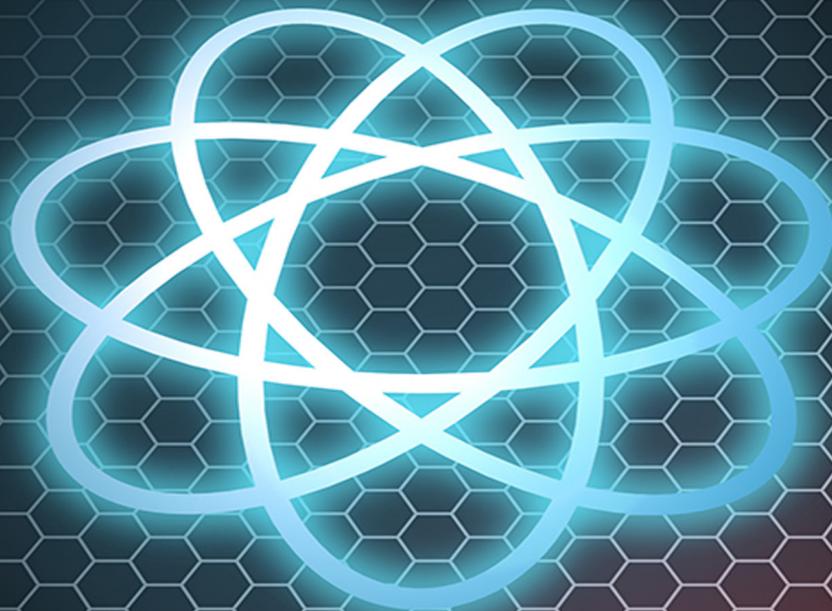
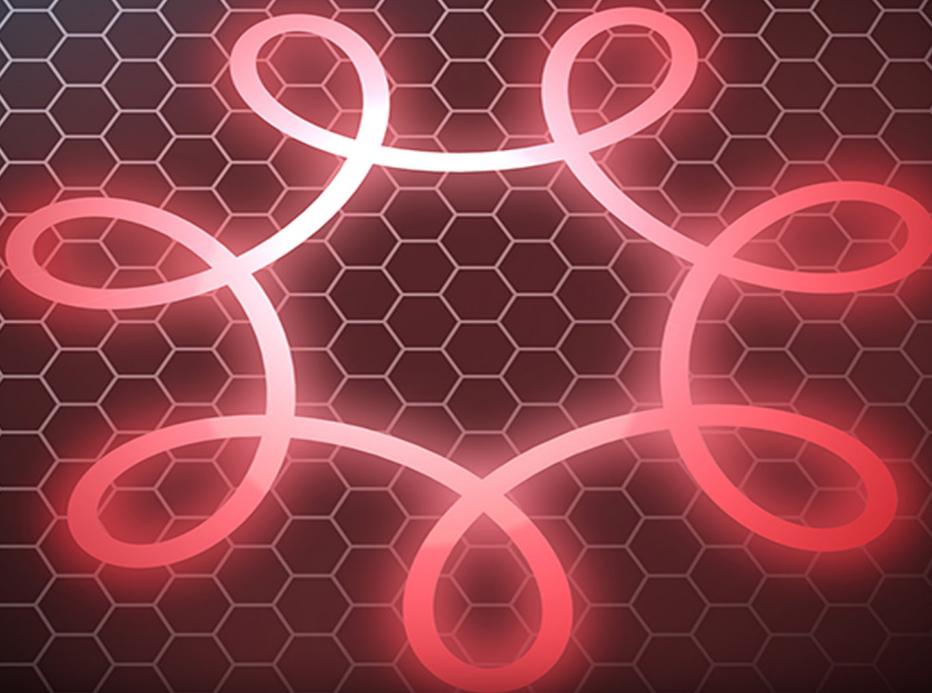


THE CNST NEWS

SPRING 2017



WHAT A SWITCH! TURNING
QUANTUM'S BERRY PHASE
ON AND OFF



INSIDE

NANOFAB TAKES BIOTECH CHIP FROM PROTOTYPE TO FINAL PRODUCT

NEW INSIGHTS INTO SOLAR CELLS

BOB CELOTTA: CNST'S FOUNDING DIRECTOR RETIRES

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Cover: These images show the orbital paths of electrons trapped within a circular region within graphene. In the classical orbit (top image), an electron that travels in a complete circuit has the same physical state as when it started on the path. However, when an applied magnetic field reaches a critical value (bottom image), an electron completing a circuit has a different physical state than its original one. The change is called a Berry phase, and the magnetic field acts as a switch to turn the Berry phase on. The result is that the electron is raised to a higher energy level.

Credit: Christopher Gutiérrez, Daniel Walkup/NIST

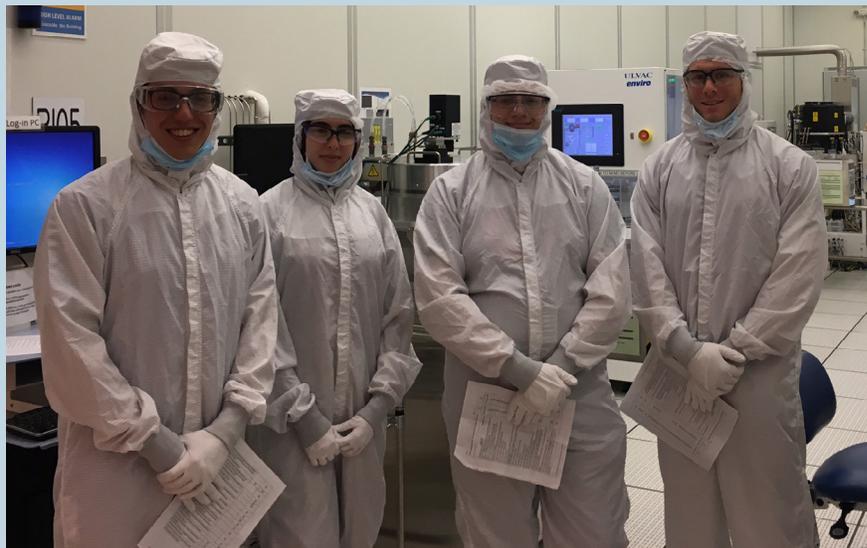
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SURF SUMMER INTERNS AT THE NANOFAB



FROM PROTOTYPE TO FINISHED PRODUCT: NANOFAB COLLABORATES WITH BIOTECH COMPANY

Earlier this year, engineer and small-business entrepreneur John Warden came to the NanoFab with a prototype of a laboratory on a chip—a handheld device that uses a mix of carbon nanotubes and dried antibodies to detect harmful bacteria within seconds. Warden, the head of a biotech startup, wasn't sure of the detailed structure of the prototype. Moreover, the chip's designer was no longer available.

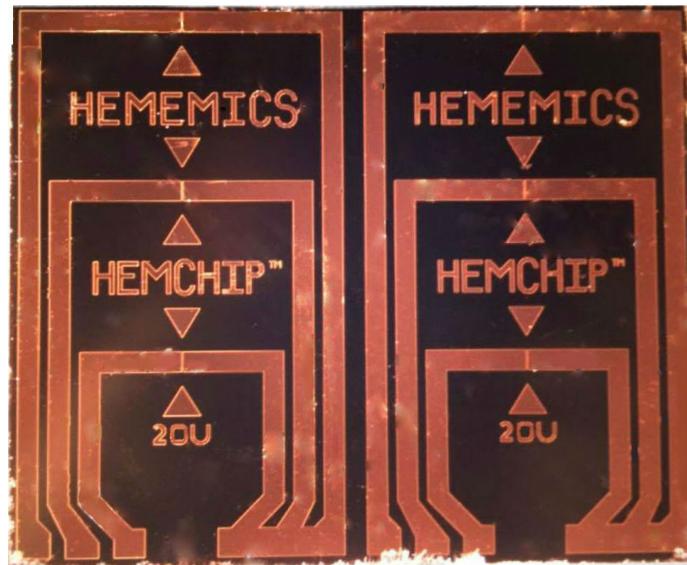
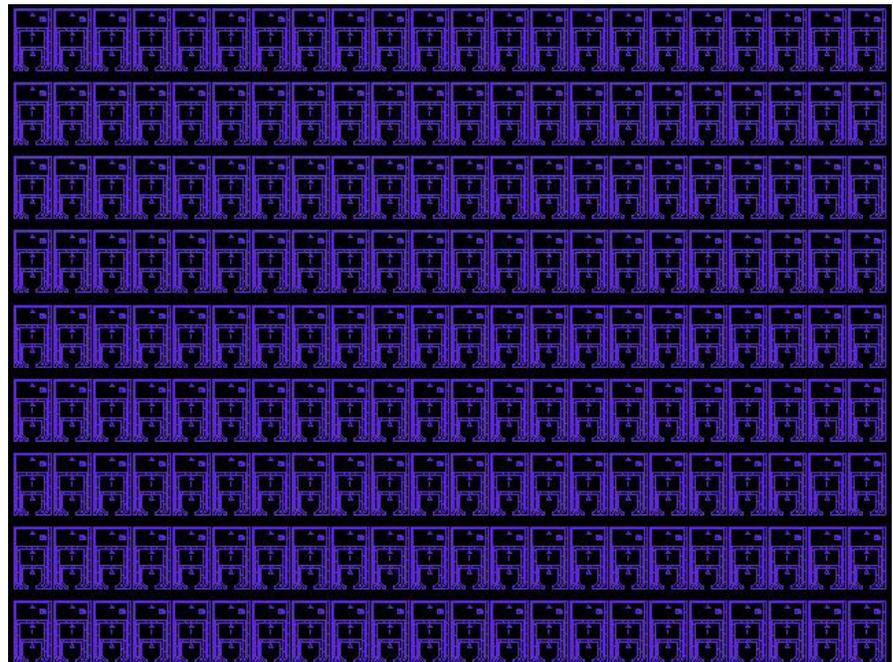
"Our business is protein preservation—not chip fabrication," said Warden.

Yet only four weeks later, the NanoFab staff presented Warden with a redesigned chip that worked so well that his company, HeMemics Biotechnologies in Tysons Corner, Va., is now ready to market the device.

"The NanoFab not only did the fabrication but the staff suggested several design modifications and gave us recommendations about how to manufacture chips more cheaply," said Warden. For instance, deputy NanoFab manager Jessie Zhang advised Warden that he could cut costs by using commercially available silicon-dioxide-coated wafers rather than having them custom made. She also determined that the chip did not require a second layer of metal to function, as Warden's company had thought, saving additional money.

That guidance was invaluable, he adds, because if a product—even a great one—can't be produced economically, "your project is going to die."

To analyze the structure of the prototype chip, NanoFab imaging specialist Joshua Schumacher and process technician Matt Robinson used the CNST's focused ion beam to cut thin slices of the device and examine the layers with a scanning electron microscope.



Evolution of chip for detecting bacteria, from the design of an array of chips (top) to a single finished product.

The device consists of an open electric circuit, with a tiny gap—tens of micrometers in width—separating the circuit's positive and negative terminals. The gap is filled with the mixture of carbon nanotubes and antibodies.

To detect bacteria or proteins, the chip is first wet with water. Then a liquid containing the sample to be tested is placed in the gap. If antibodies bind to a targeted bacteria

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RESEARCHERS DEVELOP MAGNETIC SWITCH TO TURN ON AND OFF A STRANGE QUANTUM PROPERTY

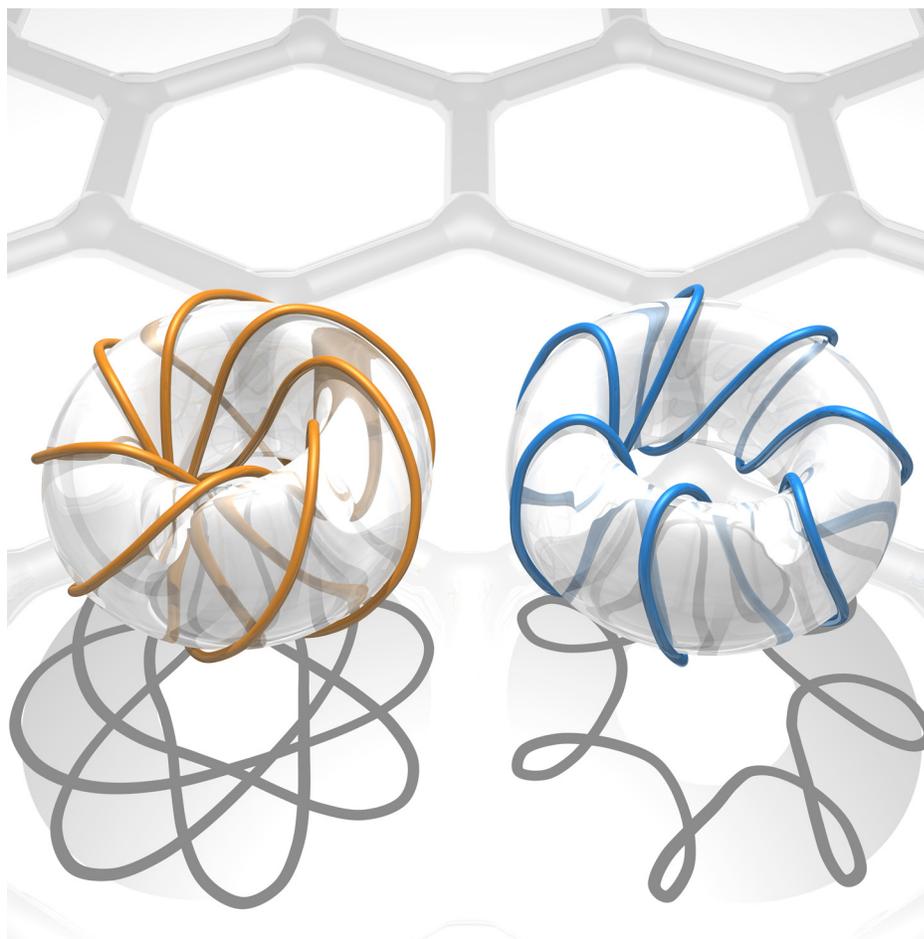
When a ballerina pirouettes, twirling a full revolution, she looks just as she did when she started. But for electrons and other subatomic particles, which follow the rules of quantum theory, that's not necessarily so. When an electron moves around a closed path, ending up where it began, its physical state may or may not be the same as when it left.

Now, there is a way to control the outcome, thanks to an international research group led by scientists at the CNST. The team has developed the first switch that turns on and off this mysterious quantum behavior. The discovery promises to provide new insight into the fundamentals of quantum theory and may lead to new quantum electronic devices.

To study this quantum property, CNST physicist and NIST fellow Joseph A. Stroscio and his colleagues studied electrons corralled in special orbits within a nanometer-sized region of graphene—an ultrastrong, single layer of tightly packed carbon atoms. The corralled electrons orbit the center of the graphene sample just as electrons orbit the center of an atom. The orbiting electrons ordinarily retain the same exact physical properties after traveling a complete circuit in the graphene. But when an applied magnetic field reaches a critical value, it acts as a switch, altering the shape of the orbits and causing the electrons to possess different physical properties after completing a full circuit.

The researchers report their findings in the May 26 *Science*.

The newly developed quantum switch relies on a geometric property called the Berry phase, named after English physicist Sir Michael Berry who developed the theory of this quantum phenomenon in 1983. The Berry phase is associated with the wave function of a particle, which in quantum theory describes



Three-dimensional renderings of electrons trapped within a special orbit inside graphene and their projections on the honeycomb graphene lattice (shadows). In the configuration at left, an electron that completes a closed circuit has exactly the same properties as when it began the circuit—its wavefunction is the same. But when a weak magnetic field reaches a critical value, the classic electron orbit (left) abruptly transforms into the skipping type with outer loops (right). This transition is marked by the presence of a Berry phase—the wavefunction of an electron no longer is the same when it completes a closed circuit within the graphene. Credit: Christopher Gutiérrez, Jon Wyrick, CNST/NIST

a particle's physical state. The wave function — think of an ocean wave — has both an amplitude (the height of the wave) and a phase — the location of a peak or trough relative to the start of the wave cycle.

When an electron makes a complete circuit around a closed loop so that it returns to its initial location, the phase of its wave function may shift instead of returning to its original value. This phase shift, the Berry phase, is a

kind of memory of a quantum system's travel and does not depend on time, only on the geometry of the system — the shape of the path. Moreover, the shift has observable consequences in a wide range of quantum systems.

Although the Berry phase is a purely quantum phenomenon, it has an analog in non-quantum systems. Consider the motion of a Foucault pendulum, which was used

to demonstrate Earth's rotation in the 19th century. The suspended pendulum simply swings back and forth in the same vertical plane, but appears to slowly rotate during each swing—a kind of phase shift—due to the rotation of Earth beneath it.

Since the mid-1980s, experiments have shown that several types of quantum systems have a Berry phase associated with them. But until the current study, no one had constructed a switch that could turn the Berry phase on and off at will. The switch developed by the team, controlled by a tiny change in an applied magnetic field, gives electrons a sudden and large increase in energy.

Several members of the current research team — based at the Massachusetts Institute of Technology and Harvard University— developed the theory for the Berry phase switch.

To create the switch, CNST team member Fereshte Ghahari built a high-quality graphene device to study the energy levels and the Berry phase of electrons corralled within the graphene.

First, the team confined the electrons to occupy certain orbits and energy levels. To keep the electrons penned in, team member Daniel Walkup created a quantum version of an electric fence by using ionized impurities in the insulating layer beneath the graphene. This enabled a scanning tunneling microscope at the CNST to probe the quantum energy levels and Berry phase of the confined electrons.

The team then applied a weak magnetic field directed into the graphene sheet. For electrons moving in the clockwise direction, the magnetic field created tighter, more compact orbits. But for electrons moving in counterclockwise orbits, the magnetic field

had the opposite effect, pulling the electrons into wider orbits. At a critical magnetic field strength, the field acted as a Berry phase switch. It twisted the counterclockwise orbits of the electrons, causing the charged particles to execute clockwise pirouettes near the boundary of the electric fence.

Ordinarily, these pirouettes would have little consequence. However, says team member Christopher Gutiérrez, “the electrons in graphene possess a special Berry phase, which switches on when these magnetically-induced pirouettes are triggered.”

When the Berry phase is switched on, orbiting electrons abruptly jump to a higher energy level. The quantum switch provides a rich scientific tool box that will help scientists exploit ideas for new quantum devices, which have no analog in conventional semiconductor systems, says Stroscio.

FROM PROTOTYPE TO FINISHED PRODUCT: NANOFAB COLLABORATES WITH BIOTECH COMPANY (CONT'D.)

present in the sample, the resistance of the circuit changes and the signal is interpreted by a microcontroller.

Two weeks into the project, the NanoFab staff produced chips with gaps of different widths; Warden's company conducted tests with the devices to determine the optimal gap width and reported back to the staff. “The NanoFab team really held our hand throughout the process,” he said.

Warden “came to us with an idea and a prototype and we gave him a product,” said Zhang.

The close collaboration with Warden is actually typical of interactions between users and the NanoFab, notes Robinson. “People may think of us just as a place to get a device



Image of full chip that can detect bacteria in less than 30 seconds. Credit: HeMemics Biotechnologies

built, but we routinely advise users on how to improve their design,” he said.

“We are delighted with the NanoFab,” Warden said. “Now we have a new design for our long-shelf-life chips that can withstand

the punishing heat of a car trunk and still perform well at a test site, recording the presence of bacteria in concentrations as low as 1000 colony forming units/millimeter,” he added. “We could not have done this without the NanoFab.”

UNEXPECTED PROPERTY MAY RAISE MATERIAL'S PROSPECTS AS SOLAR CELL

Crystalline materials known as perovskites could become the next superstars of solar cells. Over the past few years, researchers have demonstrated that a special class of perovskites—those consisting of a hybrid of organic and inorganic compounds—convert sunlight into electricity with an efficiency above 20 percent and are easier to fabricate and more impervious to defects than the standard solar cell made of crystalline silicon. As fabricated today, however, these organic/inorganic perovskites (OIPs) deteriorate well before the typical 30-year lifetime for silicon cells, which prevents their widespread use in harnessing solar power.

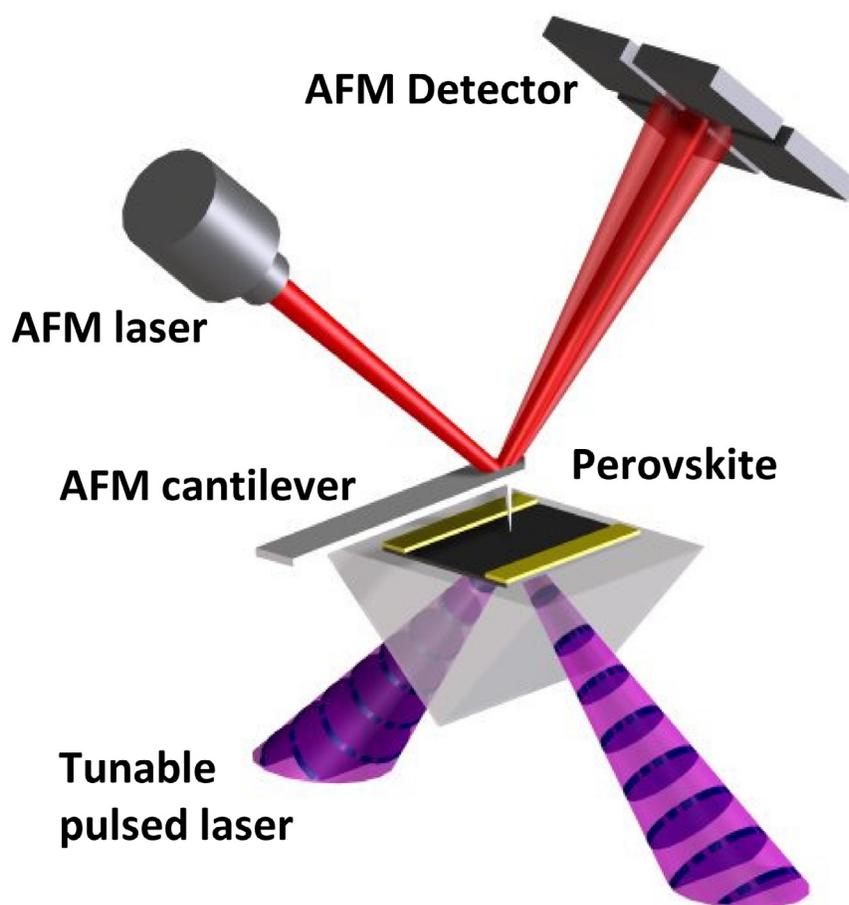
Now a team led by Andrea Centrone at the CNST and Jinsong Huang and Alexei Gruverman of the University of Nebraska has found the first solid evidence for a property of OIPs that may provide a new way to improve their long-term stability as solar cells.

The unexpected feature that the team found is known as ferroelasticity—a spontaneous rearrangement of the internal structure of OIPs in which each crystal subdivides into a series of tiny regions, or domains, that have the same atomic arrangement but which are oriented in different directions. This rearrangement creates a spontaneous strain in each domain that exists even in the absence of any external stress.

“The role of the ferroelastic domains on the material stability must be understood,” said Centrone.

At high temperatures, OIP crystals do not subdivide and have the same cubic arrangement of atoms throughout. At room temperature, however, the OIP crystal structure changes from cubic to tetragonal. That’s where the ferroelastic property of the material comes into play.

“To transform from a cubic to a tetragonal arrangement, one axis of the cube must elongate. In the process, each crystal subdivides into smaller domains in which the elongated axis can point in a different



Schematic shows a perovskite sample (black) examined by the photothermal induced resonance technique. When the sample absorbs pulses of light (depicted as disks in purple cones), the sample expands rapidly, causing the cantilever of an atomic force microscope (AFM) to vibrate like a struck tuning fork. The cantilever’s motion, which is detected by reflecting the AFM laser light (red) off the AFM detector, provides a sensitive measure of the amount of light absorbed. Credit: NIST

direction, leading to spontaneous internal strain,” explained team member Evgheni Strelcov of the CNST and the University of Maryland.

It remains unknown whether ferroelasticity is a property that improves or hinders the performance and stability of perovskite solar cells, noted Centrone. But the very fact that OIPs have this internal structure, breaking up single crystals into domains, is important to investigate, he added. Boundaries between crystals—so-called inter-grain boundaries—are known to be weak points, where structural defects concentrate. Similarly, the boundaries between the newly discovered ferroelastic domains inside a single crystal—*intra-grain boundaries*—might also affect

the stability of OIPs and their performance as solar cells.

The researchers discovered that by bending the crystals, they could reliably move, create or eliminate the ferroelastic grain boundaries—the borders between subdivided crystal regions having different orientations—thus enlarging or reducing the size of each domain. The bending also changed the relative fraction of domains pointing in different orientations. The researchers recently described their work in *Science Advances*.

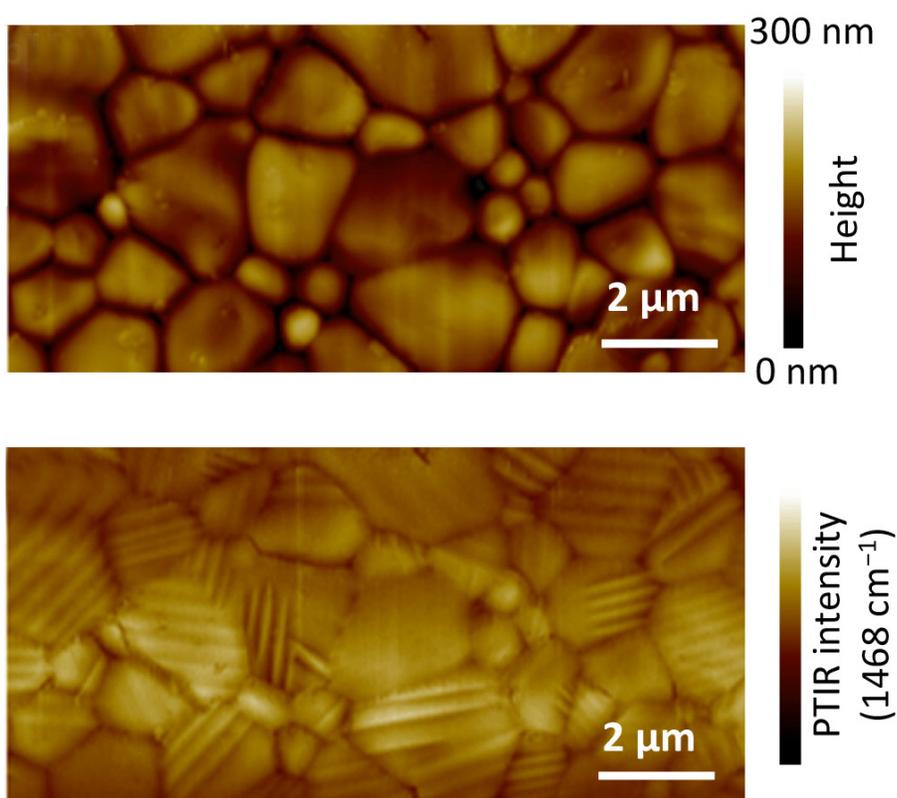
In their study, the team found no evidence that the OIPs were ferroelectric; in other words, that they formed domains where

the separation of the center of positive and negative electric charges is aligned in different directions in the absence of an external electric field. This finding is significant, because some researchers had speculated that ferroelectricity might be the underlying property that makes OIPs promising candidates for solar cells.

The researchers created single whole crystals large enough to reveal ferroelastic domains, which appeared as striations with an optical microscope. They also studied OIPs consisting of polycrystalline thin films, which were examined using nanoscale techniques.

The researchers used two nanoscale methods employing atomic force microscope (AFM) probes to measure ferroelasticity in OIP thin films. At the University of Nebraska, Gruverman and his collaborators used piezoresponse force microscopy (PFM), which mapped the electrically-induced mechanical response of an OIP sample in repose and under mechanical stress by gently bending the sample.

In the other nanoscale method, performed at the CNST, laser pulses ranging in wavelength from the visible to the infrared struck a perovskite thin film, causing the material to heat up and expand. The tiny expansion was captured and amplified by the AFM probe using photothermal induced resonance (PTIR), a technique that combines the resolution of an AFM with the precise compositional information provided by infrared spectroscopy. PTIR imaging revealed the presence of microscopic striations that persisted even when the samples were subjected to heating or applied voltage. Experiments showed that the striations were not correlated with the local chemical composition or optical properties, but were due to differences in thermal expansion coefficient of the ferroelastic domains.



Top: Image recorded by an atomic force microscope reveals the topography of a polycrystalline sample of the perovskite, including the boundaries between crystals. **Bottom:** Image taken with the photothermal induced resonance technique shows the newly discovered ferroelastic domains (striations) within most crystals. Scale shows the PTIR signal intensity, a measure of the infrared light absorbed by the sample. Credit: NIST

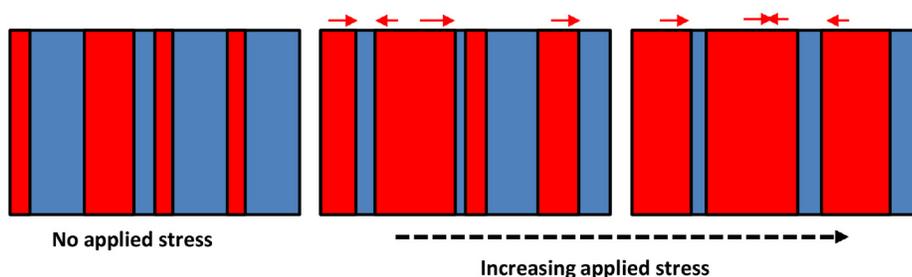


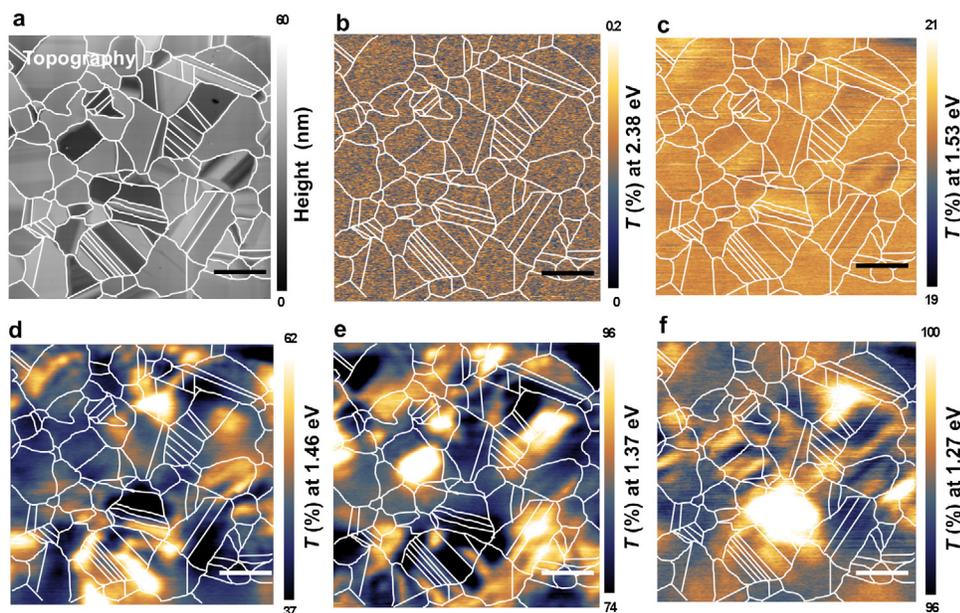
Illustration shows that in response to an applied stress, such as bending, the boundaries of the ferroelastic domains (red and blue regions depict domains oriented in different directions) become bigger or smaller. Credit: NIST

NOVEL TECHNIQUES EXAMINE SOLAR CELLS WITH NANOSCALE PRECISION

Using two novel spectroscopic techniques, CNST researchers have for the first time examined with nanoscale precision the variations in chemical composition and defects of polycrystalline solar cells. The new techniques, which examined a common type of solar cell made of the semiconductor material cadmium telluride, promise to aid scientists in better understanding the microstructure of solar cells and may ultimately suggest ways to boost the efficiency at which they convert sunlight to electricity.

Even though standard methods to characterize solar cells have proven useful in guiding solar cell fabrication and design for years, these diagnostic tools “give us only a limited understanding of why the devices operate at sub-optimal efficiency,” says Nikolai Zhitenev, leader of the CNST Nanoscale Imaging and Spectroscopy Group. For instance, although a method known as electron-beam induced current provides data on nanoscale variations in solar cell efficiency, it gives little information on the underlying crystal defects and impurities that degrade efficiency. Two other methods, photoluminescence and cathodoluminescence, which induce characteristic light emission from the samples, provide only insufficient or indirect information on the mechanisms of efficiency losses.

To close that knowledge gap, “we’ve now developed new techniques to examine the microstructure of solar cells and demonstrated that we can visualize defects through their optical signature,” says lead



Topographic image (a) of the thin slice of a cadmium-telluride sample and images (b-f) of same slice taken with the direct-transmission near-field scanning optical microscopy technique. Credit: Yoon et al./NIST

author Yohan Yoon of the CNST and the University of Maryland in College Park. He and his colleagues at the CNST, the University of Maryland and the University of Utah described their work in *Nanoscale*.

In their study, the scientists used two complimentary methods that rely on an atomic force microscope (AFM). Photothermal induced resonance (PTIR) provides information on the solar cell’s composition and defects at the nanoscale by measuring how much light the sample absorbs over a broad range of wavelengths, from visible light to the mid-infrared. The other method, known as direct-transmission near-field scanning optical microscopy (dt-NSOM), creates detailed nanoscale images that capture the variations in the composition of the solar cells and

defects in their structure by recording how much light is locally transmitted, and offers the advantage of higher signal-to-noise ratio than PTIR.

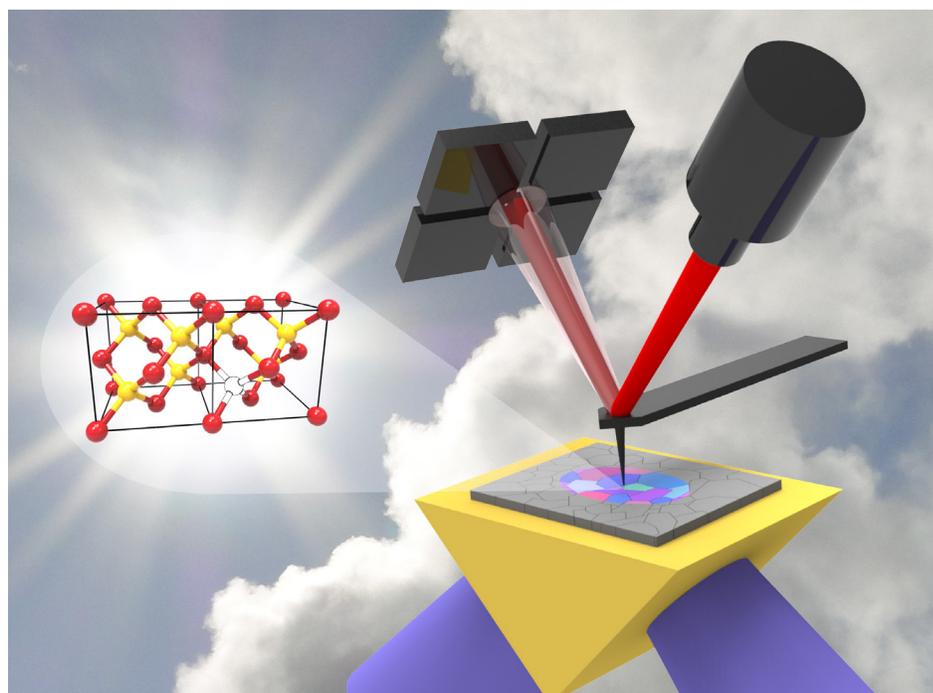
The setup for PTIR, assembled by CNST researcher Andrea Centrone, resembles a finely-tuned version of a Rube Goldberg contraption. First, light pulses from a laser illuminate a sample of cadmium telluride. When the sample absorbs the laser light, it heats up and expands. The expansion nudges the sharp tip of an AFM that is in contact with the sample. The tip converts the thermally-induced expansion into mechanical motion, causing the cantilever on which it is mounted to vibrate. Finally, the vibration is detected by bouncing light from another laser off the cantilever into the AFM detector.

Because the measured amplitude of the cantilever's vibrations is proportional to the energy absorbed by the cadmium telluride sample, PTIR provides key information about the material. For instance, when the tip is held at one location on the sample but the wavelength of pulsed laser light is varied, PTIR generates an absorption spectra of the sample with nanoscale resolution. When the AFM tip moves over the sample but the laser's wavelength remains fixed, PTIR yields an absorption map of the material that reveals variations in chemical composition from one part of the sample to the other. Notably, the small size of the probe tip provides absorption information with a spatial resolution smaller than the laser wavelength used in the experiments.

In the dt-NSOM technique, light from the sharp tip of an AFM probe illuminates a small part of the sample. A photodetector in contact with the sample measures the amount of light transmitted through the material as the probe scans over the sample.

Critical to the success of the two techniques, notes Zhitenev, was access not only to an AFM but to other advanced equipment available in the CNST, including a focused ion beam that could cut slices of the cadmium telluride material a mere 350 nanometers (350 billionths of a meter) in thickness.

"Without the ability to obtain such ultrathin slices, it would not have been possible to take full advantage of the high-resolution



Schematic of cadmium telluride examined by the photothermal induced resonance technique. Credit: Yoon et al./NIST

techniques and reveal fine details of the solar cell material," he says. The wavelengths of light used to probe the semiconductor would normally penetrate to a depth of several millionths of a meter. By cutting slices thinner than that depth, the thickness of the slices determines the effective spatial resolution of the analysis, explained Zhitenev.

The experiments showed that defects in the crystal arrangement of the material are related to impurities, propagated along and from the boundaries between adjoining crystal grains. The team also demonstrated that the techniques can measure the spatial variation of so-called deep defects in cadmium telluride samples. These defects,

which cause electrons and holes (positively charged particles) in cadmium telluride and other semiconductors to recombine instead of generating electricity, are one of the key reasons that solar cells do not perform as well as theoretical models.

Although the new measurements are presented as a proof of concept in studying cadmium telluride, a well characterized material, the findings "are of broad applicability and will aid solar cell research, leading to a better understanding of a variety of photovoltaic materials and consequently engineer them for greater efficiency," the researchers conclude.

ROBERT J. CELOTTA—CELEBRATING HIS 45 YEARS AT NIST

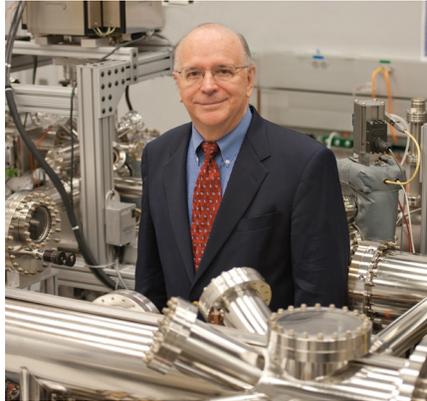
He's the founding director of the CNST, the recipient of Presidential Rank Awards that recognize both his research and management accomplishments and a born and bred New Yorker who got his first research job—helping to build a cyclotron at Columbia University—while still a teenager. After 45 years of service at NIST, Robert J. Celotta retired at the end of April.

In his office on the second floor of Building 216, Celotta recently reminisced about his career and what it was like to transform the idea of a NIST nanocenter into a renowned user facility that attracts an ever-growing number of industry, academic and government researchers from throughout the U.S. and abroad.

When the Center was first proposed around 2000, Celotta was the long-term leader of the Electron Physics Group and had earned a long list of research awards. He had no intention of becoming a manager of a major new facility.

In the Electron Physics Group, his studies embraced atomic and surface physics, nanoscale magnetism and scanning tunneling microscopy. As group leader, "Bob was always very good at picking good people, promoting them and giving them the support they needed to do their work," says Daniel Pierce, a CNST Visiting Fellow and NIST Fellow Emeritus of the Electron Physics Group who collaborated with Celotta on several studies using spin-polarized electrons. Celotta and Pierce developed the first gallium arsenide low-energy spin-polarized electron gun, which the scientists ultimately used to probe the properties of surface magnetism.

"The research part of my career was fantastic because I had an inordinate amount of freedom and I could go where the interesting science was; I wasn't cubby-holed and that was just wonderful for me," says Celotta.



Celotta had fostered an increasing number of studies in the Electron Physics Group focused on the nanoscale, and his laboratory director, the late Katharine Gebbie, asked him to develop a working plan for the proposed nanocenter. Celotta used his investigative skills to explore how a nanotech user facility could best function, reaching out to industry to understand its needs and studying how nanotech laboratories operated at universities and the Department of Energy.

In some user facilities, he found, researchers were often in a time crunch, split 50-50 between maintaining laboratories with up-to-date equipment for outside users and keeping up with their own research. At some government laboratories, industry could use equipment for free, but the application process could be long and arduous, especially for start-up companies that had few resources. Companies told Celotta that they wanted a system in which an application could be reviewed quickly. If a proposal was accepted, industry needed rapid access—along with training—to use the required equipment.

Mulling over the information he had gathered, Celotta came up with a two-pronged approach. The CNST, as he saw it, would consist of two parts: a NanoLab, in which NIST scientists expert in nanoscience and nanotechnology would collaborate with

other researchers on advancing nanoscale measurement and fabrication science—topics relevant to NIST's mission. The NanoFab, which would train industrial and other users to use the facility's commercial state-of-the-art equipment, would have its own staff, devoted to maintaining and updating the equipment and developing new nanofabrication processes. As Celotta envisioned it, "we would have top-of-the-world researchers here and at the same time we were providing key services" to users.

NIST's director at the time, William Jeffrey, not only embraced Celotta's plan but asked him to head the new center. With some trepidation after devoting more than 30 years to research at NIST and becoming a NIST Fellow, he accepted. The CNST opened its doors in May 2007.

One of the biggest challenges, Celotta recalls, was simply getting started. Until it became official, the fledgling Center had only a single group secretary for its support staff, but Gebbie and members of the Physics Laboratory administrative staff came to the rescue, even helping with accounting.

"It was a daunting exercise," says Celotta. "We started with less than a dozen people and a huge budget; it was kind of like running a startup company but inside the federal government," he adds. "The people who were here at the beginning worked very hard, providing help for which I will always be grateful."

"Bob spots trends well before other people identify the topic, whether it is a technical area or an opportunity for funding," says Lloyd Whitman, the first deputy director of the CNST who is now NIST chief scientist and currently on detail at the White House Office of Science and Technology Policy. "That really enabled him to build the CNST into the great user facility it has become."

Even as a group leader, adds Whitman, Celotta made sure that he used funds not only to get the best scientists but to make sure they were supported by having enough qualified support staff and the best equipment. “Very few people have that kind of long-term vision to build the human and capital research infrastructure needed to make major advances in measurement science,” he says.

Celotta, who still has lunch at the NIST cafeteria with some of the same researchers he collaborated with for decades, says he’s particularly proud of one facet of his business model for the CNST. Members of industry had told him that they wanted the ability to conduct proprietary research at the NanoFab—work that they would not be required to share with the public. Celotta came up with a novel idea: NanoFab staff would train people doing proprietary research so that they could use the equipment on their own, without further assistance. That research could then be kept confidential since no government worker was involved.

At the same time, companies that conducted research that furthered CNST’s measurement science and fabrication development mission and didn’t mind sharing those studies with the public would receive a discount on user fees.

“This model has worked out really well and it’s made it very easy for companies to come here and access the equipment,” says Celotta.

“Since the beginning, Bob has clearly articulated a vision for a nanocenter unlike any other in the world—working within the framework of a federal facility to create a truly user-focused, customer-friendly institution,” says Jabez McClelland, group leader of the Electron Physics Group at the CNST. “The realization of this vision has taken an admirable degree of persistence, and even at times stubbornness, which have

paid off handsomely in the form of a vibrant, exciting nanofacility buzzing with activity,” he adds.

It took a few years for Celotta to realize the CNST was becoming a success. “The industry people came to us with such interesting measurement and fabrication problems that it really drove us to think in new directions,” he says.

“We have a kind of synergy going on,” he adds. “There are people who come to the NanoLab because we have some outstanding project leaders and they want to do a project with that person. And while they’re here, they realize that they can fabricate something in the NanoFab. Similarly, people come to the NanoFab because we have these unique tools, but they will bump into somebody in the NanoLab and then start a research project with them. The two are not just free-standing entities, they’re something that together makes for a greater whole.”

Born in Manhattan, Celotta grew up in Long Island City, Queens, within view of the rumbling No. 7 elevated train. While attending the City College of New York in upper Manhattan he got a job in the storeroom of the IBM Watson Laboratory, then at Columbia University, and was soon promoted to research assistant, helping build a high-current cyclotron proposed by physicist L. H. Thomas. For graduate school, he headed to the Bronx—the uptown campus of New York University—where he studied collisions between electrons and atoms.

In 1969, he left New York for JILA, a joint institute between NIST and the University of Colorado. At JILA, he worked closely as a postdoc with future physics Nobel Laureate John (Jan) Hall on a new way, using lasers, to determine how strongly electrons are bound to negative molecular ions. Soon after giving a talk at the NIST Gaithersburg campus, he was offered a research position here in 1971.

“It’s hard to overemphasize the intellectual stimulation that comes with this job,” says Celotta. “During my career, I’ve been personally involved with perhaps a dozen Nobel Laureates and a multitude of other people of similar intellect who are discussing novel and exciting ideas.

“I’m certainly going to miss that, but right now I’m going to be doing some relaxing, some traveling, some visiting with family, while my wife and I decide what the next stage will be.”

If Celotta is still fleshing out his own plans, he has some definite ideas about the future of nanotechnology.

In addition to its critical importance for information technology—making better computers, storing the vast, ever-increasing amounts of information, improving optical communication and developing quantum computing—nanotechnology has begun to insinuate itself into nearly every facet of NIST research, he notes.

“Every place here at NIST that sets standards for the physical properties of material has to extend that into the nanoscale because the properties are different at the small scale,” Celotta says. “And scientists will need to have different measurement techniques and tools to do that.”

Ultimately, he adds, “nanotechnology’s biggest human impact may be the treatment and diagnosis of disease, from targeted therapies for cancer to miniature sensors that can identify disorders at the cellular level.”

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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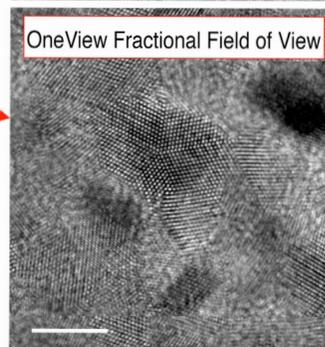
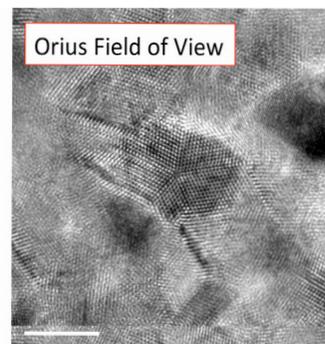
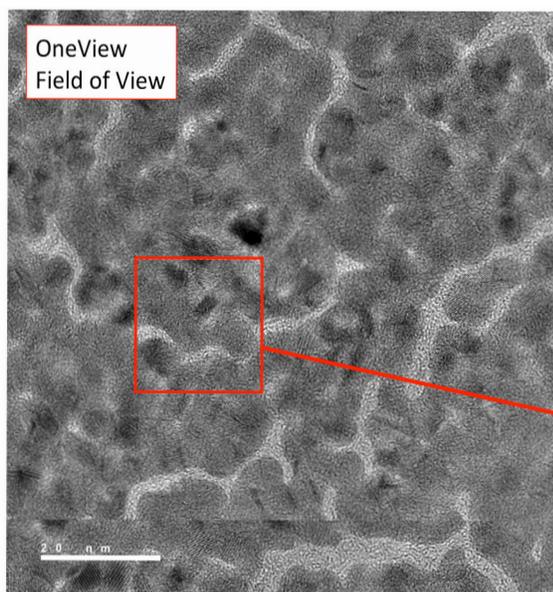
NANOFAB NEWS

Rate Reduction

On May 1, the NanoFab cut by 10 percent its rate for all tools and lab access. The high level of user activity over the past fiscal year enabled the reduction. Rates can be viewed on our [web page](#). For any questions, please contact the user office at nanoFabuseroffice@nist.gov

TEM Gets Wide-Field-of-View Camera

The NanoFab's Titan transmission electron microscope (TEM) has a new camera. The camera, a Gatan OneView Model 1095, has a highly sensitive 4k x 4k CMOS sensor, providing a much larger field of view than the Gatan Orius Model 830 camera also installed on the TEM. Other features of the new camera include a high signal-to-noise ratio, a dynamic range beyond 16 bits, and real-time drift correction, allowing for very high quality TEM imaging. (Drift of the sample can blur images.) The camera records movies in the in-situ mode at 25 frames per second (fps) at full 4k x 4k resolution and 300 fps at 512 x 512 resolution. The OneView camera is ideal for high-resolution TEM studies, imaging of beam-sensitive specimens requiring low electron dose, in-situ heating experiments and electron diffraction studies.



Left: Full field of view on the new TEM camera shows gold on a carbon support film. Due to the large field of view and small pixel size of the camera, columns of gold atoms can be observed everywhere in the image when viewed at full resolution (bottom right image). **Right:** The field of view of the old camera (top), which still operates on the TEM, covers only a fraction of the new camera's field of view (bottom). Credit: Alline Myers/CNST