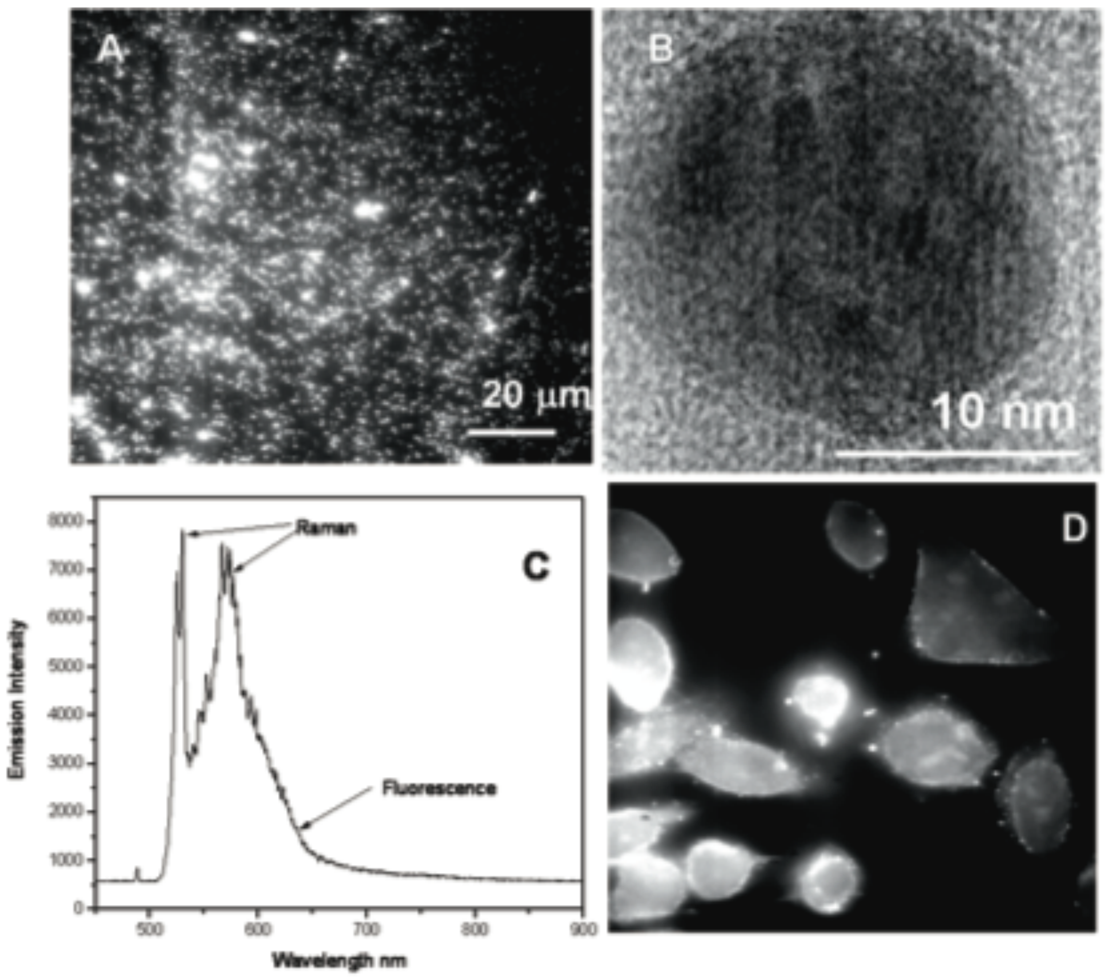
4. CENTER HIGHLIGHTS

Fluorescent and Raman Active Silver Superclusters

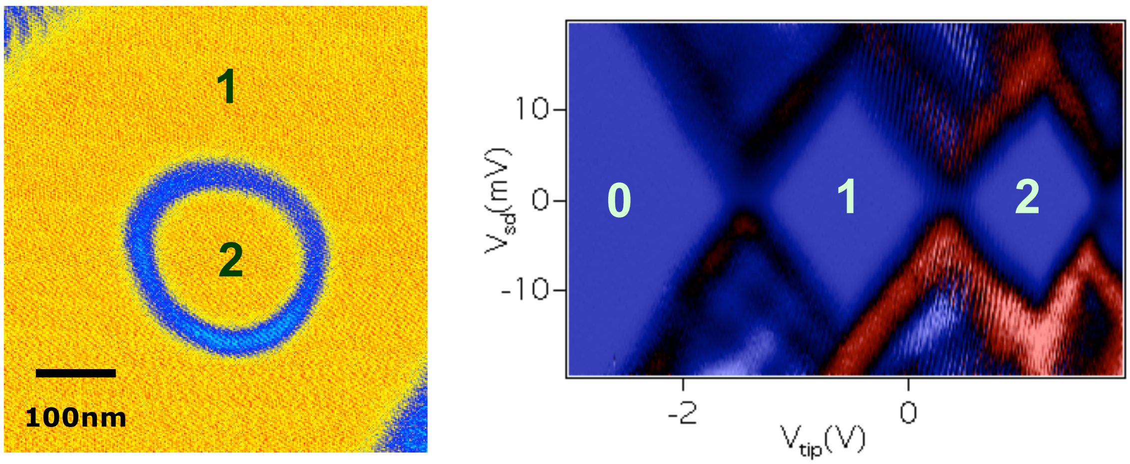
Xiaowei Zhuang (Harvard)



We have developed highly fluorescent and Raman-active silver superclusters to image individual biomolecules and their interactions i*n vivo.* (A) Fluorescence and Raman image of silver superclusters. (B) High resolution TEM image of a single silver supercluster. (C) A Fluorescence and Raman spectrum of silver superclusters. (D) Fluorescence image of fixed HeLa cells labeled with silver superclusters.

Image of a One-electron InAs Quantum Dot inside an InAs/InP Nanowire

Robert M. Westervelt (Harvard) and
Lars Samuelson (Lund University)

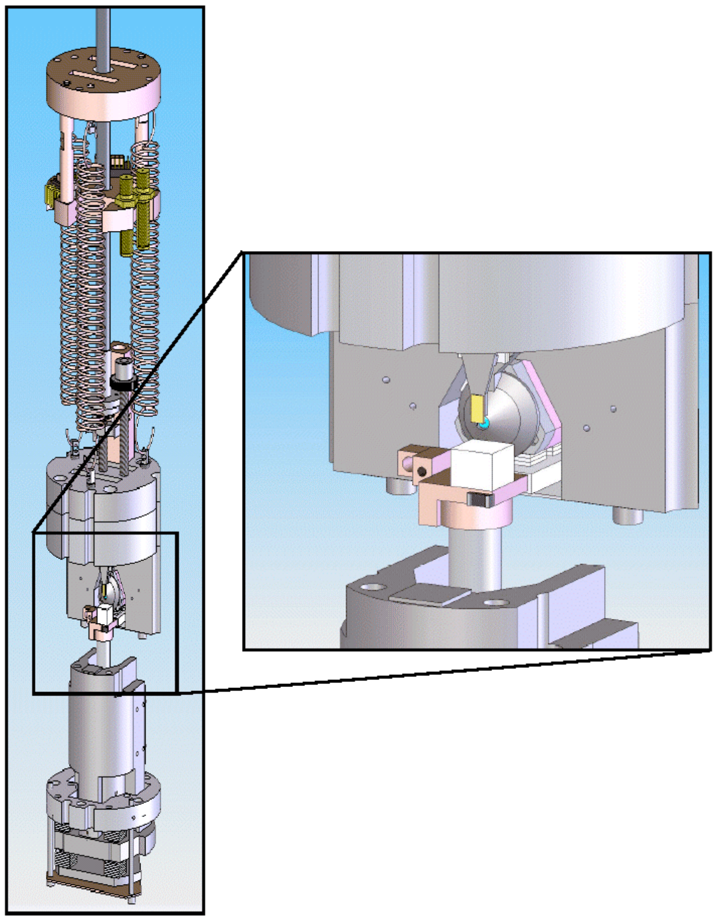


(*left*) Image of an InAs quantum dot in a InAs/InP nanowire heterostructure at 4.2 K showing the Coulomb blockade conductance ring between 2 and 1 electrons on the dot. (*right*) Coulomb blockade diamonds for 0, 1, and 2 electrons on the dot.

An InAs quantum dot was formed inside an InAs/InP nanowire heterostructure by two InP barriers. The dot has the shape of a hockey puck, and it can be very small. Coulomb blockade diamonds above show that the number of electrons can be reduced to 1, then 0. Conductance through the InAs dot was imaged at liquid He temperatures by using a scanning probe microscope (SPM) tip as a moveable gate. The image above shows a Coulomb blockade ring separating 2 and 1 electrons on the dot. By changing the tip voltage the number can be reduced to 0. SPM imaging will be a powerful tool to manipulate one-electron dots inside InAs/InP nanowires.

Design of a Magnetic Force Microscope for Imaging Nanoscale Vortex Motion

Jennifer Hoffman (Harvard)

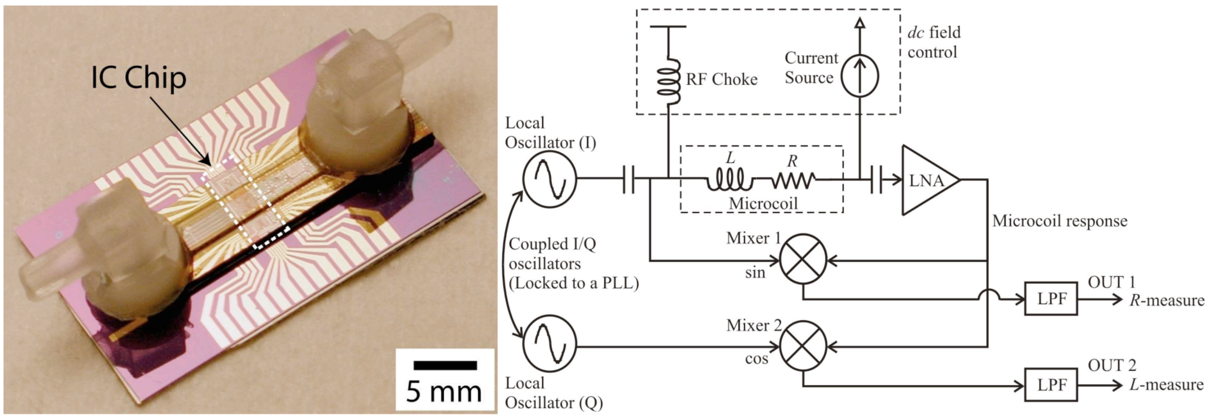


Superconductors have many potential uses, including generation of large magnetic fields and minute sensor arrays for medical diagnostics. These applications are presently limited by the uncontrolled motion of 'vortices': swirling currents that contain magnetic fields within the superconductor. On the other hand, controlled vortex motion presents new opportunities for computing.

Given these challenges and opportunities, it is imperative to gain a better understanding of the dynamics of single vortices. We have therefore designed a new cryogenic magnetic force microscope to detect and measure magnetic forces with 10 nanometer spatial resolution and sub-pico Newton force resolution. The drawing shows the instrument design, with a blow-up of the sample imaging region. The sample sits face-up on the white surface, while a magnetic-tipped cantilever (shown in yellow, just above the sample) is used to measure magnetic forces and to manipulate vortices. The magnetic force results in a deflection of the cantilever, which is measured via a laser beam reflected off the cantilever from behind (the small blue circle). The unique feature of this new imaging tool is the vertical cantilever, which allows direct detection of magnetic forces in the plane of the sample.

CMOS/Microfluidic Hybrid System for RF Sensing of Biological Cells

Donhee Ham and Robert M. Westervelt (Harvard)

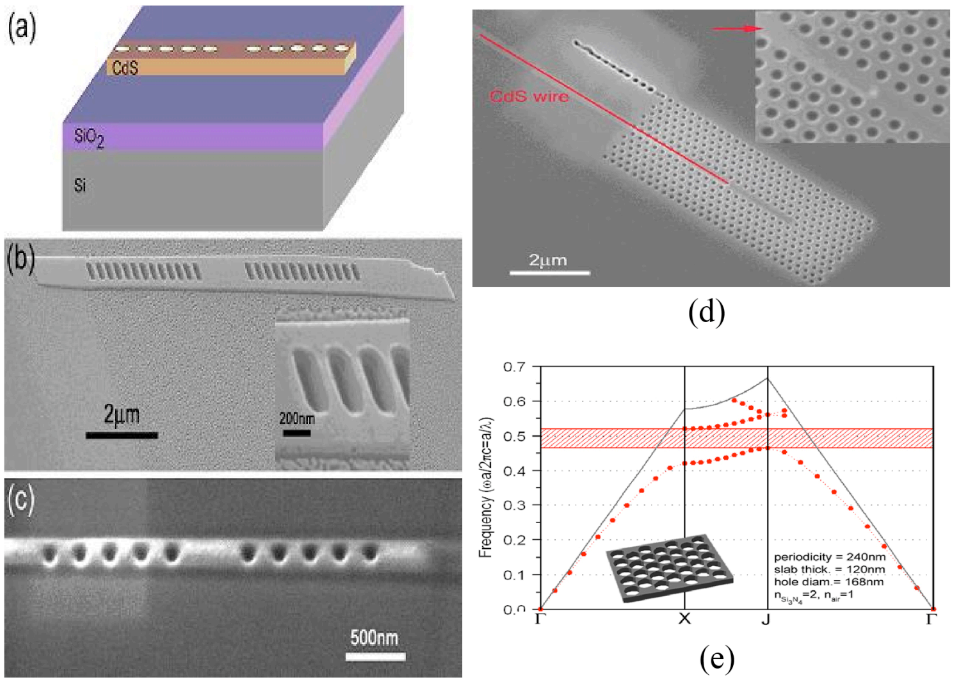


Previously we developed a CMOS/microfluidic hybrid system that combines a CMOS integrated circuit (IC) with a microfluidic system fabricated on top. The CMOS chip produces spatially patterned microscopic magnetic fields using an array of microcoils. By dynamically reconfiguring the magnetic field pattern, we demonstrated that the CMOS chip can manipulate multiple individual biological cells attached to magnetic beads that are suspended inside the microfluidic system.

Our new study seeks to incorporate a detection capability into the hybrid system, in addition to its already-demonstrated manipulation capability. The microcoils used for manipulation of bead-bound cells readily lend themselves to detection of the bead-bound cells, since a magnetic bead changes the resonance characteristic of the microcoil, which can be detected via RF measurement. A CMOS RF IC is being incorporated into the hybrid system for the on-chip RF measurement for the bead-bound-cell sensing. When the RF sensor is used with the microcoil array, the RF sensor allows imaging of 2-D distribution of bead-bound-cells, where a single microcoil can be thought of as a "pixel".

Nanowire Photonic Devices

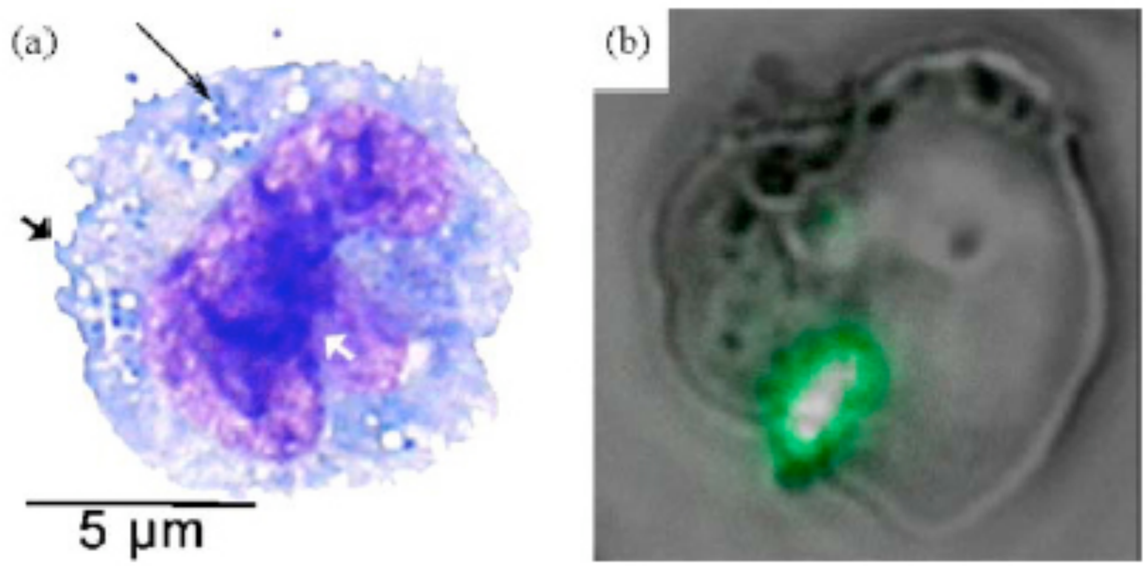
Marko Lončar, Carl J. Barrelet, Jiming Bao, Hong-Gyu Park, Charles M. Lieber, Federico Capasso (Harvard)



(a) Schematic of Cadmium Sulphide (Cd S) nanowire light-emitting device patterned with one-dimensional Bragg mirrors. (b) Experimental realization in CdS nano-ribbon and (c) in CdS nanowire using focused ion beam processing; (d) CdS nanowire embedded in a silicon nitride photonic crystal slab. Silicon nitride is deposited on a silicon chip; then CdS nanowires are placed on the chip and are then capped with a top layer of silicon nitride. (e) Photonic band diagram for the silicon-nitride photonic crystal slab. The photonic band gap (PBG) strongly confines light to the wire, reducing the laser threshold and achieving extremely narrow divergence. In this way the light emitted from the nanowire can be guided around the chip, making possible future generations of planar light wave-guiding circuits.

Nanomaterials Guiding Antimicrobial Host Defense

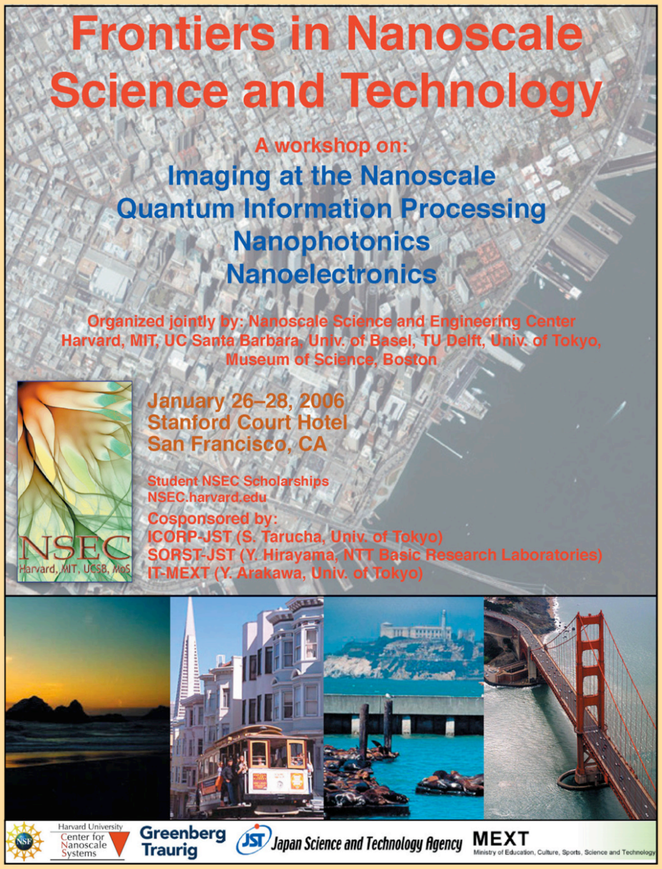
Joseph Mizgerd (Harvard School of Public Health)



Polymers of polyacrylamide, ~100 nm in size, were engineered to coat gram-positive bacteria with antibodies in order to stimulate phagocytosis by macrophages. Polymers present vancomycin (for attaching to bacteria) and fluorescin (for attaching anti-fluorescin antibodies). Bacteria coated with antibodies can be visualized inside of macrophages, (a) using stains or (b) using the fluorescent nature of the polymers coating the bacteria.

Frontiers in Nanoscale Science and Engineering International Workshop

January 26–28, 2006
San Francisco, CA



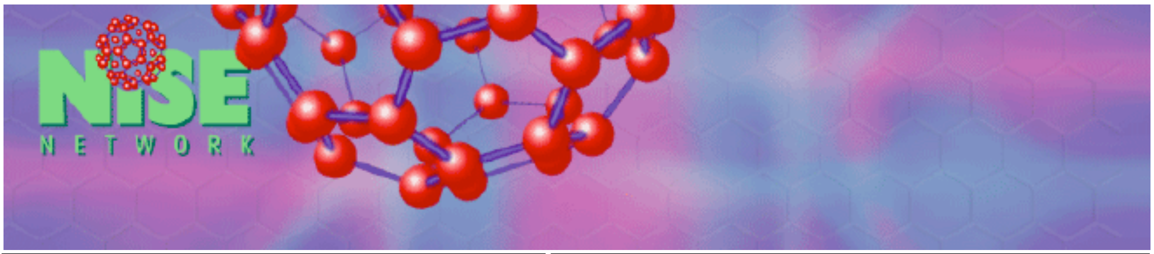
Invited Speakers

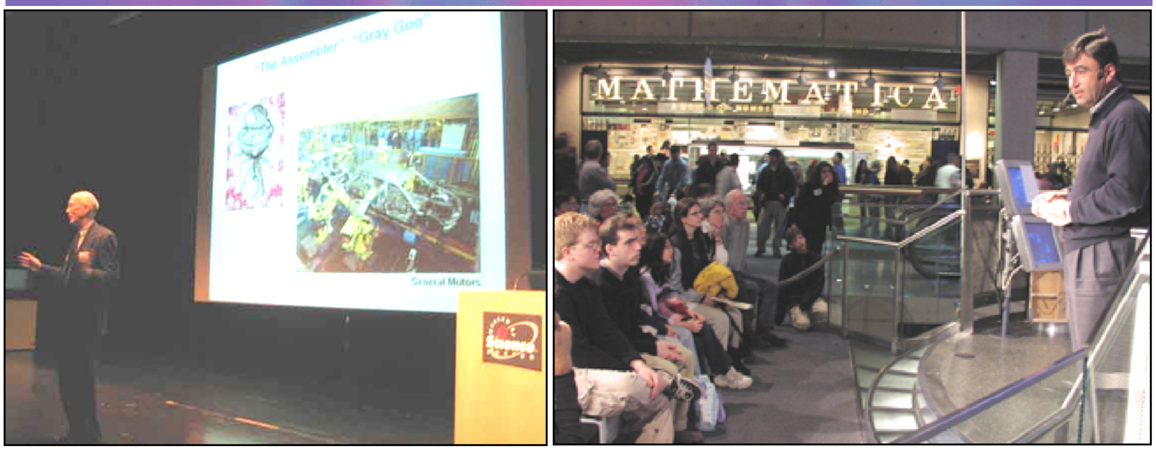
Pushkar Apte (SIA)
Yasuhiko Arakawa (IT-MEXT, U Tokyo)
Raymond Ashoori (MIT)
Phaedon Avouris (IBM)
George Bourianoff (Intel)
Federico Capasso (Harvard)
Hongjie Dai (Stanford)
Robert Doering (TI)
Andre Geim (Manchester)
Tsuyoshi Hatano (ICORP)
Eric Heller (Harvard)
Kazuhiko Hirakawa (U Tokyo)
Yoshiro Hirayama (NTT)
Cyrus F. Hirjibehedin (IBM)
Pablo Jarillo-Herrero (Delft)
Daniel Loss (Basel)
Mikhail Lukin (Harvard)
Susumu Noda (U Kyoto)
Jason Petta (Harvard)
Lars Samuelson (Lund)
Yasuhiro Tokura (NTT & ICORP)
Michihisa Yamamoto (U Tokyo)
Yoshihisa Yamamoto (Stanford)
Naoki Yokoyama (Fujitsu)

Our third international workshop was held on January 26–28, 2006 in San Francisco. The workshop brought together international collaborators of the Center including Daniel Loss, Lars Samuelson, and Seigo Tarucha, and other outstanding researchers from Japan and Europe. The first day was devoted to industrial, and the development of ultrasmall quantum switches for the Nanoelectronics Research Initiative.

Nanoscale Informal Science Education Network (NISE Network)

Carol Lynn Alpert, Larry Bell, Robert M. Westervelt, George Whitesides, Eric Mazur, Kathryn Hollar





Left: Professor **George Whitesides** discusses possible societal impacts of nanotechnology at a recent Teachers' Symposium. *Right*: Professor **Eric Mazur** gives a talk on nanowire fabrication at the Current Science & Technology Center at the Museum of Science, Boston.

The Museum of Science, Boston, in partnership with the Science Museum of Minnesota (SMM) and the Exploratorium in San Francisco, was selected by the NSF to lead a five-year effort to form a national Nanoscale Informal Science Education Network (NISE Network), linking multiple science museums, research institutions, and professional organizations. The NISE Network will collaboratively develop and distribute innovative approaches to engaging Americans in nanoscale science and engineering education, research, and technology. In making the award, the review panel noted the Museum of Science's four years of experience in working with the researchers and staff of the "Science of Nanoscale Systems and their Device Applications" NSEC to produce a robust program of engaging live presentations, guest researcher events, New England News cablecasts, multimedia, online materials, and special events. Much of this expertise will now be shared nationwide. **Harvard NSEC PI Robert Westervelt** is serving as Chairman of the Scientific Advisory Board of the NISE Network and **NSEC researchers George Whitesides** and **Eric Mazur** are also participating as advisors. **MOS VP Larry Bell** and **NSEC Public Engagement Director Carol Lynn Alpert** developed the NISE Network approach and partnership with the SMM and the Exploratorium and serve as PIs for the Network.

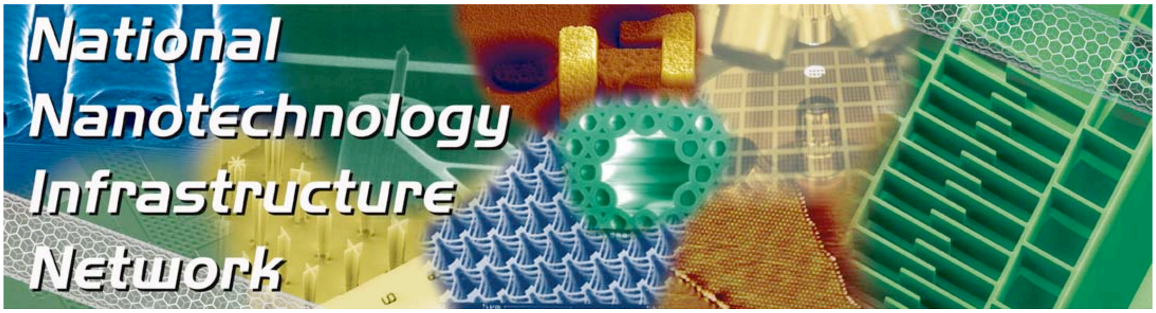
Teacher Professional Development

Kathryn Hollar, Christina Talbot, George Whitesides, Carol Lynn Alpert

An inexpensive soft lithography laboratory appropriate for high school and college chemistry courses was developed by RETs Christina Talbot and Colleen O'Shell, and graduate student Logan McCarty of Professor **George Whitesides**' laboratory. Students are able to perform replica molding and microcontact printing using common objects such as feathers and shower curtains. The lab module has been piloted with high school and college students, and has been shared with high school teachers in various teacher workshops.

National Nanostructure Infrastructure Network

Harvard University and University of California at Santa Barbara



Harvard and UC Santa Barbara are two of an integrated partnership of thirteen user facilities, led by Cornell and Stanford that provide opportunities for nanoscience and nanotechnology research. At Harvard, the NNIN provides expertise in soft lithography and assembly, and computation through the Center for Nanoscale Systems. At UCSB, the NNIN provides expertise in optics and electronic materials. The NNIN was funded by the NSF in January 2004.

Laboratory for Integrated Science and Engineering
Harvard University

A computer image of the Laboratory for Integrated Science and Engineering (LISE) that will house shared facilities for Harvard's Center for Imaging and Mesoscale Structures and NSEC, and will provide space for interdisciplinary research. LISE will contain an Imaging Laboratory for electron, scanning probe and optical microscopy, a cleanroom for nanofabrication and soft lithography, and an Advanced Materials Science Laboratory.

Center for Nanoscale Systems

Harvard University

Center for Nanoscale Systems

Mission and Goals of the Center for Nanoscale Systems at Harvard University:

- To provide world-class, centralized facilities and technical support for Harvard faculty research groups as well as the larger community of external users from academia and industry.

- To foster leading-edge, multi-disciplinary research and education in the area of imaging and nanoscale systems, bridging the disciplines of chemistry, physics, engineering, materials science, geology, biology, and medicine.

- To create an environment for collaborative research by providing shared research facilities and meeting places conducive to productive scientific interactions.