CNST Center for Nanoscale Science & Technology
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The CNST Quarterly

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From the Director
Robert Celotta

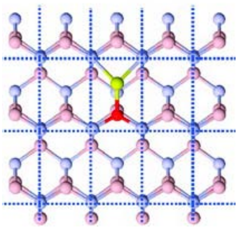
Now having just completed its second full calendar year of operation, the CNST is quickly approaching its originally designed goals. The NanoFab now operates a nearly complete set of nanofabrication and nanoscale measurement tools, along with the necessary associated processes. The initial tool set will be completed in 2010 with the installation of a transmission electron microscope and a stepper. Additional experienced staff members have been added to support both the NanoFab's new capabilities and its rapidly growing user base.

Of course, not all researchers working with the CNST use the NanoFab. Many collaborate on research projects with members of our research staff. Here also there have been major changes in the past two years, with increases in both the number of research projects and in the diversity of topics. Currently, there are 18 Project Leaders involved in a broad range of collaborative activities; we expect to add a few more in the coming year. Further, the close coupling between the collaborative research projects and the NanoFab shared-use facility has proven to be invaluable to NanoFab users, who benefit from consultation with the researchers, as well as to the collaborative research programs, which profit from interactions with the NanoFab users and the processes they develop.

All of this progress could not have been accomplished were it not for the tireless efforts of a great many people. Their contributions have been essential to establishing the infrastructure that enables the science and technology now being produced by the many CNST research participants from NIST and beyond.

Research Highlights

CNST Researchers Develop Method to Induce Single Magnetic Impurities in a Semiconductor Crystal



In the September issue of Nano Letters, CNST researchers announced a new technique for atom-by-atom exchange manipulation using a scanning tunneling microscope probe. In their work, a magnetic Mn atom was first deposited on top of the crystal. Then, using the electrical current coming from the STM probe tip, the Mn atom was induced to exchange, or change places, with an In atom in the top surface layer of the In crystal. By combining detailed measurements using high resolution scanning tunneling microscopy and calculations using density-functional theory, the researchers learned the exact pathway of the atoms during the exchange. The process occurred when tunneling out of the InAs surface exceeded a critical voltage threshold to create a substitutional Mn impurity atom. The theoretical calculations determined the minimum energy reaction pathway in which the In atom was ejected by the substitution of a Mn atom into the In site. The researchers believe this new exchange manipulation method will be useful for future studies in nanomagnetism/spintronics and for low-dimensional electron systems with tailored impurity potentials.

Upcoming CNST Seminars

Exchange Bias Enhancement by Cr Addition To CoO in a CoO-Co/Pt Multilayer System

Hans J. Hug, Director, Nanoscale Materials Science, Swiss Federal Laboratories for Materials Testing and Research.
Contact: Joseph Stroscio
January 25, 2010 - 10:30 AM - 217/ H107

Single-Photon Atomic Cooling

Gabriel N. Price, Postdoctoral Candidate, University of Texas at Austin
Contact: Jabez McClelland
January 26, 2010 - 10:30 AM - 217/ H107

Advanced Use of Vibrational Spectroscopy in Nanotechnology: Application in Hydrogen Storage and Cancer Detection

Andrea Centrone
Contact: Nikolai Zhitenev
February 25, 2010 - 10:30 AM - 217/ H107

For the complete list of CNST Seminars, visit our web site, www.cnst.nist.gov.

CNST Awards Contracts for Two Transmission Electron Microscope (TEM) Systems to FEI

The CNST has recently awarded contracts to FEI Company for two Transmission Electron Microscope systems that will bring significant new capabilities to the CNST. The CNST NanoFab will be receiving a Titan 80-300 300 keV analytical TEM with both x-ray and imaging electron energy loss analytical capabilities. This TEM, which will be installed in June 2010 and made accessible to all NanoFab users, will enable atomic lattice-scale imaging and analysis of a wide range of samples. The CNST Research Program will be obtaining NIST's first Environmental [Scanning] TEM, or E[S]TEM, also based on an FEI Titan 80-300, to be located adjacent to the NanoFab TEM and accessible to other researchers through collaboration. This instrument will have a high-brightness, monochromatic source, spherical aberration correction of the objective lens, and a state-of-the-art imaging energy filter with an energy resolution of 0.2 eV. It will permit atomic-scale, real-time imaging and analysis of catalytic material processes, such as carbon nanotube growth, under high-temperatures (up to 900 °C) and pressures (up to 2000 Pa = 15 Torr). The research instrument will be developed by Renu Sharma, who recently joined the CNST from Arizona State University (see Profile below).

CNST Researchers Design Optical Interface to Probe Single Quantum Dots

CNST researchers have designed a very efficient nanophotonic interface to collect light emitted from single semiconductor quantum dots. This interface will provide high-resolution measurements needed for the development of future generations of classical and quantum information processing devices. The system consists of a single quantum dot embedded in a GaAs channel waveguide with cross-sectional dimensions of about 250 nm x 250 nm. The channel waveguide forms one half of a directional waveguide coupler, with the second half formed by an optical fiber taper waveguide. The taper waveguide is fabricated from a standard 125 µm diameter, single mode optical fiber that is gradually tapered down to a diameter of about 1 µm along an approximately 1 cm long section. Through a detailed characterization of the device's electromagnetic properties, the researchers have shown that this structure can be used for highly efficient fluorescence spectroscopy and resonant scattering measurements of a single quantum dot. The key innovation in the system is that the directional waveguide coupler provides an almost ideal mechanism for taking light from a single mode optical fiber and transforming it into a tightly confined mode within the GaAs waveguide. There, the light can interact with the quantum dot before transforming back into a mode of the fiber. The net result is a device in which a single semiconductor quantum dot, a structure with a characteristic length scale of 10 nm, can be effectively connected to macroscopic fiber optics that are integral to modern communications. The results are described in "Fiber-coupled Semiconductor Waveguides as an Efficient Optical Interface to a Single Quantum Dipole," M. Davanço and K. Srinivasan, *Optics Letters* **34**, 2542-2544 (2009).

Project Leader Profile:

Renu Sharma

What is your background?

I majored in Chemistry and Physics and later received a degree in education from Jhajjar – Nehru College, in Haryana, India. I then taught high school chemistry for six years before going to University of Stockholm, Sweden for my M.S. and Ph.D. in Inorganic Chemistry. In Stockholm, we made fully oxidized materials with the same crystal structures as tungsten bronzes. We then used high resolution electron microscopy images to help determine the structure of these materials. From there, I went to Arizona State University (ASU) as a postdoc. I stayed as an Assistant Research Scientist and was later promoted to Associate and then finally to Senior Research Scientist. While at the CNST, I plan to continue my association with ASU as an Adjunct faculty member.

While at ASU, I modified an existing old Transmission Electron Microscope (TEM) to develop an Environmental TEM (ETEM) that allowed us to observe the gas-solid interactions. Electron microscopes work in a high vacuum of 10^{-4} Pa, which does not let you learn how phenomena work in liquids or higher gas pressures. In order to better understand charge-discharge processes in batteries, we studied a model process of ammonia intercalation in dichalcodenides. In 2003, in collaboration with FEI, we modified a newly acquired TEM to introduce up to 10^{3} Pa (8 Torr) of gasses in the sample area and to observe the gas-solid interaction at elevated temperatures. This work opened up many opportunities for experiments, particularly in catalytic reactions. It is a unique setup that permitted us to collect structural, chemical and kinetic data under reaction conditions. In addition to many other reaction processes studied since then, we used the microscope's electron beam to decompose organometallic compounds to deposit catalysts for site specific carbon nanotube growth. This catalyst deposition process was almost like nanolithography. Using the ETEM, we measure the nucleation and growth rates of nanotubes and nanowires under different reaction conditions.

What are your plans and challenges at the CNST?

I plan to further develop in-situ measurement techniques. The CNST will be acquiring an Environmental Scanning Transmission Electron Microscope, one of a few in the world. This microscope will allow for imaging in a gaseous environment at elevated temperature. I intend to develop a liquid cell holder for this microscope to allow us to observe nanoparticle motion in liquids. I plan to incorporate Raman spectroscopy into the system in order to identify adsorbed species on catalyst surfaces. This will allow us to determine the decomposition path of carbon precursors prior to carbon nanotube growth, a step that could be important for controlled CNT synthesis.

What drew you to the CNST?

Our goals really match. The CNST develops measurement techniques at the nanoscale and is particularly interested in techniques that are useful to industry. This is a perfect combination of important research, difficult to develop measurement techniques, and practical utility.

Honors and Awards

CNST Researchers Recognized by Science Societies

Robert McMichael has been elected a Fellow of the American Physical Society (APS). His fellowship citation notes his "broad contributions to the measurement, modeling, inter-pretation, and understanding of magnetization dynamics." The status of fellow is limited to no more than one-half of one percent of the APS membership and is awarded to recognize outstanding contributions to physics. Bob is a Project Leader in the Electron Physics Group, where he develops dynamic measurement methods and supporting models for characterizing magnetic properties and spin polarized transport in magnetic nanostructures.

NIST Fellow **Mark Stiles** has been designated a 2010 Outstanding Referee by the American Physical Society (APS). This lifetime APS award was initiated in 2008 "to recognize scientists who have been exceptionally helpful in assessing manuscripts for publication in the APS journals." The status is conferred to only a small percentage of the 44,000-strong referee pool, and is awarded to show appreciation for the essential work that anonymous peer reviewers do for the journals. Mark is a Project Leader in the Electron Physics Group, performing fundamental calculations that broadly elucidate the properties of nanostructures, ranging from magnetic materials and devices, to superconductors, to graphene.

NIST Fellow **Joseph Stroscio** was honored with the 2009 Nanotechnology Recognition Award at the AVS 56th International Symposium in San Jose, CA, on Nov. 10, 2009. This award recognizes a member of the Nanoscale Science and Technology Division of the AVS for outstanding scientific and technical contributions in the science of nanometer-scale structures, technology transfer involving nanometer-scale structures, and/or the promotion and dissemination of knowledge and development in these areas. Stroscio was cited "for his pioneering development of instrumentation to create and characterize nanostructures enabling fundamental insights into the mechanisms of atom manipulation and the magnetoelectric properties of low-dimensional structures." Joe is a Project Leader in the Electron Physics Group, performing measurements of the geometric and electronic structure of surfaces and nanostructures, including those created by atom manipulation, using innovative ultrahigh vacuum, cryogenic/high-magnetic field scanning probe microscopy systems developed at NIST.

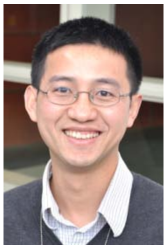
CNST's Rudnitsky Elected Chair of International Nanotechnology Policy Body

Robert Rudnitsky has been elected chair of the Organisation for Economic Cooperation and Development (OECD) Working Party on Nanotechnology (WPN). The election by the OECD's 30 member countries continues Rudnitsky's tenure as chair, which began when he was at the U.S. Department of State prior to joining NIST in September 2009. The WPN is the principal multilateral group for coordinating national nanotechnology policies among countries with active nanotechnology research programs. It was begun three years ago as a U.S. initiative, and U.S. participation is led by the Office of Science and Technology Policy, Executive Office of the President. The WPN's work focuses on sharing policy experiences regarding commercialization of nanotechnology, developing economic metrics for measuring its impact, setting standards for communicating with the public and engaging stakeholders, and promoting international nanotechnology research collaborations. Prior to joining the CNST, Rudnitsky worked at the U.S. State Department as an advisor on advanced technologies and chaired the U.S. National Nanotechnology Initiative's Global Issues in Nanotechnology Working Group. Rudnitsky is currently the scientific advisor to the CNST, where he provides scientific, policy, and operational support to the center, and is spearheading a regional outreach program for the NanoFab, the CNST's shared-use nanofabrication facility.

New Staff at the CNST

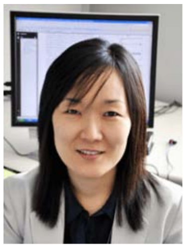
Adam Berro is a CNST Post-doctoral Researcher in the Nanofabrication Research Group. He received a Ph.D. in Organic Chemistry from the University of Texas at Austin. At the CNST, Adam is working with J. Alexander Liddle to develop fluorescence techniques for the measurement of acid diffusion in photoresists with single molecule resolution.

Jerry Bowser is a NanoFab Technician for the CNST NanoFab Operations Group. Jerry has over 13 years of experience in semiconductor manufacturing engineering in the private sector, including five years at Allied-Signal and eight at Covega, where he held both engineering and supervisory positions. In the NanoFab, Jerry will be developing CMOS grade diffusion/oxidation and chemical vapor deposition processes.



Zhao Deng joined the CNST as a CNST/UMD Postdoctoral Researcher in the Electron Physics Group. Zhao received bachelor's and master's degrees in Chemical Engineering from Shanghai Jiao Tong University, China, and received a Ph.D. in Analytical Chemistry from University of California, Davis. Zhao is working with Rachel Cannara studying the origins of nanoscale friction by varying the thermal properties of materials.

Monica Hudson is the Group Secretary for the Nanofabrication Research Group. Prior to joining NIST in 2009, Monica worked for the University of North Carolina-Charlotte and Florida Vocational Rehabilitation. She has over 15 years experience in private industry, including work at Scientific American Magazine and Goldman Sachs.



Seung-Hyeon (Sarah) Ko is a CNST/UMD Postdoctoral Researcher in the Nanofabrication Research Group. She received a Ph.D. in Chemistry from Purdue University. Sarah is working with J. Alexander Liddle to develop hybrid nanofabrication methods that combine top-down and bottom-up techniques.

Chester Knurek is a Process Engineer in the NanoFab Operations Group. Chester has a B.S. in Electronics Engineering from DeVry University in Chicago, IL. Prior to joining NIST, he worked at AT&T Microelectronics / Lucent Technologies - Bell Labs on characterization and process development for next generation lithography, including binary/phase-shift, point source X-ray, and flood e-beam mask formats. Chester is now responsible for training and process support for NanoFab users in various nanofabrication areas, including optical lithography and metrology.

Ceren Susut is a CNST/UMD Post-doctoral Researcher in the Energy Research Group. She received a B.S. in Chemical Engineering from Boğaziçi Univer-sity, Turkey, an M.S. in Chemistry from the University of Texas at Arlington, and a Ph.D. in Chemistry from Georgetown University. Ceren is working with Alec Talin on developing new tools and integrated measurement systems to characterize nanoelectrochemical energy storage and conversion devices.

Outreach and Events

The NanoFab outreach campaign exhibited at fifteen venues in 2009. Visit our booth at the following upcoming conferences:

- **PittCon Conference & Expo**
  Orlando, Florida
  February 28 – March 5
- **World's Best Technologies**
  Arlington, Texas
  March 15 - 18
- **American Physical Society**
  Portland, Oregon
  March 15-19
- **Materials Research Society Spring Meeting**
  San Francisco, California
  April 5-9

News from the CNST NanoFab

NanoFab Increases Industrial Participation in 2009

The NanoFab research community continues to grow thanks to increased interest from industry, academia, and government researchers. In 2009, the CNST exhibited at fifteen conferences nationwide, with a particular focus at letting industrial researchers know about our capabilities and rapid access; fourteen new industrial research groups are now using the NanoFab. As our user community grows, we continue to improve the NanoFab's infrastructure, installing several new tools in 2009, with additional tools to be added throughout 2010.

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