

Tuesday Afternoon, November 10, 2009

Nanometer-scale Science and Technology

Room: L - Session NS2-TuA

Templated Self-Assembly

Moderator: N.A. Burnham, Worcester Polytechnic Institute

2:00pm **NS2-TuA1 Size-selective Templated Self-Assembly of Particles**, *C. Kuemin*, ETH Zurich, Switzerland, *E. Loertscher, A. Rey, A. Decker*, IBM Research GmbH, Zurich Research Laboratory, Switzerland, *N.D. Spencer*, ETH Zurich, Switzerland, *H. Wolf*, IBM Research GmbH, Zurich Research Laboratory, Switzerland

The special properties of nanoscale objects, such as metal and semiconductor nanoparticles, nanowires, or nanotubes, make them promising building blocks of novel optical and electronic devices. The systematic fabrication of devices usually requires the integration of these heterogeneous materials into a larger, ordered structure. More complex device architectures may, in addition, entail the selective assembly of several different types of small objects into pre-defined locations or demand an assembly with the correct orientation when such objects are nonspherical.

Serial pick-and-place techniques are no longer economical at these length scales. Self-assembly mechanisms can arrange a large number of objects in parallel, but will mainly produce homogeneous monolayers limited to the characteristic length-scale of the assembled objects (e.g. the diameter of the particles). Templated assembly on the other hand, provides an adequate strategy for the massively parallel arrangement of particles into designed patterns of arbitrary structure. With selective assembly sites, integration of different components becomes feasible.

Here we show concepts and experimental implementations for the selective templated self-assembly of spherical particles of different size. Particles between 200 and 500 nm in size are assembled selectively into predetermined locations on a template. We use capillary assembly from aqueous suspensions onto templates with topographic features that are selective for a certain particle size. The templates are prepared in poly(dimethylsiloxane) (PDMS) molded from a topographically patterned master. The master is a Si wafer patterned by electron beam lithography.

As a model system for the templated self-assembly of nonspherical objects we use Au nanorods.

2:20pm **NS2-TuA2 Templated Self Assembly of 6 nm Gold Nanoparticles by Means of micro-Trough Technique**, *L.E. Ocola*, Argonne National Laboratory, *A. Chao*, Illinois Mathematics and Science Academy

This paper demonstrates that combining top-down electron beam lithography and bottom-up colloidal chemical assembly leads to large scale placement of nanoparticles on arbitrary flat substrates. We report on the templated self-assembly of 6 nm gold nanoparticles using template geometries that lend themselves to induce self-assembly at distances significantly larger than typical trench geometry constraints. We can obtain oriented and ordered arrays of 6 nm gold nanoparticles that extend hundreds of nanometers away from any template boundary. The goal is to be able to create oriented arrays of nanoparticles over hundreds of microns. We have developed a micro-Trough technique where we define a specific area on where to create an equivalent of a Langmuir Blodgett trough directly on a sample surface. Using this technique we overcome liquid current effects usually encountered in traditional colloid dispersion deposition techniques. Progress in templated self-assembly will lead to novel nanophotonic and chemical sensing devices, along with the means to extend top-down nanofabrication below the 10 nm barrier.

2:40pm **NS2-TuA3 Focused Ion Beam Templating and Doping of Si(Ge) Nanostructures**, *J.F. Graham, C.D. Kell, J.A. Floro*, University of Virginia, *R. Hull*, Rensselaer Polytechnic Institute

An important application of the focused ion beam (FIB) is nanoscale modification of surfaces for directed self-assembly of nanostructures. In previous work, we have demonstrated Ga⁺ FIB patterning of Si(100) substrates followed by epitaxial deposition, resulting in templated nucleation of Ge quantum dots (QDs) and SiGe quantum dot molecules (QDMs). Such positional control of QD growth using FIBs should be useful in fabricating potential, QD-based nanoelectronic devices like quantum-dot cellular automata and spin exchange switches. However, since Ga is a *p*-type dopant in Si, patterning with Ga⁺ ions from a conventional liquid metal ion source (LMIS) leads to uncontrolled doping of the Si substrate. Moreover, Ga can behave as a surfactant during epitaxial growth of Si and

Ge. In this work, we use electrically non-invasive ions for FIB-templated growth in order to avoid Ga doping and as a means to investigate fundamental mechanisms involved in templated nucleation of QDs. We employ a mass-selecting FIB and alloy LMISs to work with ions which are unobtainable from elemental sources. Ions of particular importance for non-invasive patterning include Si (obtained from a AuSi LMIS) and Ge (from a AuGeMn LMIS). In addition, the use of B ions (from an AsPdB LMIS) is explored as a potential method of producing auto-doped, templated QDs. These techniques are establishing a platform for nanoscale control of the formation, position and doping of epitaxial QD arrays of any desired complexity.

4:00pm **NS2-TuA7 Clathrin: A Protein Scaffold for Biotemplating 2-D and 3-D Nanostructures**, *A.P. Schoen, S.C. Heilshorn*, Stanford University

Nature has evolved numerous methods for the self-assembly of nanoscale architectures with high levels of precision. Biomolecules such as DNA, bacterial membranes, viral particles, and proteins all exhibit stunning regularity and reproducibility in the structures they can achieve, making them ideal templates for the patterning of inorganic nanostructures. While some success has been realized in patterning materials from these biological templates, they generally have been limited to simple 0-D or 1-D structures. In contrast, proteins have the ability to form 2-D and 3-D structures, and the immense library of naturally available proteins encourages the development of new techniques to reproducibly template these materials.

Using clathrin as a model protein, we are developing flexible biotemplating protocols to interface protein structures with a variety of inorganic materials. The intracellular transport protein clathrin is composed of three semi-flexible arms that form a pinwheel structure with three-fold symmetry. Clathrin provides a framework that offers access to a variety of architectures, both 2-D and 3-D, such as sheets, tetragons, and geodesic spheres depending on the environmental conditions (pH, concentration, buffer ionic strength) during assembly. The ability of this single protein to assemble into multiple structures makes clathrin an ideal model system for investigating the underlying kinetic and thermodynamic principles of self-assembly. To interface these biological templates with inorganic materials, we design bi-functional peptide linkers that serve as molecular bridges between the clathrin protein and inorganic materials. Rational design of these bi-functional peptide linkers includes a conserved clathrin-binding motif fused to an inorganic-binding peptide sequence. This newly developed strategy enables great flexibility to interface a single protein biotemplate with a variety of different inorganics without requiring any direct modifications to the template. The ability of a single protein biotemplate to assemble into multiple 2-D and 3-D protein nanostructures and to interface with a variety of inorganic materials makes this modular, self-assembling system applicable to a broad range of applications.

4:20pm **NS2-TuA8 Assembly of Block Copolymer Micelles on a Lithographically Modified Surface**, *A. Pearson, R.C. Davis*, Brigham Young University

Block copolymer self-assembly is a promising method of creating ordered arrays with feature sizes smaller than possible by conventional lithography techniques. Block copolymer micelle patterning has proven to be a versatile method of creating hexagonal arrays of metal nanoparticles with sizes less than 10 nm and spacing that can be adjusted by changing the molecular weight of the block copolymer used. In order to use these nanoparticles for many lithographic applications, registration of the nanoparticles with other surface patterns is essential. Here we exploit the self-aligned assembly of PS-P2VP block copolymer micelles with both topographical and chemical surface patterns to achieve micelle registration. Specifically e-beam lithography and plasma etching of SiO₂ surfaces was used to create recessed boxes and ovals where controlled numbers of micelles were deposited by dip coating. Chemical patterning was used to selectively place micelles in the recessed patterns with low micelle adsorption in the non-recessed regions. Gold nanoparticles were formed from the micelles by adding HAuCl₄ to the micelles in solution prior to deposition. After dip coating, an oxygen plasma etch removes the polymer, leaving gold nanoparticles. Scanning electron and atomic force microscopy were used to measure nanoparticle alignment.

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