Department of Electrical and Computer Engineering
Center for Integrated Bio and Nano Systems
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11:15 a.m., Room: CBB 122

Anisotropy, Symmetry, and Valency in Nanoparticle-Based Materials Design

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Abstract: The a priori design of inorganic solid state materials is often limited by the compatibility of different atomic precursors and a lack of generalized rules for crystallization. An intriguing way to circumvent these challenges is to imagine nanoparticles as 'meta-atoms', where the composition of the core dictates material properties and the surface ligands control bonding and structure formation. However, because most syntheses produce nanoparticles that are spherical, assembled materials are often limited to densely-packed, high-symmetry arrangements. Atomic systems, on the other hand, make use of directional bonds and the principle of valency to create low-symmetry molecules and crystals of impressive sophistication. In this talk, I will introduce the concept of nanoparticle shape anisotropy as a means to mimic the highly-directional interactions found in atoms and molecules. In particular, I will show that when functionalized with duplexed DNA strands, the flat facets of anisotropic particles act to bundle and orient molecules in well-defined surface-normal orientations. Thus, the symmetry and valency of the building block can be controlled by the shape and surface faceting of the underlying nanoparticle. This has profound consequences for creating low-dimensionality nanoparticle superlattices when particles are programmed to assemble via the hybridization of complementary DNA strands. By tailoring the length and sequence of the DNA ligands, crystalline nanoparticle-based materials can be assembled that have no atomic analogues and would be difficult, if not impossible, to synthesize using traditional lithographic techniques. Next, I will explore the synthetic origins of shape anisotropy by introducing liquid-phase transmission electron microscopy as a tool for monitoring single-particle reaction dynamics in real time. When a range of different anisotropic gold nanoparticles are exposed to an oxidizing environment triggered by the electron beam, they undergo structural transformations to higher-energy particle shapes as they are etched and ultimately dissolved completely. The nature of these unusual intermediate objects is rationalized on the basis of detailed Monte Carlo simulations and a simple coordination-number driven etching mechanism. Separately, I will show that the kinetic trajectory observed for a particular nanocrystal oxidation reaction is heavily-dependent on the spatial distribution of surface-bound ligands. This observation allows one to map the location and conformation of molecular ligands bound to nanocrystal surfaces with high spatial resolution. Taken together, these results contribute new design rules at the atomic, molecular, and nanoparticle levels for the synthesis of inorganic solid state materials and promise a more complete control over the dimensionality, symmetry, and properties of matter.

Bio: Matthew R. Jones was born in San Diego, California, and obtained B.S. degrees in materials science & engineering and biomedical engineering from Carnegie Mellon University in 2007. He received an NSF Fellowship to pursue his Ph.D. in materials science & engineering under the guidance of Chad Mirkin at Northwestern University and investigated the assembly of anisotropic nanoparticles using DNA as a programmable linker. In 2014 he began postdoctoral work with Paul Alivisatos at UC Berkeley as an Arnold O. Beckman Fellow and used liquid-phase transmission electron microscopy to investigate high-energy nanocrystal shape transformations. His research interests include nanoparticle-based materials that assemble under non-equilibrium conditions and exhibit dynamic, time-dependent properties.
Contact Prof. Jiming Bao (jbao@uh.edu) if you would like to arrange for a time to meet with Dr. Jones.