Watching Paint Dry: Controlling the Microstructure of Particle-Based Coatings

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ABSTRACT Nanoparticle and polymer composite coatings are ubiquitous in industry and consumer products such as cosmetics, latex paints, automotive paints and chemical agent resistant coatings (CARC) for defense applications, and more recently in pharmaceutical applications for drug delivery films. It is desirable to disperse, order, and lock-in the 3D structure of active constituents that determine the coating’s optical/mass/electronic transport properties. Despite a long history of development, challenges remain with regard to particle dispersion and self-assembly to impart a prescribed 3D microstructure to thin films. This talk will discuss recent research breakthroughs in coating/drying of particles-based thin films. First, convective deposition and Automated Langmuir-Blodgett will be described in our scalable nanomanufacturing efforts to make highly ordered 2D and 3D particle arrays for optical materials and nanostructured membranes for bioMEMS. Second, the microstructure evolution in drying polymer-particle based coatings will be demonstrated using dynamic 3D high speed confocal laser scanning microscopy. The solution composition, particle interactions, and processing conditions have a large effect on the dynamic structural evolution. Perhaps more intriguing is the distribution of polymer in these films. While flow and drying stresses set the colloidal microstructure of these films, after this microstructure is set various modes of air entrainment into the matrix are observed following various capillary, viscous, and elastic modes of instabilities. The predominant mode of air entrainment at moderate polymer concentrations shows micron-scale viscous fingering reminiscent of the Saffman-Taylor instability, yet at length scales much smaller than expected. We hypothesize this is due to the polymer nanoconfinement and demonstrate similar viscous fingering instabilities in nanoporous colloidal crystals. Support for this work has come from the National Science Foundation’s CBET and Scalable Nanomanufacturing Programs, the Department of Energy, and the PA NanoMaterials Commercialization Center.

BIO Dr. James Gilchrist is a Professor of Chemical and Biomolecular Engineering at Lehigh University. Gilchrist directs the Laboratory for Particle Mixing and Self-Organization with research interests spanning various particle technologies including nanoparticle self-assembly, suspension rheology and transport, coatings, microfluidics, chaotic mixing, and granular dynamics. He received his B.S. in Chemical Engineering from Washington University in St. Louis and Ph.D. from Northwestern University. Prior to joining the faculty of Lehigh University in 2004, he was a postdoctoral research associate in the Department of Materials Science and Engineering at University of Illinois. He received the North American Mixing Forum Young Faculty Award in 2007, served as chair AIChE's Fluid Mechanics, is chair-elect of AIChE's Particle Technology Forum, and serves on the executive committees of the International Society of Coating Science and Technology and the International Polymer Colloids Group. Dr. Gilchrist was a visiting professor in the Department of Chemical Engineering at the California Institute of Technology for the 2011-2012 academic year, and a Visiting Professorial Fellow at University of New South Wales in 2016.