Nanometer-Scale Science and Technology
Room 210 - Session NS2-MoA

Nanometer Scale Assembly

Moderator: D.W. Carr, Sandia National Laboratories

2:00pm **NS2-MoA1 Seeing SAMs**, ***R.G. Nuzzo***, University of Illinois, Urbana-Champaign **INVITED**

We have begun a new program that exploits optics as a tool for exploring complex forms of surface chemistry. In this talk, I will describe the progress made in our recent work in this area, one that exploits the use of SAMs in several areas of technology. Of particular interest in this regard is the development of new SAM-based assembly systems-and chemistry for their modification-that allows their use as a platform for array-based proteomic assays. I will highlight in this presentation recent work that has led the development of new protocols-ones exploiting assembly, surface modification, soft lithography, and microscopy-that possess considerable potential for chemical sensing. The enabling of label free detection of protein binding events using non-spectroscopic methods of detection based on new imaging protocols will be discussed. The hope for SAMs, in this context then, is to demonstrate that seeing is believing.

2:40pm **NS2-MoA3 Directed Assembly and Separation of Self-Assembled Monolayers Via Electrochemical Processing**, ***T.J. Mullen***, *A.A. Dameron, J.R. Hampton, P.S. Weiss,* The Pennsylvania State University

We have directed separation in self-assembled monolayers (SAMs) on Au{111} using electrochemical desorption and characterized them with scanning tunneling microscopy (STM) and voltammetry. Separated domains of 1-dodecanthiolate were created by solution insertion into 1-adamantanethiolate SAMs. The adamantanethiolate domains were selectively desorbed by applying a reductive potential. Subsequently, the samples were immersed in 1-octanethiol solution, thereby producing SAMs with separated domains of dodecanthiolate and octanethiolate. We have investigated the molecular order of each lattice type with STM. The apparent height difference in the STM images and the two distinct cathodic peaks observed with voltammetry indicate distinct separated domains. The fractional coverages of each lattice before and after electrochemical desorption were calculated using both STM images and voltammograms. Using this electrochemical process, high-resolution chemically patterned surfaces with application in areas ranging from microelectronics to biocompatible systems have been assembled and characterized with molecular precision.

3:00pm **NS2-MoA4 AFM Investigation of the Growth of Self-Assembled MOSUD Layers**, ***T.Y. Shih***, *B.E. Koel, A.A.G. Requicha,* University of Southern California

Designed fabrication of structures on a nanometer scale often requires progress in the efficiency and control in deposition of self-assembled monolayers, especially in an approach that we have called layered nanofabrication (LNF). We report results demonstrating controlled growth of layers of (10-carbomethoxydecyldimethylchlorosilane) MOSUD that are used for embedding and planarizing patterns of Au nanoparticles. These studies of the growth of self-assembled monolayers of MOSUD extend previous investigations of modification of silicon surfaces by silane adsorption. In particular, we studied the influence of an anchor layer for stabilizing the Au nanoparticles. Atomic force microscopy (AFM) was used ex-situ to characterize the formation and quality of self-assembled mono and multilayers. In addition, ellipsometry was used to monitor the MOSUD film thickness and characterize the film growth mode. Growth of layers with a uniform packing and constant height could be obtained and the film thickness could be increased without covering the Au nanoparticles.

3:20pm **NS2-MoA5 Submicron Dispersions from Urea-Based Liquid Crystalline Phases**, ***C. Fong***, CSIRO Molecular Science, Australia; *J. Booth,* RMIT School of Applied Sciences, Australia; *C.J. Drummond, I. Krodkiewska, D. Wells, P.G. Hartley,* CSIRO Molecular Science, Australia

Surfactant self assembly phases such as micelles, vesicles / liposomes, and lyotropic mesophases are of technological importance as carriers for cosmetic formulations, as drug delivery systems, and as protein crystallisation media. Lyotropic mesophases offer particular advantages since under certain conditions they are robust to dilution, temperature and composition. The three dimensional structure also enhances solubilisation of hydrophilic and/or hydrophobic moieties when compared to their liposomal analogues. There are currently a limited number of materials which exhibit dilutable mesophase behaviour. Our aim was to design surfactants capable of self assembling into higher order surfactant liquid crystalline phases, which would be stable to dilution over a broad temperature range. In this study we have explored the urea based surfactants since the conventional wisdom suggested that this class of compounds was unable to form liquid crystalline phases. This work negates this long held view and demonstrates for the first time that surfactant mesophases with the urea head group are favoured by highly splayed hydrophobes with exaggerated cross sections. Hydrophobes such as hexahydrofarnesyl and phytanyl were successful in promoting room temperature inverse hexagonal phases which are stable against dilution and robust for a large temperature and composition regime. The current synthesis strategy has therefore more than doubled the previously known numbers of compounds with these properties. Colloidal dispersions of the bulk inverse hexagonal phase were prepared with average particle size < 300 nm. These nanoparticles have much reduced viscosities over the bulk phase with high surface area and the benefit that the bulk structure has been preserved. Significantly, they are of a suitable size range for applications such as intravenous drug delivery or bioremediation.

3:40pm **NS2-MoA6 Nanometer-scale Structures Created using Molecular Self-Assembly for Building Blocks and Components**, ***M.E. Anderson***, *C. Srinivasan, R. Jayaraman, E.M. Carter, M.W. Horn, P.S. Weiss,* The Pennsylvania State University

Molecular self-assembly plays an important role in the development of many nanolithographic techniques acting as building blocks and/or an active components for nanometer-scale devices. We have utilized self-assembled multilayers in conjunction with conventional lithography to create metal electrode structures with precise proximal placement in the 10-50 nm regime.@footnote 1-3@ By controlled placement and thickness of these multilayers (building blocks), the spacing between the electrodes can be fabricated with single nanometer resolution. Much effort has gone into developing the lithographic process steps to create precise nanometer-scale gaps reproducibly with electrical integrity.@footnote 4@ We will present methods relevant to the processing parameters and data regarding the electronic characterization of these nanogaps. The optimization of lithographic processes compatible with self-assembly has opened a novel avenue for directed chemical patterning of multi-component self-assembled films. The multilayers themselves are interesting complex nanometer-scale materials; studies are underway to understand and to manipulate their formation and electrical properties. We continue to push this technology toward architectures relevant for device fabrication; these techniques will be discussed. @FootnoteText@ @footnote 1@ A. Hatzor and P.S. Weiss, Science 291, 1019 (2001).@footnote 2@ M. E. Anderson et al., Journal of Vacuum Science and Technology B 20, 2739 (2002).@footnote 3@ M. E. Anderson et al., Journal of Vacuum Science and Technology B 21, 3116 (2003).@footnote 4@ M. E. Anderson et al., MicroElectronic Engineering, in press.

4:00pm **NS2-MoA7 Electric Nanocontact Lithography to the Directed Self-Assembly of Nanoparticle Based Devices**, *C.R. Barry, A.M. Welle, U. Kortshagen, S. Campbell,* ***H.O. Jacobs***, University of Minnesota **INVITED**

The first part of this talk will review recent results in the area of Electric Nanocontact Lithography while the second part will discuss the use of electrostatic forces to direct the assembly of nanomaterials. First we report on a programmable, reconfigurable, printing approach for parallel nanofabrication of three different types of structures: patterns of charge, oxide, and e-beam sensitive resist. Our approach that we refer to as Electric Nanocontact Lithography (ENL) is based on previous knowledge in the area of conducting scanning probe lithography which uses a conducting probe to electrically expose and modify a surface. ENL makes use of the same physical principles; however, instead of using a single electrical point contact, we use programmable electrical nanocontacts of different size and shape to expose a surface. In the second part we report on a novel directed self-assembly process to assemble nanoparticle based devices. Nanoparticles are considered potential building blocks for the fabrication of future devices. The use of nanoparticles and nanomaterials in general, however, requires novel assembly concepts. The concept that we present is based on electrostatic interactions. In particular we demonstrate directed self-assembly of nanoparticles onto charged surface areas (receptors) with 40 nm resolution. A liquid-phase assembly process where electrostatic forces compete with disordering forces due to ultrasonication has been developed to assemble nanoparticles onto charged based receptors in 10 seconds. A gas-phase assembly process has been developed that uses a transparent particle assembly module to direct and monitor the assembly of nanoparticles from the gas phase. A process is also being developed to

enable the patterning of any organic and inorganic nanomaterials with sub 100 nm resolution. First patterns of bio-molecules will be presented. Currently, the electrostatically directed assembly of sub 10 nm sized proteins, 10 - 100 nm sized metal, 40 nm sized silicon nanocubes, and 30 nm - 3000 nm sized carbon nanoparticles has been accomplished. The application to nanoparticle devices will be discussed and first results on a nanoparticle transistor will be presented.

4:40pm **NS2-MoA9 Self-Assembly Activated by Molecular Motors**, ***H. Hess***, University of Florida; *J. Clemmens,* University of Washington; *C. Brunner,* ETH Zurich, Switzerland; *R. Doot,* University of Washington; *S. Luna,* ETH Zurich, Switzerland; *K.-H. Ernst,* EMPA Duebendorf, Switzerland; *V. Vogel,* ETH Zurich, Switzerland

In molecular self-assembly, the transport of the interacting parts is typically diffusive, and thermal forces prevent the mismatched assembly of non-complementary parts. This situation has serious disadvantages: Diffusive transport slows as building blocks become larger, thermal forces are distributed over a wide range which is difficult to adjust, and thermal forces strain even correctly assembled connections. Active transport on a molecular scale, for example powered by biomolecular motors, can overcome these disadvantages and provide strong, tunable, and directed forces which facilitate the ordered assembly of supramolecular structures. Furthermore, the assembled structures can be under internal strain and internally ordered without representing a minimum energy configuration. As a consequence of the transport properties of the system a high degree of long-range order can emerge. We experimentally demonstrated such a self-assembly system relying on active transport of functionalized microtubules by kinesin motor proteins.@footnote 1@ @FootnoteText@footnote 1@ Hess, H.; Clemmens, J.; Brunner, C.; Doot, R.; Luna, S.; Ernst, K.-H.; Vogel, V., Molecular self-assembly of "Nanowires" and "Nanospools" using active transport. Nano Letters 2005, 5, (4), 629-633.

5:00pm **NS2-MoA10 Directed Assembly and Real-Time Electrical Detection of Nanowire Bridges**, ***L. Shang***, *M. Marcus, J. Streifer, B. Li, R.J. Hamers,* University of Wisconsin-Madison

We have explored the use of dielectrophoretic manipulation combined with biomolecular recognition to control bridging of individual metallic and semiconducting nanowires across micron-sized electrical gaps. While dielectrophoretic manipulation is only temporary, more permanent assembly can be achieved using biomolecular recognition. For example, while biotin-modified nanowires interact only weakly with bare Au electrodes, they bind strongly to avidin-modified electrodes. The bridging of a nanowire across the gap can be detected electrically even though the nanowire is spaced away from the gold contact by the biomolecular contact. We have develop a novel method for achieving real-time monitoring of nanowire bridging events, using one AC electric field to manipulate the wires and a second field to measure the changes in electrical response induced by nanowire bridging. Because the change in electrical response is primarily capacitive, detection of bridging events is most sensitively achieved at higher frequencies, on the order of 1 kHz-100 kHz. At a fixed measurement frequency, we observe a step-like increase in current when a nanowire bridges the electrodes. Individual silicon and metal nanowires can be detected visually as well as electrically, allowing visual confirmation of the origin of the electrical response.

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