Self Assembly to 2D Nano-Particles

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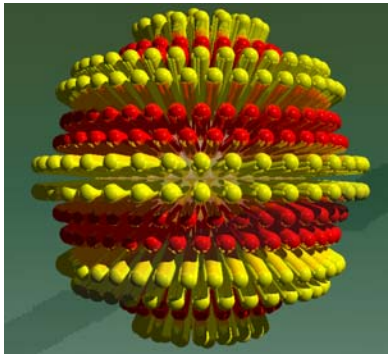
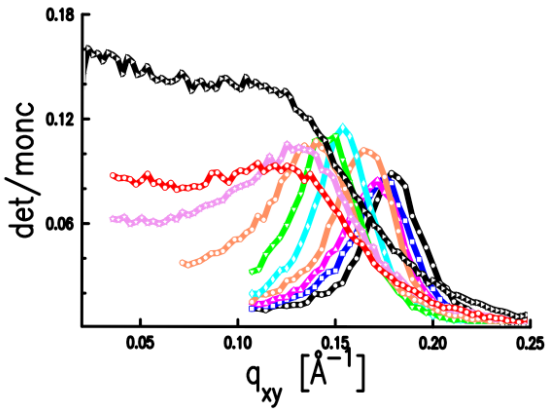
The formation of ordered arrays of nano-scale structures is a major contemporary technological objective. One approach is to use natural thermodynamic processes to control the self assembly of nano-scale objects into ordered arrays. In this project we study the self assembly process through control of the adsorption of thin liquids (i.e. <10nm) on the surfaces of a monolayer of organically capped Au particles that have been deposited on a solid substrate. The evolution from a diffraction peak to a broad diffuse structure illustrates the change from partially ordered 2D to a dissolved, or melted structure.



Cartoon of ~3 nm Au particle capped with a mixture of two different organic molecules.

Changes in diffraction from a 2D monolayer of the Au particles with increasing solvent.



There is growing interest in the use of nano-particles for both technological electronic applications as well a for diverse other problems such as the understanding of the adhesion process necessary for viral recognition of host cells and for development of self-assembly methods using DNA crystals as a programmable molecular scaffolding. Although some of the technology for manipulation of nano-particles is fluid free, it is important to know whether or not it will be possible to self assemble nano-particle arrays from fluid solutions. One goal of this project will be to understand the basic physics of solvation and self-assembly in confined geometries with various solvents. In this project we use synchrotron radiation to measure the structure of 2D assemblies of monolayers of Au particles in equilibrium with nano-thick liquids. By controlling degree of under saturation of the vapor pressure of the liquid film, film thicknesses that vary from ≤0.1nm to ~ 10 nm can be formed. The lower right figure illustrates diffraction measurements that show the evolution from a 2D dense packed amorphous solid (sharp peak) to a thicker 2D liquid in which the particles are partially dissolved. All of the applications of metal nano-particles (MNP) in solution require that the MNP surface be stabilized by some type of surfactant "cap" that results in a "soft outer shell." As a result the interparticle interactions are more complicated than just simple hard_core repulsion and van der Waals attraction. The cartoon above illustrates a 3nm Au particle whose cap consists of a mixture of two types of surfactants. By varying both the nature of the cap and the solvent we can manipulate the conditions for self assembly.

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Education:

One graduate student and one postdoctoral fellow at Harvard are being trained in the specialized techniques for study of liquid surfaces that make use of the National Synchrotron Radiation facilities

Societal Impact:

One possible path for development of nano-scale devices is to harness the potential for self assembly from solution of nano-scale particles. In this project we are developing unique methods for studying the fundamentals of the self assembly process of selected nano-scale particles in confined geometries.