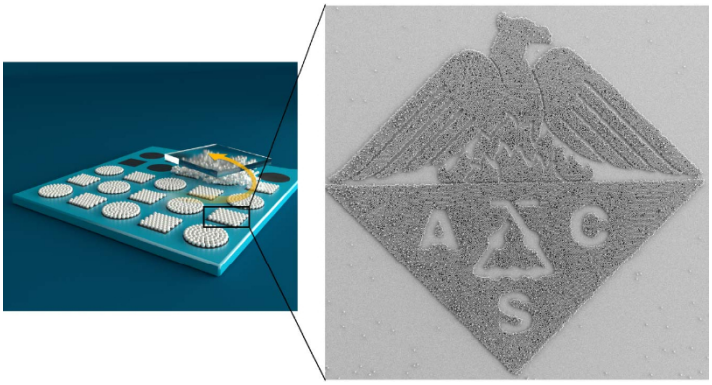
a { text-decoration: none; color: #464feb; } tr th, tr td { border: 1px solid #e6e6e6; } tr th { background-color: #f5f5f5; }
Electroactive interfaces formed from close-packed colloidal particles provide a novel pathway for designing soft energy-harvesting systems. In this talk, I will show how monolayers 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

References:

[1] Toward the Assembly of 2D Tunable Crystal Patterns of Spherical Colloids on a Wafer-Scale, Kai Sotthewes, Gijs Roozendaal, Andris Sutka, Ignaas S. M. Jimidar, ACS Appl. Mater. Interfaces 9, 12007 (2024)
[2] Granular Interfaces in TENGs: The Role of Close-Packed Polymer Bead Monolayers for Energy Harvesters ,Ignaas S. M. Jimidar, Kaspars Malnieks, Kai Sotthewes, Peter C. Sherrell, Andris Sutka, Small 21, 2410155 (2025)
[3] Strong piezoelectric-like electromechanical response from single granular PMMA interface, Ignaas S.M. Jimidar, Artis Linarts, Kai Sotthewes, Janis Lungevics, Peter C. Sherrell, Andris Sutka, Nano Energy 146, 111519 (2025)