Monday Afternoon, October 15, 2007

Nanometer-scale Science and Technology

Room: 616 - Session NS-MoA

Nanoscale Assembly and Manipulation II

Moderator: H. Schift, Paul Scherrer Institute, Switzerland, H. Wolf, IBM Research GmbH, Zurich Research Laboratory

2:40pm **NS-MoA3 Controlled Manipulation of Self-Organized Ni (II)-Octaethylporphyrin Molecules Deposited from Solution on HOPG with a Scanning Tunneling Microscope**, ***L. Scudiero***, *K.W. Hipps*, Washington State University

We have investigated the controlled manipulation of self-assembled NiOEP molecules adsorbed from a benzene solution onto a freshly cleaved high ordered pyrolytic graphite surface using the scanning tunneling microscope (STM) under ambient conditions. STM images acquired before and after scans of different patterns at a high current setpoint value reveal the creation of molecule free regions. In these cleared regions STM images reveal a 2D HOPG lattice with atomic spacing of 2.5 Å and a pattern depth of about 1.2 Å which is a typical STM height value for a monolayer NiOEP film on graphite. These molecule free regions are created by the transfer of NiOEP molecules from the surface to the tip when the STM is operated at very high current setpoint (tunneling resistance of about 120 MΩ or less). Once the molecules are picked up by the tip they then diffuse along the wire as confirmed by the absence of molecular build-ups around the patterned areas of the STM images. Furthermore, once the molecular film is damaged the size of the uncovered area keeps on growing larger with subsequent scans. In the case of square scans performed at high current setpoint values the freshly created regions exhibit straight edges with directions that are dictated by the lattice vectors of the underlying graphite substrate.

3:00pm **NS-MoA4 Manipulation and Electrical Characterisation of Carbon Nanotubes by using Nanomanipulators in the SEM System**, ***M. Passacantando***, *F. Bussolotti, V. Grossi, S. Santucci, L. Lozzi*, University of L'Aquila - Italy

The results of in situ manipulation and electrical transport characterisation of individual MWCNT grown on nickel tip by using a piezoelectric nanomanipulation system operating in a SEM chamber have been reported. The growth of MWCNT directly on nickel wire by chemical vapour deposition technique ensures a good electrical contact with the catalyst substrate. Using the electron beam induced welding a fully characterization of electronic properties of several MWCNT has been explored without the usual postprocessing methods which may alter, in principle the intrinsic properties of the CNT. Thanks to the high mechanical and electrical stability ensured by the electron beam welding procedure a detailed study of the CNT electrical transport properties modification under CNT buckling has been performed. The crucial role played by the structural defects in determining an irreversibility of a long MWCNT IV characteristic under mechanical stress has been clearly evidenced. Finally, by a proper sequence of CNT/tip welding and movement the potentiality in creating ohmic junction between two nanotubes has been demonstrated opening the route to a systematic investigation of one of the most fundamental aspect of the CNT physics.

3:40pm **NS-MoA6 Automatic Manipulation of Nanoparticles with a Software-Compensated AFM**, *B. Mokaberi, D.J. Arbuckle, J. Yun,* ***A.A.G. Requicha***, University of Southern California

Manipulation of nanoparticles by pushing them with the tip of an Atomic Force Microscope (AFM) has been under development for over a decade, and is now routinely performed in several laboratories around the world. However, AFM nanomanipulation of small particles with sizes on the order of 10 nm has been until now a time-consuming and labor-intensive process. Automation has remained a desirable but elusive goal, primarily because of the spatial uncertainties associated with the positioning mechanisms of the AFM and with the manipulation process itself. Extensive user intervention has been required, resulting in very low throughput and severely limiting the complexity of structures that could be built with a reasonable amount of time and labor. This talk describes an automatic system for building patterns of nanoparticles by AFM manipulation. A planner determines the paths required to convert an initial, random distribution of particles on a surface into a desired pattern. The planner generates a sequence of motion commands for positioning the tip and pushing the particles. The commands are executed through software that compensates for thermal drift, creep and hysteresis. Experimental results show that the system can build in minutes a pattern that would take an experienced user several hours to construct interactively.

4:00pm **NS-MoA7 Directed Assembly of Metal Contacts to Silicon Nanowires using Electrodeposition**, ***S. Ingole***, *P. Aella,* Arizona State University, *S.J. Hearne,* Sandia National Laboratories, *S.T. Picraux*, Los Alamos National Laboratory

A technique based on electrodeposition for electrically contacting semiconductor nanowires (NWs) is presented. In the majority of exploratory studies electron-beam lithography has been utilized for establishing the metal-nanowire contacts. While useful for laboratory investigation this technique requires a post nanowire-assembly photolithography step and is too slow for large scale assembly. Thus new techniques are needed that are easy to integrate, low cost and involve minimum additional time for integration of nanowires onto device platforms. In the present work we report a process based on electrodeposition for establishing metal contacts to silicon nanowires (SiNWs). In this technique nanowires are first aligned between pairs of planar metal electrodes using dielectrophoresis. These electrodes have been predefined on top of an oxidized silicon substrate using photolithography. After the alignment, the ends of SiNW are resting on top of the metal electrodes and held in place by the Van der Waals attraction with the electrodes. In order to achieve good electrical contacts, metal has to be conformally deposited encapsulating the ends of these nanowires. In the present work this has been achieved via electrodeposition where prefabricated metal electrodes act as selective sites for deposition of metal. As the deposition proceeds the ends of nanowire become encapsulated by the electrodeposited metal. This avoids post NW-assembly photolithography, reducing the associated processing complexity. Metal doesn't deposit on the SiNW surfaces because of the native oxide present around them. We have demonstrated this process using electrodeposited Ni on electrically doped Si nanowires. Good coverage and control for nanowires aligned between Au/Cr pre-defined electrodes has been achieved and post-electroplating annealing resulted in specific contact resistivities ~10^{-6} Ohm-cm^2. Although native oxide is useful for avoiding metal plating on the surface of NW, it acts as barrier for metal-SiNW reaction during annealing of such contacts. Also Au is not a desirable metal for devices. Therefore we have explored the use of other electrode array metals such as Ni/Ti to replace Au as well as to assist in reducing the native oxide during annealing for good metal-SiNW contacts. The results are promising for development of a general self-assembly technique for the integration of nanostructures on device platforms.

4:20pm **NS-MoA8 Multi-Island Single-Electron Transistors Made by Lithographic Contacting of Gold-Nanocrystal Chains**, ***D.N. Weiss***, Washington Technology Center, *X. Brokmann, L.E. Calvet,* CNRS, France, *M.A. Kastner, M.G. Bawendi*, Massachusetts Institute of Technology

We demonstrate a fabrication scheme that bridges the dimensional gap between lithographic dimensions and nanocrystal sizes. The method involves lithographic contacting of previously self-assembled, alkanethiol-coated nanocrystal chains. Because one nanocrystal is incorporated into the edge of the larger electrode, all of the important tunnel junctions are defined by self-assembly rather than lithography. This method allows the fabrication of one-dimensional island arrays, similar to those used for metrology, with predictable electronic characteristics. Specifically, we show that the electronic behavior of a double-island device can be fully explained using the standard theory of Coulomb blockade, with very few adjustable parameters.

4:40pm **NS-MoA9 Dip Pen Nanolithography using NanoInk's NSCRIPTOR System: Nanolithography and Nanoscale Assembly Using Biological and Metal Inks**, ***E.R. Tevaarwerk***, *M. Parpia, N.A. Amro, S. Rozhok, J. Haaheim, F. Villagran, T. Renner, M. Nelson, J. Fragala, T. Levesque*, NanoInk

Precision nanoscale deposition of biological, organic, and inorganic materials is a fundamental need in nanoscience research. Relative to other nanopatterning techniques, dip-pen nanolithography-DPN is a direct-write technique maintaining high resolution (30 nm line widths, 50 nm pitches), and among sub-50 nm techniques, DPN is the only one that can directly deposit molecules under ambient conditions. A wide variety of biological, organic and inorganic materials can be deposited. We will discuss the development of a silver nanoparticle based ink for the writing of conductive metal traces, as well as recent developments in "Just Add DNA" inks for DNA nanopatterning for the making of DNA nanoarrays. We demonstrate results of DPN patterning with these two inks using NanoInk's one dimensional probe arrays, and microfluidic ink delivery tools. We discuss the implications of these results and tools in furthering the application of

dip-pen nanolithography as a large scale, multi-ink patterning tool, including recent developments for massively parallel patterning using the two-dimensional nanoprint array (2DnPA).

Authors Index

Bold page numbers indicate the presenter