Toward Dynamic Control of Magnetic Nanoparticle Monolayers Fabricated by Electrophoretic Deposition: A New Path to Ordered Superlattices?

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Studies of nanoparticle monolayer formation have been motivated by potential applications of the films in magnetic storage, surface-enhanced Raman scattering coatings, ceramic joining, and biosensors, among others. Potential applications of nanoparticle monolayers rely on fabrication techniques that are facile, rapid, and site selective. Three of the most common techniques used to create monolayer films are Langmuir-Blodgett, ligand-mediated self-assembly, and evaporative self-assembly. Electrophoretic deposition (EPD) of nanoparticles s from colloidal suspensions stands as an equally powerful and versatile liquid-phase process to fabricate inexpensively films and coatings of materials. A wide assortment of materials, from macroscopic crystals to nanoparticles and including luminescent, magnetic, and ceramics materials, can be cast by EPD onto field-emanating conducting, semiconducting, and insulating substrates. Many potential commercial and industrial applications of nanoparticle ensembles rely on fabrication techniques that are facile, rapid, and site-selective which create homogenous, densely packed, defect-free thin films. EPD is a technique that meets all of these criteria.

In this presentation, we discuss the development of a new technique for fabricating locally-ordered arrays of NPs, electrophoretic deposition (EPD). EPD is a rapid, safe, and facile method for depositing suspended nanomaterials on a large scale. In one minute of deposition, we can fabricate homogeneous NP monolayers on macroscopic surfaces as large as square centimeters. Colloidal suspensions of magnetic nanoparticles [iron oxide (FeO_x/Fe_3O_4 core/shell, Fe_3O_4, and $CoFe_2O_4$ NPs] have been employed to fabricate nanoparticle monolayers by EPD. The rate of deposition and the total particle deposition were controlled by varying the concentration of nanoparticles and the deposition time, respectively. Using scanning electron microscopy and transmission electron microscopy, we observed tight, hexagonal packing of the nanoparticles, indicating strong particle-particle interactions. Multilayer growth also was achieved and assessed using scanning electron microscopy and atomic force microscopy, revealing a monolayer-by-monolayer growth process. Evidence of ordered monolayer films and the ease of creating multilayers based on said monolayers provide substantial promise for future device applications, ones for which the facile assembly of macroscopic, tightly packed, ordered casts of nanoparticles, i.e., a crystal of nanoparticles, could be transformative.