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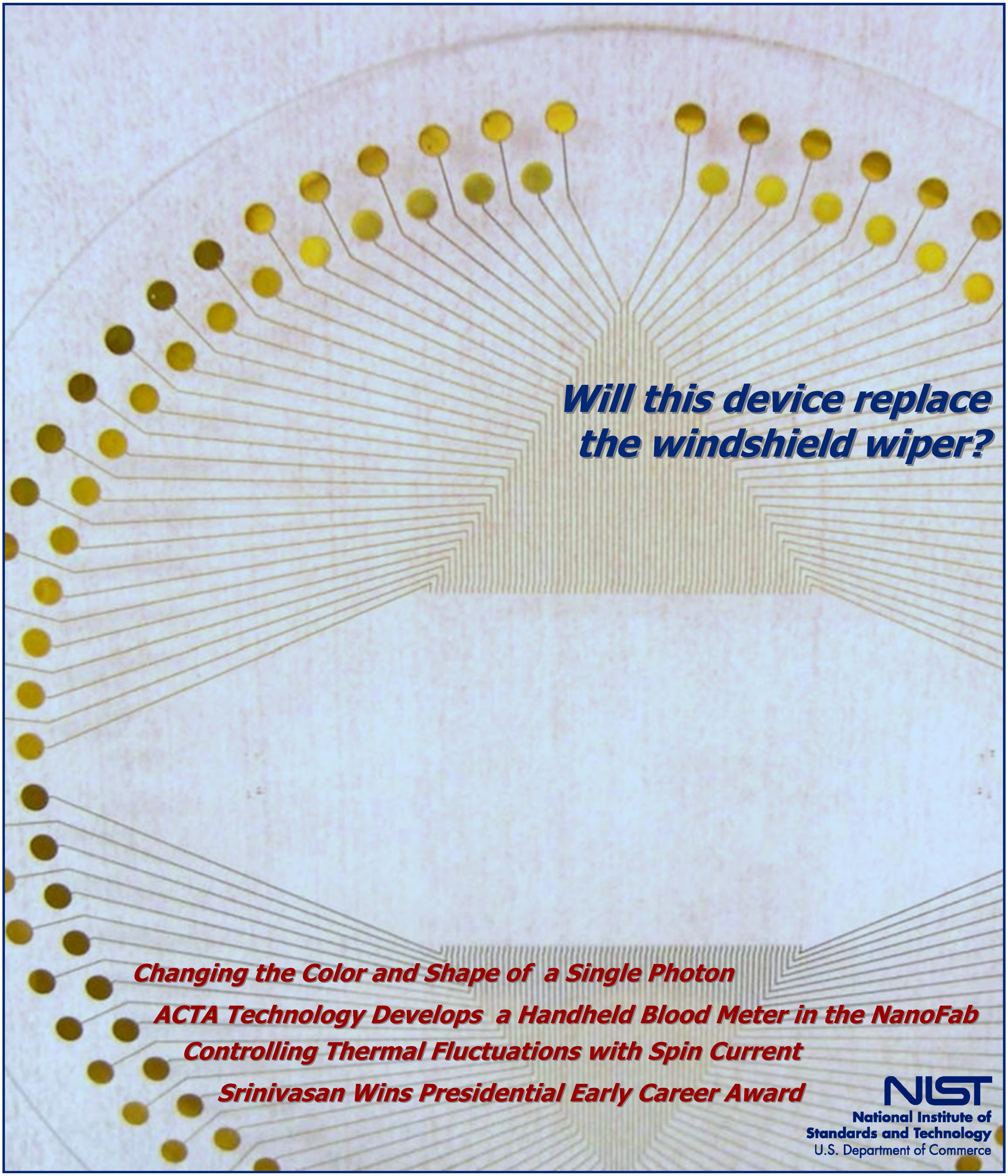
The CNST News



Will this device replace the windshield wiper?

Changing the Color and Shape of a Single Photon

ACTA Technology Develops a Handheld Blood Meter in the NanoFab

Controlling Thermal Fluctuations with Spin Current

Srinivasan Wins Presidential Early Career Award

NIST
National Institute of
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From the Director

We work hard at the CNST to bring a broad range of researchers together to develop and share interdisciplinary solutions to nanoscale measurement and fabrication problems. To foster such interactions in this time of fiscal constraint, I want to call your attention to multiple mechanisms that we have fashioned to facilitate and support collaborative research with the CNST and visits to our NanoFab.

CNST research is creating the next generation of nanoscale measurement instruments and methods, which we make available at no cost through collaboration. Collaboration may be informal, on a "bench-to-bench" level, or performed in residence through our postdoctoral and visiting fellow programs. Postdoctoral researchers typically come to the CNST for two years as National Research Council Postdoctoral Research Associates or CNST/University of Maryland Postdoctoral Researchers. Our Visiting Fellows Program allows outstanding senior researchers from industrial, academic, and government laboratories to come to NIST to collaborate. Fellows receive financial support and may collaborate for extended periods via regular, short-term visits, or be in residence full-time, e.g., during a year-long sabbatical. To learn more, please contact a CNST Project Leader in your area of interest.

If you have an existing NSF grant and have identified an area for collaboration with one of our Project Leaders, you may make use of a special NSF program that provides supplemental support for up to $25,000 for travel expenses and per diem associated with such research to be performed at NIST — ask your NSF Program Manager about Solicitation 11-066.

The CNST's shared-use NanoFab gives researchers economical access to and training on a state-of-the-art, commercial nanotechnology tool set for development. Although a popular resource for experienced researchers needing access to a reliable, professionally-run "fab", the NanoFab is also a great place for people that require hands-on assistance and training. For well-defined, non-proprietary projects, you may even find it most efficient to be a "remote user," with our staff performing your work in the NanoFab at an additional hourly cost. Check with Vince Luciani, our NanoFab Manager, for staff availability.

Finally, to help researchers get started with collaborative research or visits to the NanoFab, the NIST-University of Maryland Cooperative Program provides a limited number of competitively awarded travel grants of up to $1000. Highest consideration for awards is given to first-time participants, to scientists at the early stages of their careers, and for expenses related to graduate student research at the CNST. See http://www.nist.gov/cnst/umd_travel_award.cfm for guidance.

–Robert Celotta

CNST
Center for Nanoscale Science & Technology

Pulsed Argon Etch Process Improves Si Etch Rate and Selectivity

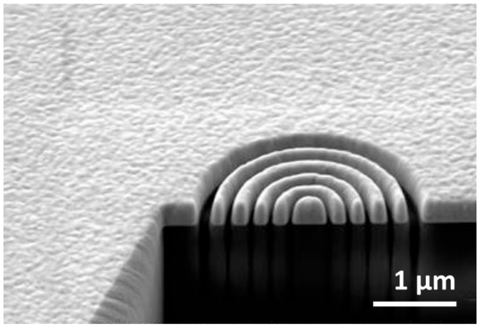
Engineers in the CNST NanoFab have developed a new plasma etching technique for silicon which improves the etch rate, the mask selectivity, and the sidewall profile by optimizing the addition of argon to the process flow. Small and high aspect ratio silicon structures can now be easily and more rapidly fabricated in the NanoFab using fluorinated plasma chemistry that is inherently isotropic. Directly adding argon to a typical SF_6/C_4F_8 plasma primarily causes dilution and reduces the etch rate. By alternating the etch step with an argon-only step, both high selectivity and high etch rates can be obtained while maintaining anisotropic etching. In a deep silicon etch, C_4F_8 is used to protect the Si sidewalls and SF_6 is used to etch. Mixing argon with the etchant gases provides very limited or no improvement to the etch rate due to dilution. However, alternating argon surface bombardment steps with the chemical etch steps results in a four-fold increase in the silicon etch rate while maintaining vertical sidewalls. The silicon etch rate increases with the argon step time, independent of the SF_6 step time. The argon bombardment step is rate-determining, influencing the etch rate as well as the selectivity and etching profile. The engineers postulate that argon surface bombardment renders the top atomic layers of the silicon amorphous, and then gas phase fluorine can react with and efficiently remove the silicon. Given the long etch times currently associated with etching deep nanoscale silicon trenches, this new process is likely to become widely used.

Effect of alternating Ar and SF_6/C_4F_8 gas flow in Si nano-structure plasma etching, L. Chen, V. Luciani, and H. Miao, *Microelectronic Engineering* **88**, 2470-2473 (2011).

CNST NanoFab engineers have developed a new plasma etching technique for silicon which improves the etch rate, the mask selectivity, and the sidewall profile.

Surface Plasmonic Lens Bridges Nanophotonics and Conventional Optics

Researchers from the University of Maryland and the CNST have experimentally demonstrated superfocusing of light using an optical fiber-based surface plasmonic (SP) lens. Optical fibers have been used as low-loss light waveguides for decades. However, light strongly diverges at the fiber end, limiting the utility of fiber optics for applications that require a high numerical aperture as well as a sub-diffraction-limit focal size. As described in a recent publication in *Optics Express*, this limitation can be overcome by fabricating an SP lens directly on the end of an optical fiber. The fiber-based SP lens is composed of a set of concentric annular slits with varied nanoscale widths cut through a uniform gold coating at the end face of a single-mode optical fiber. The slits were fabricated using the focused ion beam system in the CNST NanoFab. When the light in the fiber impinges on the SP lens, surface plasmon polaritons (SPPs) at the slit edges are excited. Because the slit widths are smaller than the light wavelength, the light passes through the slits only as SPP modes that are coupled back to optical waves at the exit of the slits. Moreover, the SPP propagation delay can be controlled by the width of the slits in order to induce a curved wavefront of exiting optical waves and thereby achieve a tight focus at the desired distance. The research team has experimentally demonstrated a transverse spot size of 450 nm ± 60 nm, which is below the diffraction limit for the 808 nm light. This fiber-based SP lens design can be readily integrated into many existing systems to bridge nanophotonics and conventional optics. Possible applications include laser nanofabrication, optical trapping, high-density optical storage, and high-resolution fluorescence sensing. The researchers are currently exploring applications for fiber based SP lenses for both high-resolution imaging and biological sensing.



Cross-cut of a plasmonic lens fabricated onto the end of an optical fiber.

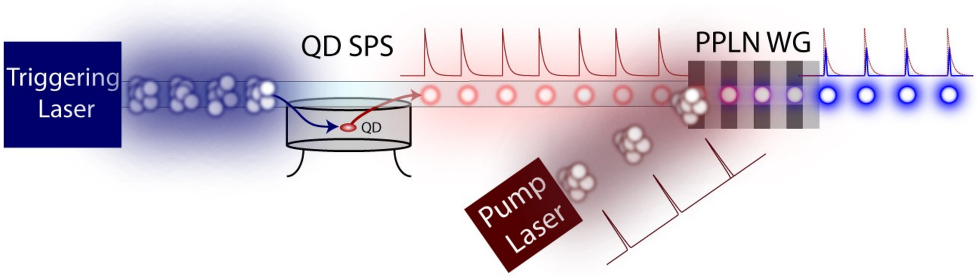
Far-field superfocusing with an optical fiber based surface plasmonic lens made of nanoscale concentric annular slits, Y. Liu, H. Xu, F. Stief, N. Zhitenev, and M. Yu, *Optics Express* **19**, 20233-20243 (2011).

While the NanoFab provides a comprehensive suite of commercial tools, the CNST research program is creating the next generation of nanoscale measurement instruments and fabrication methods, which are made available through collaboration with CNST scientists.

Changing the Shape and Color of a Single Photon

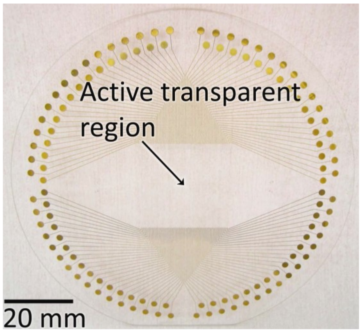
A team of researchers from the CNST and the NIST Information Technology Laboratory has simultaneously changed the color and shape of a single photon, the smallest unit of light. The work represents an important step towards implementing communication over long distances with privacy secured by the laws of quantum physics. Using a specially designed optical fiber probe, a single photon at a telecommunications wavelength was extracted from a quantum dot, a semiconductor analog of an atom, that was engineered to emit photons one at a time. Each photon was then combined with a much stronger pulsed laser beam inside a nonlinear optical crystal that enables the two light beams to interact efficiently. After exiting the crystal, the wavelength, or color, of the photon is shifted by almost 600 nm, an amount greater than the size of the entire visible spectrum. Because the researchers use a pulsed laser, its temporal shape becomes imprinted on the single photon during the color-conversion process. Researchers utilizing different quantum technologies, which often require single photons of a specific wavelength and shape, may be able to use this approach to link their previously incompatible systems together in a large-scale network for quantum information processing applications.

Simultaneous wavelength translation and amplitude modulation of single photons from a quantum dot, M.T. Rakher, L. Ma, M. Davanço, O. Slattery, X. Tang, and K. Srinivasan, *Physical Review Letters*, **107**, 083602 (2011).



The color and shape of single photons produced by a quantum dot single photon source (QD SPS) are changed by combining them with a strong, pulsed pump laser in a nonlinear crystal (PPLN WG).

Building Invisible Windshield Wipers in the NanoFab



Prototype of a transparent windshield wiper. Each gold lead charges a transparent 25 nm-thick wire generating an electric field on the surface of the clear center of a quartz wafer. When the charges are changed, the water experiences a force that pushes it out of the transparent region.

Working with the NanoFab engineering staff, researchers from WCH Technologies Corporation, based in Potomac, MD, have developed 100 mm-diameter quartz wafer prototypes of a potential replacement for conventional windshield wipers. Their approach uses an electrostatic field to move water across a glass or quartz surface faster than conventional wipers and uses a fraction of the energy.

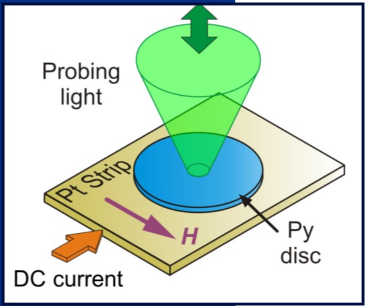
In the center region of each wafer are 128 wires made of transparent indium tin oxide (ITO), each 25 nm thick x 200 μm wide. Voltage is applied to the wires giving them alternating positive and negative charges. The entire wafer is covered with a transparent insulating surface layer of SiO_2. As water aggregates on the surface, it behaves like a parallel plate in a capacitor and is attracted to the embedded wires. A computer controls the voltages, creating a varying electric field which applies a force to the water, causing it to move rapidly off the surface.

Windshield wipers were invented in 1903, and have had only two significant upgrades since then – the introduction of power wipers in the 1920s and of intermittent wipers in the late 1970s. Five years ago, CEO Walter Hernandez, a physicist, decided to try to build a wiper without vision-obstructing moving parts that could rapidly clean a whole windshield in heavy rains.

After testing dielectric samples made at the University of Maryland, Hernandez and his team came to the CNST NanoFab with their design. They worked with the NanoFab staff to develop a fabrication process and to make prototypes. They initially tested their concept using parylene as an insulating layer. They then built wafer-scale prototypes with ITO, using plasma-enhanced chemical vapor deposition and depositing SiO_2 as an insulator. According to Hernandez, "I didn't have expertise for making nanofabricated devices. I worked with the staff to develop the production steps, and the technicians did the fabrication work, including all the lithographic etching. They outlined the steps and at the end the work came out exactly as specified."

The researchers believe that when scaled up the device will do everything a windshield wiper does but will clean the entire windshield. Because it has no moving parts, Hernandez believes it may find early use in airplanes, which travel at 800 km/hr and cannot use mechanical windshield wipers. He is developing an agreement with a windshield manufacturer to build a full-size windshield using his imbedded technology and expects a patent on his device to be issued in the next few months.

Controlling Thermal Fluctuations with Spin Current



Magnetic fluctuations in a 2 μm-diameter permalloy (Py) disk were measured using microfocus Brillouin light scattering while a current passed through a supporting Pt strip.

A team of researchers from the CNST, the University of Muenster, and West Virginia University have demonstrated control of magnetic thermal fluctuations using current. The work represents an important step towards manipulating the noise properties of magnetic nanosensors and memory devices. The magnetic fluctuations of a 2 μm-diameter disk of a Ni-Fe alloy (permalloy) were measured using microfocus Brillouin light scattering while a current passed through a supporting platinum (Pt) strip. The current generated a spin current, which was injected into the permalloy disk through its back surface. As electrons flow along the Pt strip, they scatter differently, depending on each electron's spin: those with "up" spin scatter slightly toward the top surface, while those with "down" spin scatter slightly toward the bottom surface. This "spin Hall effect" drives a spin current, but not a charge current, into the bottom of the magnetic disk. The measurements show that the thermal fluctuations of the disk's magnetization are suppressed if the injected spins are parallel to the magnet's spins, and that the fluctuations are strongly amplified if the injected spins and the magnet's spins are antiparallel. By changing the current down the Pt strip, the fluctuations were controllably reduced to 0.5 times or amplified to 25 times their thermal level. The measured population of the disk's magnetic excitations differs from a thermal distribution, showing that the effect is not simply cooling or heating. These intriguing results provide insight into the complexity of spin current phenomena and suggest a route for controllably manipulating fluctuations in future magnetic nanodevices.

Control of magnetic fluctuations by spin current, V. E. Demidov, S. Urazhdin, E. R. J. Edwards, M. D. Stiles, R. D. McMichael, and S. O. Demokritov, Physical *Review Letters* **107**, 107204 (2011).

ACTA Technology Develops Handheld Blood Meter in the NanoFab

Researchers from ACTA Technology, based in Boulder, CO, are developing a hand-held point-of-care and home use test for measuring blood coagulation that uses a drop of whole blood taken by a finger prick. Unlike clinical devices currently on the market, which use optical analysis, cantilevers, or chemical reactions, their approach uses microelectromechanical sensors which incorporate a parallel plate to measure the blood clotting time. Based on technology developed by Nicholas Dagalakis in the NIST Engineering Laboratory, the device tests a small amount of whole blood, making it less intrusive so it can be used at home or in a doctor's office, without the need for a laboratory.

The prothrombin time test works by introducing tissue factor to begin the series of reactions that occur when a blood vessel is ruptured. The clot changes the blood from a free-flowing solution to a gel-like substance and it is this change that the sensor monitors and detects.

Various medical conditions require the use of the anti-coagulant warfarin, a powerful but potentially dangerous drug . Affected patients need their clotting time monitored to ensure proper drug dosing. ACTA's device has been demonstrated to measure the rheometric properties of complex fluids similar to blood in seconds using nanoliter-size samples.

Edward Clancy, ACTA's Chief Technical Officer, credits the CNST NanoFab staff for his company's ability to rapidly develop prototypes. "We built our entire sensor device in the NanoFab, everything from the mask writing to the ion etching to the deposition of our gold contacts," says Clancy, "Now that we have the processes optimized, we can go to a fabrication shop in the U.S. for mass production." According to Clancy, "a small company cannot do this ourselves, and it is hard to get commercial fabs to produce small quantities for prototyping."

Using a handheld measurement device whose components were built in the NanoFab, patients may one day test their own clotting time.

Medicare recently announced expanded coverage for warfarin patients, including monitoring clotting time at home. Thirty million Americans take warfarin, a number that will grow as more people use blood thinners to reduce the risk of heart attacks and strokes. Clancy believes that ACTA is well positioned to see its product widely adapted as home blood testing becomes more common.

CNST's Aksyuk Teaches Leading-Edge Nanoscience to Blind Students

In July 2011, 150 blind high school students from around the country gathered at Towson University for a weeklong annual event designed to encourage them to consider science careers long believed to be impossible for the blind. Ten of those students participated in an exciting new educational program on nanoscale science led by CNST Project Leader Vladimir Aksyuk.

During 15 intense hours of hands-on activities spread over four days, the students learned the techniques scientists use to create and measure nanoscale structures. With the aid of haptic (tactile feedback) technology they felt with their own hands how an atomic force microscope probe senses individual atoms on a surface. They explored 3-D models of nanostructures, including carbon nanotubes, and built models of graphene.

Using laptops equipped with voice output screen reading software, the students designed their own nanoscale patterns, which were quickly fabricated on silicon chips at NIST using a focused ion beam. They then compared their intended designs with scanning electron micrograph images of the fabricated structures printed on special tactile paper. They conducted a leading-edge science experiment, using optical fibers connected to a laser, a nanophotonic cavity, and a photodetector, in order to measure the mechanical motion of a CNST-built nanoscale mechanical beam.

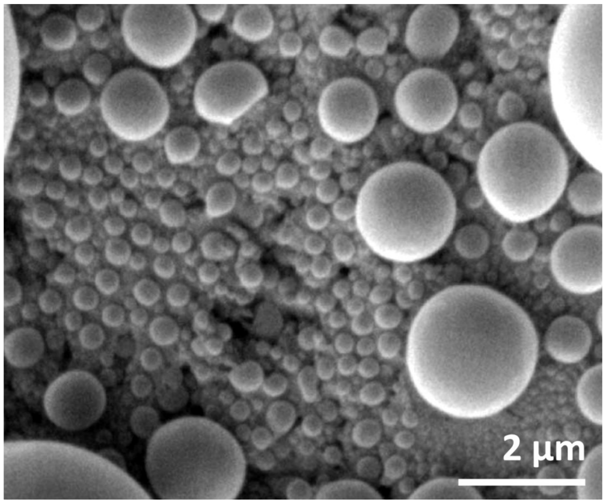
On the fifth day of the program, the students presented their results and, in turn, learned from the students in the other nine educational tracks that covered chemistry, robotics, forensics, space science, and other topics. "In just a few years many of these students will become active members of the vibrant and diverse U.S. scientific and technical enterprise," says Aksyuk, who found out about this event through a family member who is a member of the National Federation of the Blind, which sponsored the event.

The nanoscience track was developed by Aksyuk, Christopher Emborsky (Shell Global Solutions), and Andrew Greenberg (University of Wisconsin), with the help of Natalie Shaheen (National Federation of the Blind Jernigan Institute). Haptic demonstrations software, hardware and support were provided by Bradley Herring (Museum of Life and Science), Russell Taylor (University of North Carolina), and Doug Schiff (3rdTech, Inc.) Additional hardware, support, and laboratory space were provided by David Schaefer and Jeffrey Klupt of Towson University.

The students set the oscilloscope parameters and heard the output data using voice controls, and printed graphs on tactile paper.

Four students wear the type of clean-room suit worn in the CNST NanoFab.

Focused Ion Beam Uses Laser-Cooled Lithium Atoms



Secondary electron image of tin microspheres obtained using photoionized laser-cooled lithium atoms as a focused ion beam source.

A team of researchers from the CNST and FEI Company have adapted a commercial focused ion beam (FIB) column to use photoionized laser-cooled lithium atoms as an ion source, and demonstrated that NIST's patented Magneto-Optical Trap Ion Source (MOTIS) offers imaging performance competitive with the liquid metal ion sources used in most FIBs. In a MOTIS, a gas of atoms is laser-cooled to ≈ 100 μK and then photoionized. The ions are accelerated to the desired energy, forming a highly monochromatic beam that is amenable to nanoscale focusing when provided as input to a commercial focused ion beam column. The light mass and low surface sputtering rate of laser-cooled lithium allowed the researchers to demonstrate non-destructive imaging with a characteristic focal spot size of 26.7 nm ± 1.0 nm at 2 kV. As predicted theoretically, the focal spot size was shown to depend on the temperature of the laser-cooled atoms and on the ion beam energy. The researchers anticipate further improvements to the system spot size for enhanced imaging. These results demonstrate that NIST's new ion source may enable a wide range of new applications — from nanoscale imaging and defect metrology to ion implantation and material modification.

Nanoscale focused ion beam from laser-cooled lithium atoms, B. Knuffman, A. V. Steele, J. Orloff, and J. J. McClelland, *New Journal of Physics* **13**, 103035 (2011).

Kartik Srinivasan Wins Presidential Early Career Award

CNST Physicist Kartik Srinivasan was awarded the Presidential Early Career Award for Scientists and Engineers (PECASE) for developing measurement methods aimed at probing the nature of strong light-matter interactions in semiconductor optical cavities with unparalleled sensitivity and for developing processes to fabricate low-loss, on-chip, nanophotonic devices. The award is the highest honor bestowed by the U.S. government on outstanding scientists and engineers beginning their independent research careers. Winners receive up to a five-year research grant to further their study in support of critical government missions. The scientists are recognized not only for their innovative research, but also their demonstrated commitment to community service. President Obama named 94 researchers as recipients of the PECASE, including Srinivasan and two other NIST researchers, Chemical engineer Jeffrey Fagan and Physicist Jacob Taylor.

CNST Director Robert Celotta, Kartik Srinivasan, and John Holdren, Assistant to the President for Science and Technology

President Obama speaks to the PECASE award winners in the East Room of the White House, October 14, 2011.

The Presidential early career awards embody the high priority the Obama Administration places on producing outstanding scientists and engineers to advance the Nation's goals, tackle grand challenges, and contribute to the American economy. Sixteen Federal departments and agencies join together annually to nominate the most meritorious scientists and engineers whose early accomplishments show the greatest promise for assuring America's preeminence in science and engineering and contribute to the awarding agencies' missions.

The awards, established by President Clinton in 1996, are coordinated by the Office of Science and Technology Policy within the Executive Office of the President. Awardees are selected for their pursuit of innovative research at the frontiers of science and technology and their commitment to community service as demonstrated through scientific leadership, public education, or community outreach.

New Photolithography Suite Under Construction in the NanoFab Cleanroom

The MA-6 mask aligner exposes photolithographic images on the front and back sides of photoresist-coated substrates up to 150 mm in diameter.

The CNST is constructing a new NanoFab photolithography suite in the cleanroom which will consolidate most of the Center's contact lithography equipment, including ovens, spin coaters, and the MA-6 and MA-8 contact mask aligners. It will also house new industrial-scale equipment, including a new ASML stepper, a spin coater, and an automatic developer.

A former cleanroom service area, bay A105, is being upgraded to a Class 100 clean space, comparable to the other cleanroom process areas. The bay is being expanded so that it is as long as the other process bays; the interior wall will be moved to align with the rest of the bays. The electrical work is nearing completion. As part of the conversion to a clean space, a new heavy duty perforated floor has been installed and a HEPA filter ceiling will be installed shortly, along with a new heating and ventilation system. A large 5400 kg (12,000 lb.) granite isolation plate will be embedded in the new floor at the end of January to hold the ASML stepper, which will arrive a few weeks after that. Installation of a new 4-Wave ion mill is also underway; the device will be ready before the room opens. Construction is proceeding on schedule and is expected to be completed in the middle of March, with the room becoming available to users in April.

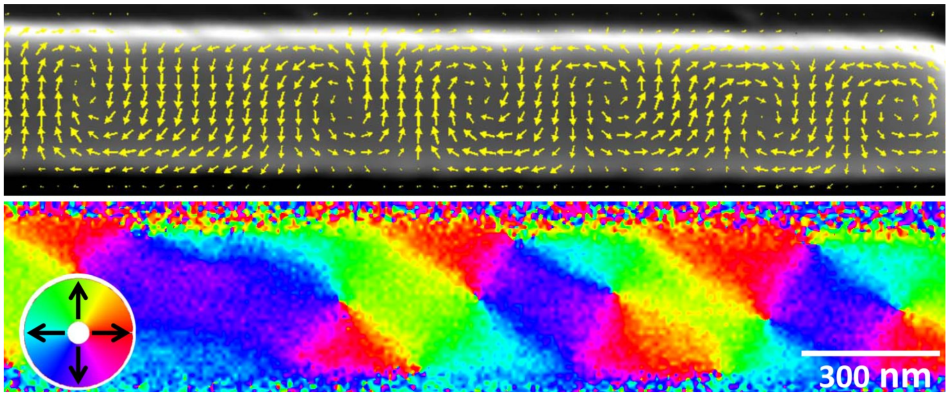
For more information, contact Vincent Luciani, 301-975-2886.

The new photolithography suite will bring industrial-scale contact lithography equipment to the NanoFab.

Revealing the Magnetization Textures in NiPd Nanostructures

An international collaboration, including researchers from the CNST, has used scanning electron microscopy with polarization analysis (SEMPA) to acquire images of the magnetic structure inside patterned nickel-palladium (NiPd) thin film nanostructures, revealing peculiar magnetization textures that can affect the behavior of these ferromagnetic alloys in experimental applications. NiPd alloys are used for studying how ferromagnets affect nearby superconductors. They are also good electron spin injectors and spin analyzers being applied to the development of carbon nanotube-based electronics using electron spin ("spintronics"). The magnetic orientation of nano-patterned NiPd thin film contacts was expected to be simple, controlled primarily by the shape of the patterned film and the applied magnetic field. The SEMPA measurements, along with magnetic force microscopy and spin-polarized photoemission electron microscopy, revealed a surprisingly complex spatial structure of the magnetization. In some devices, the magnetization was even perpendicular to the expected direction. The researchers found that complexity arises from stress-induced anisotropies caused by mismatches in both the lattice structures and the thermal expansion coefficients between the NiPd films and the underlying substrates. Although this stress-induced magnetic structure may be a problem for some applications, the researchers believe it can be used as a new route to control the orientation of the magnetization in nano-patterned electrodes.

Magnetization textures in NiPd nanostructures, J. Chauleau, B. J. McMorran, R. Belkhou, N. Bergeard, T. O. Menteş, M. Niño, A. Locatelli, J. Unguris, S. Rohart, J. Miltat, and A.



A SEMPA measurement of the magnetization direction in a 300 nm-wide NiPd nano-stripe. The measured direction is represented by arrows superimposed on the SEM image (top), or alternatively by color (bottom) with the directions given by the color wheel (inset).

CNST Center for Nanoscale Science & Technology

Center for Nanoscale Science and Technology

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Supporting the development of nanotechnology from discovery to production.

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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ARPA-E ENERGY INNOVATION SUMMIT

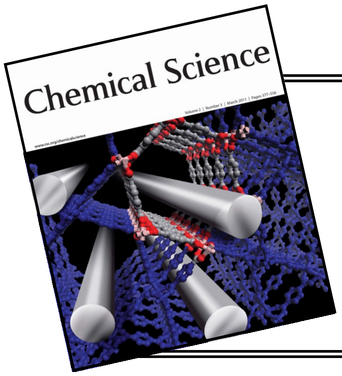
Visit the CNST Booth (#605) at the ARPA-E Energy Innovation Summit, National Harbor, MD February 27 – 29, 2012.

Announcing the Next NanoFab Users Meeting

Thursday, March 8, 2012, 2 pm to 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 a specific item added to the agenda should contact Vincent Luciani at 301-975-2886, vincent.luciani@nist.gov.



Chemical Science

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