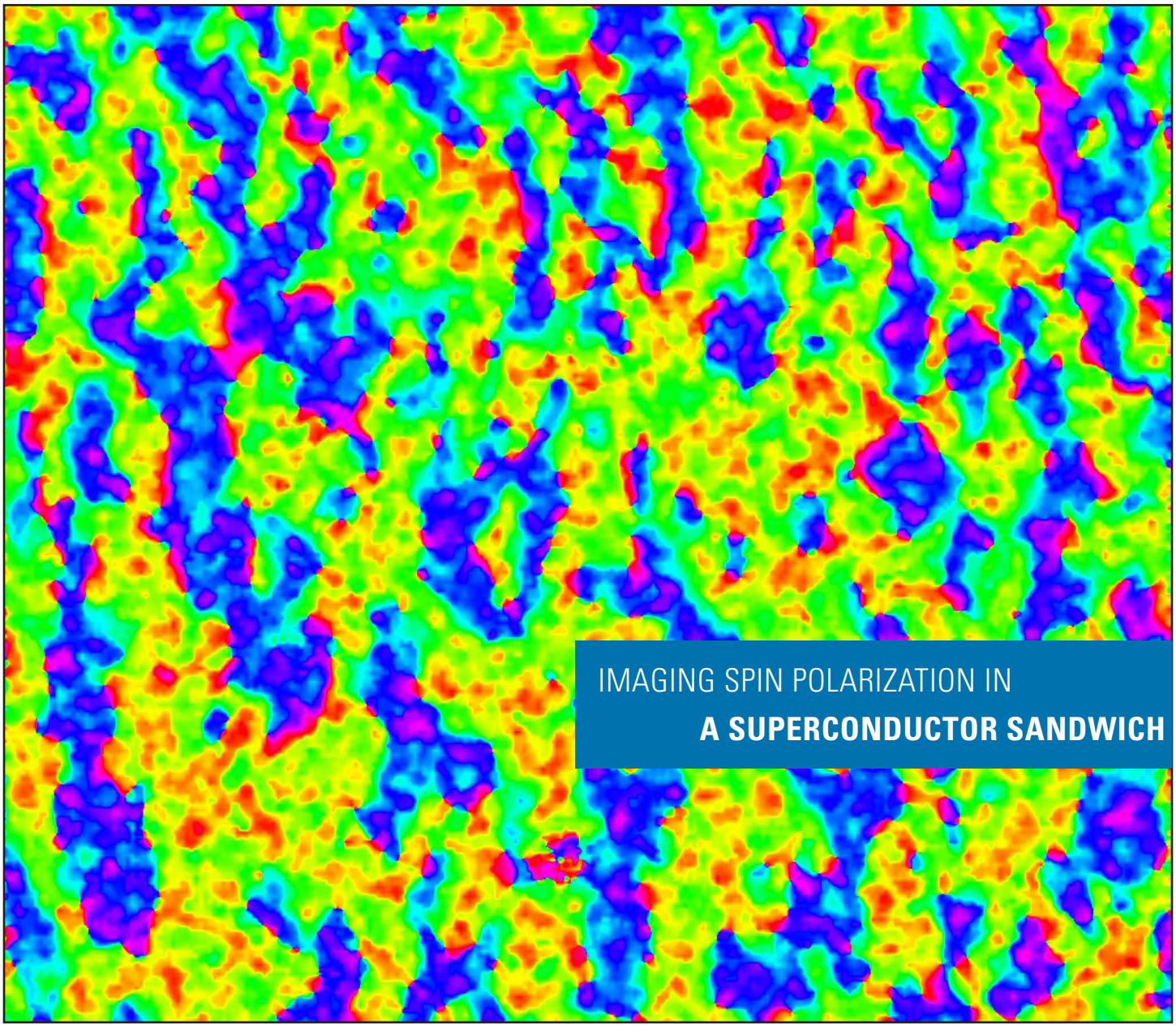
THE CNST NEWS

SUMMER 2012



IMAGING SPIN POLARIZATION IN A SUPERCONDUCTOR SANDWICH

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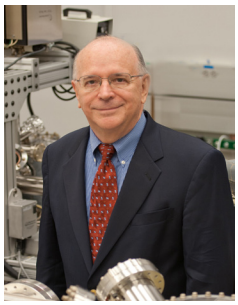


It is exciting to see the next generation of nanotechnologists filling our labs and hallways. This summer, fifteen students joined about forty full-time postdoctoral researchers working at the CNST doing cutting-edge research in our laboratories, with many working in the NanoFab and its cleanroom.

The CNST sponsors undergraduate science and engineering majors interested in nanotechnology through the highly-competitive Summer Undergraduate Research Fellowship (SURF) program, which offers the opportunity for students to spend eleven weeks during the summer performing hands-on research under the mentorship of a CNST project leader. Participants receive stipends along with housing and travel allotments. A complementary program for high school students, the Summer High School Intern Program (SHIP), provides unpaid research opportunities for students who have completed their junior or senior years; some of these students continue as interns throughout the year. Additional research opportunities for students and recent graduates will be offered through the new Pathways Program (see www.opm.gov/hiringreform/pathways/).

Supporting the development of the next generation of researchers is a responsibility that we at the CNST take very seriously. Our research programs are often a student's first research experience. These programs provide opportunities for students to experience the possibility of a research career in nanoscale science and technology, and to appreciate the value and importance of fundamental research to tomorrow's industrial applications. While our goal is to inspire a passion for research in our student researchers, we take particular pleasure when they inspire us to think about our research challenges in new ways.

This summer our undergraduate researchers came to us from universities in eleven states spread throughout the country. Reflecting an emerging academic trend as well as the interdisciplinary nature of nanotechnology, most of the students are double majors or are majoring in one discipline while minoring in another, including Physics, Electrical Engineering, Mechanical Engineering, Biology, Nanoscale Engineering, Mathematics, French, and Engineering Physics. The students work on a wide range of projects. For example, Anthony Gianfrancesco worked with CNST researchers Nikolai Zhitenev and Joseph Stroscio characterizing photovoltaic materials using thin film phosphors as a near-field optical source. Victoria Savikhin, who worked with Veronika Szalai, learned to prepare DNA oligonucleotides and to measure nanofiber assembly rates and morphologies using optical spectroscopy, gel electrophoresis, and atomic force microscopy. Sarice Barkley, a recent graduate from St. Olaf College with a B.S. in Physics who returned for a second summer in the SURF program, continued a line of research she started last summer with Rachel Cannara. Based on that work, Sarice was first author on a *Review of Scientific Instruments* publication evaluating a new lateral force calibration technique for atomic force microscopy (see the article on the next page of this newsletter). At the end of the summer, the SURF and SHIP students practice one of the most important skills for a research scientist—communicating results and analyses—by presenting their work at a three-day colloquium.

I encourage interested students to start the process early (by winter break, or sooner!). Please visit the NIST student employment page to learn about opportunities NIST-wide at www.nist.gov/hrmd/staffing/studentshome.cfm.

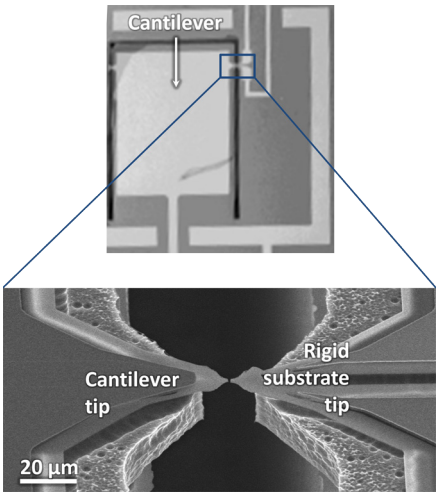
Robert Celotta

LUMEDYNE BUILDS AN INERTIAL SENSING TRANSDUCER

Lumedyne Technologies, a San Diego-based microelectromechanical system (MEMS) development company, has built a proof of concept device for measuring inertial forces that integrates precision timing with the well-defined motion of a MEMS harmonic oscillator. The device can be used as a component in small, low-cost, low-power, navigation-grade gyroscopes and to provide force measurements for position recorders.

Lumedyne's MEMS force transducer consists of a simple diving board cantilever that oscillates at its mechanical resonance. As the cantilever vibrates, a tunneling tip on its edge passes a tunneling tip on a rigid substrate. The resulting tunneling current acts as a "triggering" event that precisely defines the cantilever's location as a function of time. When the device is subjected to a force, the system measures the change in the oscillator's amplitude and frequency. Three of these transducers placed in orthogonal directions in a single device can record forces in all three directions. The system promises to allow users to know the location of the device relative to an initial location with sub-meter accuracy in places where there is no GPS signal.

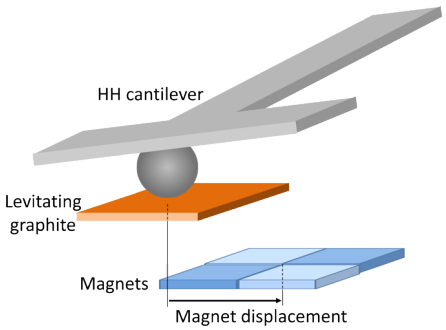
The company used a commercial foundry to fabricate the wafer structure and to provide metallization for the circuitry and tunneling junction. Working with Process Engineer Joshua Schumacher in the NanoFab, they used a focused ion beam to cut separations of 10 nm to 40 nm between the two tunneling tips without damaging the tips. They are now experimenting with scaling up production by using a CMOS process to fabricate the gap. The researchers believe that their device will be useful for applications where a GPS signal is not available, including seismic imaging for oil and gas exploration, targeting for weapons systems, and for navigation use in cell phones within buildings.



As the cantilever (microscope image, top) vibrates, a tunneling current passes between paired tips (scanning electron micrograph, bottom) on the cantilever and on the rigid substrate.

EVALUATING A SIMPLER LATERAL FORCE CALIBRATION TECHNIQUE FOR ATOMIC FORCE MICROSCOPY

Researchers from the CNST and NIST's Material Measurement Laboratory (MML) have demonstrated that a simpler technique for calibrating lateral sensitivity in an atomic force microscope (AFM) agrees with a calibration method developed at NIST to within 5 %. The equivalence of these two independent methods represents an important step towards traceable accuracy in lateral force microscopy and will allow scientists to better understand the atomic-scale origins of friction across a wide range of materials. The NIST "HammerHead" (HH) method relies on precise positioning of the arms of a specially-fabricated, tee-shaped cantilever over well-defined alignment marks in a surface; a torque is applied at different locations on the cantilever arm by pressing it against a small sphere attached to the edge of the surface. The ratio of the change in the normal (vertical) signal to the lateral signal can be used to calibrate sensitivity and extract friction forces corresponding to the lateral signals measured during an experiment. The new "Diamagnetic Lateral Force Calibrator" (D-LFC) method, developed at Brown University, requires fewer independent measurements. The AFM cantilever presses against the surface of a piece of graphite that levitates in a magnetic field. When the magnetic field is moved horizontally in the AFM, the levitating graphite behaves like a mass on a very weak spring. A lateral force is applied by the graphite to the tip of the AFM cantilever, causing the cantilever to twist. This twist leads to a change in the lateral signal in the AFM that can be used to calibrate friction directly, without the need for an independent measurement of the normal signal. While the D-LFC method is preferable for most circumstances because it uses fewer parameters and therefore has greater precision, the HH method can be advantageous if contact between the probe tip and the calibration surface must be avoided. The researchers believe that the overall accuracy and comparability of these two methods establishes the importance of the D-LFC method as a valuable tool for unifying quantitative measurements of friction at the nanoscale, and establishes a potential path towards the development of lateral force standards.

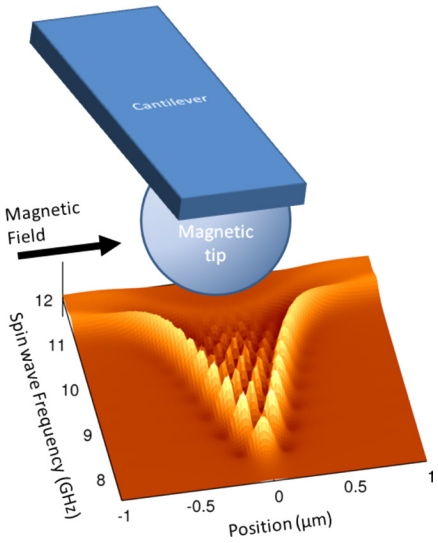


In the diamagnetic lateral force calibration method, an AFM cantilever (shown here is a NIST HammerHead cantilever) presses against the surface of a piece of graphite that levitates in a magnetic field. When the magnetic field is moved horizontally in the AFM, friction between the AFM tip and graphite surface causes the cantilever to twist. This twist leads to a change in the lateral signal in the AFM that is used to calibrate friction directly, based on the spring constant of the graphite in the magnetic field.

Quantitative comparison of two independent lateral force calibration techniques for the atomic force microscope, S. S. Barkley, Z. Deng, R. S. Gates, M. G. Reitsma, and R. J. Cannara, *Review of Scientific Instruments* **83**, 023707 (2012).

CHARACTERIZING MAGNETIC MEDIA ON THE NANOSCALE USING RIPPLING SPIN WAVES

CNST researchers in collaboration with the University of Maryland and the Royal Institute of Technology in Stockholm, Sweden have developed a new method to measure magnetic properties and defects in thin films with a spatial resolution of approximately 100 nm. Controlling variations and defects in thin films of magnetic materials is a key challenge to developing magnetic random access memory (MRAM), a new type of magnetic memory that promises to be faster, smaller, and more energy efficient than memory based on current semiconductor technology. Building on previous work at the Ohio State University, the new technique is designed to trap and image oscillating perturbations of the magnetization—known as "spin waves"—in a thin film. By trapping the spin waves at the location being measured, this approach overcomes the limitations usually associated with measurements of local magnetic properties, which are generally hindered by strong exchange and dipole-dipole interactions that make it difficult to separate the properties of one region from the next. An analogy to these localized spin waves is a frozen pond with a hole in the ice, where a breeze only excites ripples in the water filling the hole. In this new method, the frequency of a driving microwave field is tuned to a frequency below the band where spin waves can propagate, essentially preventing spin wave excitation by the microwaves and "freezing" the magnetization. The "hole" in the frozen spins is provided by a magnetic tip of a ferromagnetic resonance force microscope (FMRFM) held above the film surface on a cantilever. The magnetic tip changes the magnetic field under the tip, allowing spin wave "ripples" to form, and the tip can be scanned back and forth across the film to map out the film's nanoscale properties. The ability to image these properties is expected to prove valuable in determining the limitations and failure modes of prototype nanomagnetic data storage devices.

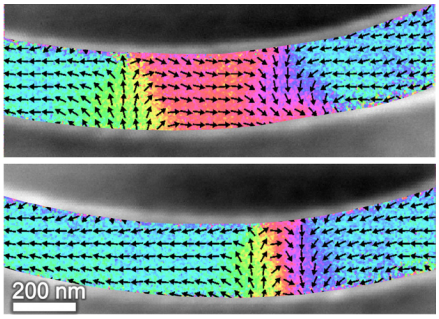


As shown in the simulation above, spin waves of different frequencies trapped beneath the magnetic tip of a microscale cantilever produce varying magnetic force profiles which can be used to non-destructively probe the properties of magnetic materials. This technique can be used to search for nanoscale defects, especially in multilayer magnetic systems like typical hard drives, where defects can be buried beneath the surface.

Nanoscale spin wave localization using ferromagnetic resonance force microscopy, H.-J. Chia, F. Guo, L. M. Belova, and R. D. McMichael, *Physical Review Letters* **108**, 087206 (2012).

IMAGING COMPLEX DOMAIN WALL STRUCTURES IN MAGNETIC NANOSTRIPES

Researchers from the CNST and MIT have used the scanning electron microscopy with polarization analysis (SEMPA) technique to provide the first direct images of the magnetic structure of highly twisted domain walls in patterned thin film magnetic nanowires. This imaging method allows these complex and delicate structures to be easily compared to magnetic simulations, a useful step for developing technology that uses domain walls in nanowires for high density data storage and for field or current driven magnetic logic. A typical domain wall separates two opposite regions of magnetization, making it a "180° wall". The researchers showed that several 180° walls could be injected into a nanowire, where they either annihilated each other or they combined to form complex walls in which the magnetization rotated by up to 540°. The 360° walls were of particular interest, since their magnetic behavior is dramatically different from the 180° walls currently used in prototype memory and logic devices. The researchers believe that, in addition to providing information about how 180° walls interact in domain wall-based nanowire memories, this work may lead to new magneto-electronic applications using 360° domain walls, such as manipulating bits using highly localized magnetic fields in magnetic logic circuits.

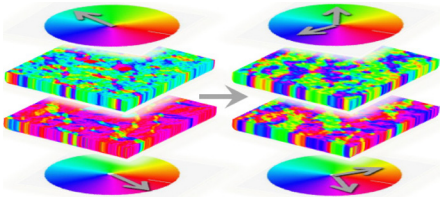


SEMPA images of magnetic domain walls in a nanowire. The magnetization direction is given by the arrows and the background colors. Top: Two separate 180° domain walls. The most common domain walls, 180° domain walls, form when the magnetization reverses direction. Bottom: An unusual 360° domain wall can form when the two 180° walls are pushed together.

Formation and structure of 360 and 540 degree domain walls in thin magnetic stripes, Y. Jang, S. R. Bowden, M. Mascaro, J. Unguris, and C. A. Ross, Applied *Physics Letters* **100**, 062407 (2012).

SPIN POLARIZED SUPERCURRENTS OPTIMIZED WITH A SIMPLE FLIP

In collaboration with researchers from Michigan State University, the NIST Center for Neutron Research and the CNST have discovered the key to controlling and enhancing the lossless flow of a current with a single electron spin state in a standard superconducting device. Production of superconducting currents ("supercurrents") that are also spin polarized opens up new possibilities in spintronics, an emerging field that integrates magnetic phenomena into conventional semiconductor electronics. The Michigan State researchers previously demonstrated that a spin-polarized super-current can be generated and sustained over a long range by passing a current through a carefully engineered stack of superconducting and magnetic thin films. However, they were surprised to discover that substantially larger currents can be created by exposing the device to a magnetic field.



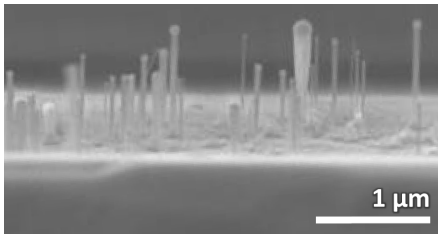
Using SEMPA, the magnetic structures in the top and bottom layers of a cobalt-ruthenium-cobalt sandwich contained within a superconducting device were imaged, both before (left) and after (right) applying a magnetic field, with the magnetization direction shown using a color wheel. The net magnetization in each layer was measured using PNR, and was shown to flip (gray arrows) after applying an appropriate magnetic field. These flips produce the local transport properties needed to sustain spin polarized supercurrents. The image layers shown above are 25 µm × 25 µm.

The mystery was solved by NIST scientists who determined the complex magnetic configuration of the layers in the stack using the complementary techniques of Polarized Neutron Reflectivity (PNR) and Scanning Electron Microscopy with Polarization Analysis (SEMPA). Together these measurements revealed that the magnetic field flips most of the magnetic layers to create a more ideal local environment for sustaining the polarized current. The researchers believe that combining spin polarized supercurrents and spintronics, such as spin transistors and spin filters, will eventually lead to novel applications similar to ones generated when superconducting devices were first combined with electronics.

Optimization of spin-triplet supercurrent in ferromagnetic Josephson junctions, C. Klose, T. S. Khaire, Y. Wang, W. P. Pratt, N. O. Birge, B. J. McMorran, T. P. Ginley, J. A. Borchers, B. J. Kirby, B. B. Maranville, and J. Unguris, *Physical Review Letters* **108**, 127002 (2012).

FABRICATION PROCESS FOR SILICON CARBIDE NANOWIRE ARRAYS

A collaboration between scientists from the NIST Material Measurement Laboratory (MML), Mississippi State University, and GeneSiC Semiconductor, a world-leading provider of high-performance silicon carbide (SiC) based power semiconductor products headquartered in Dulles, VA, has demonstrated the ability to fabricate arrays of aligned SiC nanowires. This advance opens the possibility of developing three-dimensional device platforms with SiC nanoscale elements for electrical, biomedical, and sensor applications. Nanowires of SiC have been extensively studied because of their high thermal and mechanical robustness, radiation hardness, excellent biocompatibility, and low background electrical noise for sensor applications compared to silicon. However, typical bottom-up fabrication processes result in randomly oriented SiC nanowires, limiting their utility for device applications, which are expected to require densely-packed arrays of well-aligned nanowires grown in a specific orientation to a host substrate.



Scanning electron micrograph shows an array of aligned nanowires grown on the sidewall of SiC mesa.

The researchers grew SiC nanowires on the top surfaces and walls of mesas that they created using reactive ion etching of single-crystalline SiC wafers. Catalytic nickel nanodots were deposited on the SiC substrate surfaces using the electron beam deposition system in the NanoFab. The nanowires were later fabricated at Mississippi State University utilizing a metal-catalyzed chemical vapor deposition process. Using field-emission scanning electron microscopy, transmission electron microscopy, X-ray diffraction, and electron-back-scatter-diffraction, the researchers determined that different orientations of the crystallographic planes of the SiC mesas resulted in six distinct directions of nanowire growth. Of these, well-aligned nanowires grew on one particular set of crystallographic planes on the SiC mesas with lengths in the tens of micrometers, depending on their growth time, and diameters from 20 nm to 100 nm, depending on the diameter of the catalyst. According to GeneSiC's Director of Technology, Siddarth Sundaresan, who is also a guest researcher in MML, GeneSiC has "developed highest-in-class performance SiC semiconductor devices and associated products for customers ranging from the Department of Defense and the Department of Energy to large commercial clients, such as Halliburton, Schlumberger, General Electric, and Boeing." As with other projects that GeneSiC is undertaking at the CNST, they "could not have fabricated the nanowires without the NanoFab's world-class cleanroom nanofabrication tools."

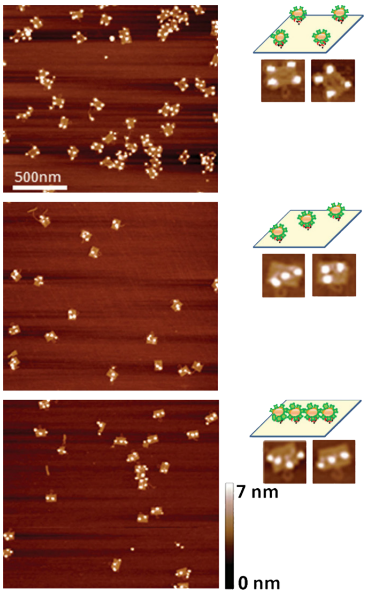
The researchers' next step is to refine the process for fabricating large-area arrays of aligned SiC nanowires and to perform additional electrical characterization. They believe that the SiC nanowire arrays may enable the development of advanced electronic and biomedical devices.

Growth of SiC nanowires on different planes of 4H-SiC substrates, R. V. K. G. Thirumalai, B. Krishnan, I. Levin, A. V. Davydov, S. Sundaresan, J. N. Merrett, and Y. Koshka, *Materials Science Forum* **717-720**, 1279-1282 (2012).

Growth on differently oriented sidewalls of SiC mesas as a way of achieving well-aligned SiC nanowires, R. V. K. G. Thirumalai, B. Krishnan, A. V. Davydov, J. N. Merrett, and Y. Koshka, *Crystal Growth & Design* **12**, 2221–2225 (2012).

RESEARCHERS QUANTIFY THE KINETICS OF NANOSCALE ASSEMBLY WITH DNA ORIGAMI

By varying the spacing and number of binding sites on DNA "origami", CNST researchers have determined the rate constants for attaching functionalized quantum dots (QDs) and identified factors that can improve the attachment yield. Using the highly specific nature of DNA hybridization, DNA can be cross-linked into relatively rigid two or three dimensional shapes known as DNA origami. These shapes can be engineered to provide molecularly precise attachment points (such as biotin) at which nanostructures functionalized with biomolecular receptors (such as streptavidin) can bind, making DNA origami an ideal test platform for learning how to manufacture diverse types of nanostructures via self-assembly in a controlled fashion. However, in order to determine whether this approach might be useful for practical tasks such as constructing semiconductor devices, drug delivery systems, or sensors for specific proteins, it is necessary to learn the rate at which binding reactions occur, what kind of yields are possible, and what specific design considerations need to be taken into account. To answer these questions, the researchers created 100 nm x 70 nm origami rectangles with different binding site configurations and mixed them with 20 nm-diameter, functionalized QDs. The results showed that the reactions between these objects—which are large compared to the typical molecular scale—are limited by diffusion and are therefore surprisingly slow, taking many hours to complete. Moreover, the large diameter of the QDs limits how closely the dots can be positioned relative to each other, reducing the yield of the desired, fully-occupied QD-origami structures. Even with three QD binding sites at each attachment point, the yields are significantly below 100 %. The work shows that while this approach will be promising for biological applications such as sensing and drug delivery, it will be difficult to apply to areas such as semiconductor device manufacturing because the placement precision is too low and the error rate is too high.

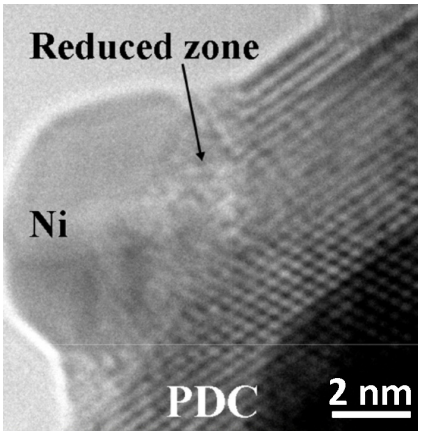


As shown in these atomic force microscope topographic images, NIST researchers made three DNA origami templates designed so that quantum dots would arrange themselves: in the corners (top), diagonally (middle), and in a line (middle). The researchers found that putting the quantum dots closer together caused them to interfere with one another, leading to higher error rates and lower binding probability.

Nanomanufacturing with DNA origami: factors affecting the kinetics and yield of quantum dot binding, S. H. Ko, G. M. Gallatin, and J. A. Liddle, *Advanced Functional Materials* **22**, 1015–1023 (2012).

IN-SITU OBSERVATIONS REVEAL HOW NANOPARTICLE CATALYSTS LOWER OPERATING TEMPERATURES IN FUEL CELLS

Researchers from the CNST and Arizona State University have used environmental transmission electron microscopy (ETEM) to explain the role of nickel nanoparticles in lowering the operating temperature of praseodymium doped ceria (PDC) anodes in solid-oxide fuel cells (SOFCs). These fuel cells are a promising technology for efficiently converting chemical fuels into electricity, and PDC-based anodes have the potential to replace the more commonly used nickel and yttria-stabilized zirconia anodes, which operate at higher temperatures (typically in excess of 1000 °C) that unfortunately cause the anodes to degrade. Nickel and PDC are being investigated as alternative anode materials because they operate at a lower temperature of 500 °C to 700 °C, making the anodes more stable. Using the ETEM, the researchers were able to visualize nanometer-scale structural and chemical changes occurring at the interface between the nickel and the PDC as a function of temperature in an atmosphere of dry hydrogen at 130 Pa, mimicking the partial pressure of hydrogen in a SOFC. Using energy-loss spectra, the researchers showed that the introduction of nickel nanoparticles lowered the reduction temperature of the PDC in a 20 nm-deep reduction zone around the interface between the two materials. The formation and size of the reduction zone is consistent with two possible mechanisms, each involving the spillover of ambient atomic hydrogen from the nickel to the PDC. The researchers believe that understanding and controlling how the nickel nanoparticles catalyze these lower-temperature reactions will enable the development of SOFCs that are both efficient and long-lived.

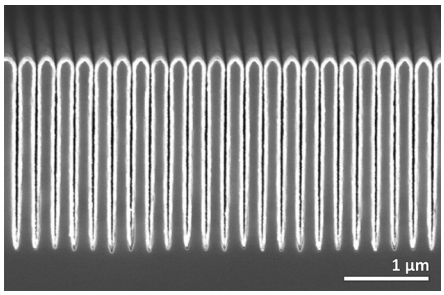


High resolution environmental transmission electron microscope image of a nickel–praseodymium (PDC) doped interface in a dry hydrogen environment.

Direct observation of hydrogen spillover in Ni-loaded Pr-doped ceria, V. Sharma, P. A. Crozier, R. Sharma, and J. B. Adams, *Catalysis Today* **180**, 2-8 (2012).

NEW ALD PROCESS FOR COATING HIGH ASPECT RATIO STRUCTURES

Process engineers in the CNST NanoFab have developed a new atomic layer deposition (ALD) process which can conformally coat platinum (Pt) on to high aspect ratio nanoscale structures. While physical vapor deposition (PVD) and chemical vapor deposition (CVD) have been used for decades to deposit thin films with accurate thickness control on to substrates, coating a thin film on to high aspect ratio nanoscale structures has remained a challenge. Unlike CVD and PVD, which coat thin films from the top of the structure, ALD uses a self-limiting, gas-phase surface chemical reaction to coat thin films from the bottom of the structure up, making it an excellent technique for coating high aspect ratio structures. The self-limiting reaction in ALD allows each deposition cycle to deposit only one monolayer of material. In principle, this advantage allows an operator to achieve excellent film conformity and desired thin film thickness by simply repeating the monolayer coating a desired number of times.



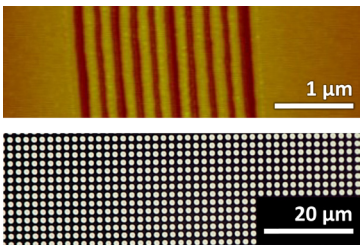
Scanning electron micrograph of a high-aspect-ratio silicon grating with 100 nm spacing and 2 µm trenches coated with 30 nm-thick platinum.

In practice, during ALD processes both PVD and CVD can occur at the same time due to incomplete purges and physical adsorption of precursor compounds. To ensure that the ALD process is completely self-limiting and that the precursors can reach the bottom of the deep trench, the new process pauses the release of the precursor inside the reaction chamber and purges out the extra precursor completely. Precursor holding and purging times have been tested and optimized. Using high aspect ratio silicon gratings provided by Professor Jay Guo's research group at the University of Michigan as a substrate, the engineers demonstrated that the new ALD coating process can conformally coat 30 nm-thick Pt on to a surface that has trenches that are 100 nm wide by 2 µm deep. During ALD, the gap spacing decreases gradually. Scanning electron micrographs show that Pt can be coated uniformly from top to bottom leaving evenly-spaced 30 nm gaps. For more information, contact Lei Chen, 301-975-2908, email: lei.chen@nist.gov.

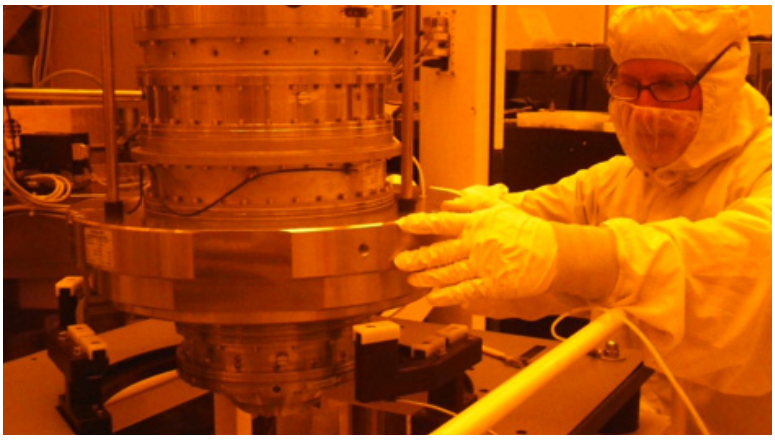
NEW DRY PLASMA ETCHING PROCESS IS AVAILABLE FOR MAKING PHOTOMASKS

The NanoFab has set up a new dry etching process using a 125 mm (5 in) mask carrier and a ceramic ring clamp installed in one of the Oxford plasma etchers to make chromium (Cr) photomasks with significantly smaller feature resolution than the traditional wet chemical etching process. The wet chemical etching process limits photomask feature sizes to greater than one micrometer. Using the new process, NanoFab engineers have successfully patterned 150 nm half-pitch Cr gratings and 1 µm-diameter dots.

The new dry Cr mask etching process also simplifies post-etch cleaning. The photoresist which was used as a Cr etching mask can now be cleaned by oxygen plasma in the same chamber that was used for etching the Cr. This dry cleaning process eliminates the solvent residual created by wet chemical cleaning and reduces the use of hazardous organic solvents. For more information, contact Lei Chen, 301-975-2908, email: lei.chen@nist.gov.



Atomic force microscope image of a 150 nm half-pitch Cr grating (top) and an optical microscope image of 1 µm-diameter Cr dots (bottom), patterned using the NanoFab's new dry plasma etching process.



An ASML engineer installs a lens in the NanoFab's new stepper, which is now available for use. The stepper can expose 80 to 120 wafers per hour, and provides frontside and backside alignment with resolution down to 280 nm and overlay accuracy of 40 nm. It can handle 200 mm-diameter wafers as well as small pieces. For more information, contact Liya Yu, 301-975-4590, email: liya.yu@nist.gov.

CNST Center for Nanoscale Science & Technology

CENTER FOR NANOSCALE SCIENCE AND TECHNOLOGY

The CNST is a national user facility purposely designed to accelerate innovation in nanotechnology-based commerce. Its mission is to operate a national, shared resource for nanoscale fabrication and measurement and develop innovative nanoscale measurement and fabrication capabilities to support researchers from industry, academia, NIST, and other government agencies in advancing nanoscale technology from discovery to production. The Center, located in the Advanced Measurement Laboratory Complex on NIST's Gaithersburg, MD campus, disseminates new nanoscale measurement methods by incorporating them into facility operations, collaborating and partnering with others, and providing international leadership in nanotechnology.

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SUPPORTING THE DEVELOPMENT OF NANOTECHNOLOGY FROM DISCOVERY TO PRODUCTION

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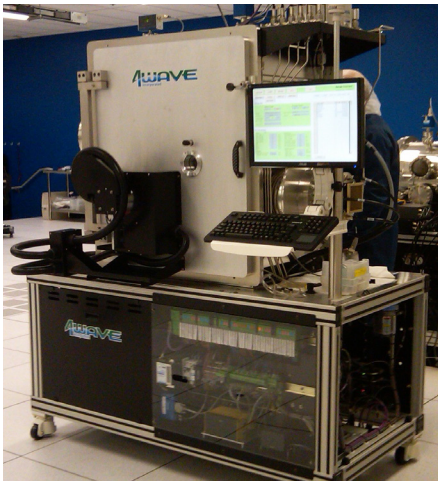

SECONDARY ION MASS SPECTROMETER ADDED TO NANOFAB ION MILL SYSTEM

The CNST has purchased a secondary ion mass spectrometer (SIMS) which will be added to its ion milling system in the fall. It will be available to users beginning in November 2012. The module detects ion mill by-products for up to four materials at one time. The SIMS can reliably determine with better than 0.2 nm accuracy the endpoint for an etch that terminates at or near the interface of almost any two dissimilar materials. For more information, contact Gerard Henein, 301-975-5645, email: gerard.henein@nist.gov.

2012 MRS FALL MEETING

Visit the CNST Booth at the

MATERIALS RESEARCH SOCIETY FALL MEETING

Hynes Convention Center
Boston, Massachusetts
November 25 - 30, 2012

NANOFAB USERS MEETING
THURSDAY, SEPTEMBER 6, 2012 | 2–4 PM
BUILDING 215/C103

Current and potential NanoFab researchers and others interested in NanoFab operations are invited to the quarterly NanoFab Users meeting. Topics typically include safety, policy changes, new equipment purchases or upgrades, research highlights, and new standard processes. Every meeting also includes an open discussion to allow users to bring ideas and suggestions to our attention. Anyone wishing to have an item added to the agenda should contact Vincent Luciani, 301-975-2886, email: vincent.luciani@nist.gov.