

Colloidal Interactions, Dynamics, and Assembly on Energy Landscapes

Michael A. Bevan, Chemical & Biomolecular Engineering, Johns Hopkins University

The autonomous and reversible assembly of colloidal nano- and micro- scale components into ordered configurations is often suggested as a scalable process capable of manufacturing meta-materials with exotic electromagnetic properties (e.g. photonic band gap, negative refraction) that could enable numerous emerging technologies (e.g. optical computing, sub-diffraction limit imaging, invisibility cloaking). However, the inability to produce such ordered materials with a sufficiently low defect density has limited the development of the science and applications of such materials. As a result, there is strong interest in understanding how thermal motion, particle interactions, patterned surfaces, and external fields can be optimally coupled to robustly control the assembly of colloidal components into hierarchically structured functional meta-materials.

We approach this problem by directly relating equilibrium and dynamic colloidal microstructures to kT -scale energy landscapes mediated by colloidal forces, physically and chemically patterned surfaces, and gravitational and external electromagnetic fields. 3D colloidal trajectories are measured in real-space and real-time with nanometer resolution using an integrated suite of evanescent wave, video, and confocal microscopy methods. Equilibrium structures are connected to energy landscapes via statistical mechanical models. The dynamic evolution of initially disordered colloidal fluid configurations into colloidal crystals in the presence of tunable interactions (polymer depletion, electric fields) is modeled using a novel approach based on fitting the Smoluchowski equation to experimental microscopy and computer simulated assembly trajectories. This approach is based on the use of reaction coordinates that capture important microstructural features of crystallization processes and rigorously quantify both statistical mechanical (free energy) and fluid mechanical (hydrodynamic) contributions. With the ability to measure and tune kT -scale colloidal interactions and quantitatively model how such interactions are connected to dynamically changing microstructures, we demonstrate real-time control of assembly, disassembly, and repair of colloidal crystals using both open loop and closed loop control to produce perfectly ordered colloidal microstructures. This approach is demonstrated for close packed colloidal crystals of spherical particles and is being extended to anisotropic particles and non-close packed states.

Michael A. Bevan is a Professor of Chemical & Biomolecular Engineering at Johns Hopkins University. He received his Ph.D. from Carnegie Mellon University in 1999. After post-doctoral appointments at the University of Melbourne, Australia, and the University of Illinois at Urbana-Champaign, he joined Texas A&M University in 2002 and Johns Hopkins University in 2008. Bevan's research investigates interactions, dynamics, and structure in interfacial colloidal systems. Bevan is a recipient of a CAREER award and a PECASE from the National Science Foundation.