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Reusable mask patterning (REMAP) opens new questions in field-induced aggregation and ordering

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Reusable mask patterning (REMAP) is a novel technological concept enabling a reconfigurable magnetic mask for micrometer-scale lithographic electroplating. Magnetic nanoparticles or microdroplets are deposited onto a substrate to form a desired pattern using tailored magnetic fields. Active ions in the surrounding electrolyte are subsequently deposited in nanoparticle-free regions, generating metallic or semiconductive patterns whose geometry can be readily reconfigured by changing the magnetic field.

In this presentation, we investigate two key aspects of the REMAP concept. The first concerns the deceleration of active-ion transport through a porous deposit of magnetic nanoparticles. Nanoparticles dispersed in a copper sulfate electrolyte are immobilized on a microelectrode surface by a permanent magnet, forming a dense cloud that slows copper-ion diffusion and significantly reduces the measured faradaic current. A theoretical model is developed to predict nanoparticle concentration profiles and the resulting current density through the cloud. The analysis demonstrates that copper-ion adsorption on negatively charged nanoparticles is a key mechanism responsible for reducing ionic transport.

The second aspect concerns the dynamics of ordered ferrofluid microdroplet patterns. Here, the masking pattern is created by magnetic microdroplets deposited on a macroelectrode. Under a homogeneous magnetic field normal to the substrate, the droplets repel each other through dipolar interactions and self-organize into a nearly hexagonal lattice. At higher magnetic fields, droplets may climb onto one another and form vertical chains while the lattice spacing simultaneously increases. This chaining process improves the lattice ordering, as quantified by the hexatic order parameter. The observed behavior is successfully described using a population-balance model combining lattice expansion with Smoluchowski-type association and fragmentation kinetics of droplet chains.

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