

NanoMeter



The newsletter of the Cornell NanoScale Facility
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Table of Contents

Welcome to the 2015 Fall Edition NanoMeter.. 3

National Science Foundation Funding! 3

University Resources are Boon for Alum's Ithaca Business.. 4

Electron Spins Controlled Using Sound Waves 5

Precision Gas Sensor Could Fit On A Chip 6

Tumor Cells Prefer Easy Way Out, Study Shows 6

Like Paper, Graphene Twists, Folds Into Nanoscale Machines. 7

New Tech Application Keeps Bacteria from Sticking to Surfaces 8

Chemists Cook Up Three Atom-Thick Electronic Sheets 9

Physicists Energized About Restart of Large Hadron Collider 10

Polymer Mold Makes Perfect Silicon Nanostructures. 11

NEW CNF PROCESSES & TOOLS

Novel Silicon Nitride ICP Etching Process with High Selectivity over SiO₂ for Gate Spacers. 12

Oxford PlasmaPro 100 Cobra ICP Etch System. 14

Disco DAD3240 Automatic Dicing Saw 15

Arradance GEMStar ALD System 16

An Update on Dielectric Etching Using Advanced Polymerizing Chemistries in the Oxford 100-ICP.. 17

Logitech Orbis Chemical Mechanical Polisher 18

CNF & COMMUNITY NEWS

OVPR Summer Carnival .. 18

New CNF Staff: Jeremy Clark .. 19

New CNF Staff: Xinwei Wu .. 19

2013 CNF REU Interns Win Prestigious Awards! 20

Society of Women Engineers Member Spotlight for July 13th-19th: Allison Bosworth, 2014 CNF REU .. 20

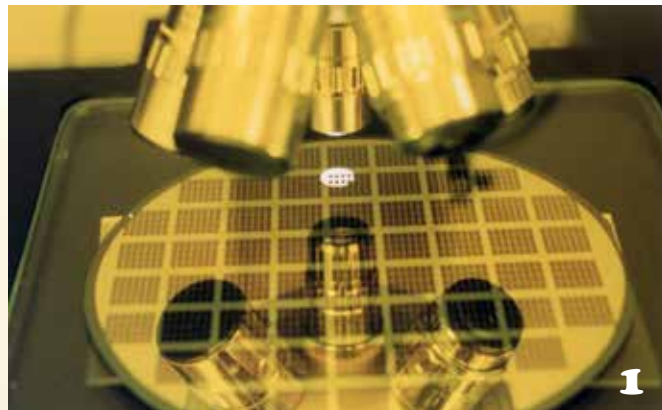
Two Researchers Awarded DOD Grants .. 21

Three Faculty Elected to American Academy of Arts and Sciences .. 22

Next CNF TCN will be held January 12-15, 2016 .. . 23

Blast from the Past. 23

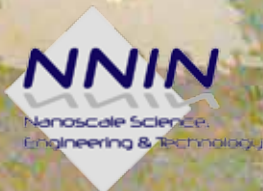
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For this issue of the CNF NanoMeter: the cover is a recaptured “art shot” from the CNF slide archives, photographer unknown (1). The inside background is a photoshopped shot of the ceiling of Duffield Hall, taken by Charles Harrington (2). Article images were provided by Cornell Chronicle, the authors and or the researchers. All other photographs are credited as shown — or if uncredited, were taken by Don Tennant.

The CNF NanoMeter is published twice a year and is formatted by Melanie-Claire Mallison. She welcomes your comments at mallison@cnf.cornell.edu

The NanoMeter is printed on 30% post-consumer paper using soy-based inks. Please reduce, reuse, recycle!



Welcome to the 2015 Fall Edition of the CNF NanoMeter

National Science Foundation Funding:

Good news! After a process that took nearly three years, CNF has been awarded NSF site funding as part of the newly-formed National Nanotechnology Coordinated Infrastructure (NNCI).



Details regarding the selection of the other NNCI sites have not yet been announced as this issue of Nanometer goes to the printer, but we expect that the new network will be a mix of some of the existing NNIN sites together with new sites. New York State has also committed a matching grant to round out the funding mix. CNF will therefore be funded for another decade to continue our mission of serving users from Academia, Government Labs, and Industry, to help advance your research and commercialize new products. We are grateful to Cornell University and the entire CNF community for your support throughout this process.

Please help us spread the word!

With the new NSF and New York State funding we want to expand our user community. New users come to CNF with the confidence that they will have the long-term access to infrastructure that is needed for ambitious, productive research.

New Equipment:

Throughout the recompetition process we have continued to improve the spectrum of tools and services we provide to the research community.

The **Oxford Instruments PlasmaLab 100 Cobra ICP Etcher** is now ready for HBr etching for improved nanophotonics structures as well as methanol etching for magnetic materials (page 14).

The **LPCVD TEOS** installation is nearly completed. The Arradiance ALD is up and available, producing Pt and Titanium Oxide atomic layers films. This system is also capable of coating particles of various sizes.

Our new **Disco Dicing Saw** is now installed, replacing our older ADT saw — see page 24 and Sam Wright for details.

And through an arrangement with Argonne National labs we are replacing our CMP system with newer **Logitech CMP** system (page 18). Chris Alpha is training on that system.

To help characterize dielectric waveguide materials, we have on order a **Metricon Prism Coupler System** with five optical sources and a germanium detector. The unit should be delivered in October 2015.

New Staff:

Please welcome two more staff members who are new to CNF since the last issue of Nanometer: Dr. **Xinwei Wu** in the development of new materials processes; and **Jeremy Clark** in etching and ALD (page 19). We are excited to have great new talent joining our team!

As always, we welcome your comments about CNF and its operations, as well as your suggestions for improvement.

Dan Ralph and Don Tennant



University Photography

University Resources are Boon for Alum's Ithaca Business

By Derek J. Moretz
April 23, 2015
Cornell Chronicle



Jason Koski/University Photography

Kwame Amponsah '06, M.Eng. '08, M.S. '12, Ph.D. '13, foreground, and Tom Schryver '93, MBA '02, background, executive director of the Center for Regional Economic Advancement, participated in a panel discussion during Entrepreneurship at Cornell's Celebration conference April 17.

Choosing Ithaca as a location to build a business after graduation was the natural choice, said Amponsah.

Amponsah founded Xallent Inc. while doing postdoctoral research at Cornell in 2013. Xallent is a semiconductor device and test equipment manufacturing startup based in Ithaca. Many of its products help the semiconductor industry identify faults in the early stages of fabrication, ultimately saving companies millions.

"The Cornell NanoScale Science and Technology Facility (CNF) and Cornell Center for Materials Research offer

state-of-the-art nanofabrication equipment and resources that are instrumental to the development of our products," Amponsah said. The CNF includes lab equipment used in nanoscale fabrication, synthesis, computation and more. The facility attracts more than 800 users per year, 50 percent of whom come from outside of Cornell.

In addition to brick-and-mortar resources, tax incentive programs played a critical role in forming Amponsah's decision to base his company in the region. "Another major driver for locating Xallent in New York state is the tax incentives that we enjoy through the START-UP NY program," Amponsah said. "Under this program, we will be operating tax-free in New York state for the next 10 years."

Launched in 2014, START-UP NY offers tax exemptions to qualifying businesses based in New York state that align with a college or university's academic mission and commit to create jobs. Qualified businesses do not pay business taxes or sales tax, and employees can be exempted from state income taxes for up to 10 years, among other tax benefits. To date, two companies have come into START-UP NY, and the program continues to generate interest from local and out-of-state firms who wish to partner with Cornell and other universities.

With these regional advantages, Amponsah said, "Locating Xallent in Ithaca, New York, was a simple decision for us."

Amponsah joins entrepreneurial Ithaca alumni including Greg Galvin, M.S. '82, Ph.D. '84, MBA '93, chairman and CEO of Rheonix Inc. and Mezmeriz Inc. and co-founder and former CEO of Kionix Inc.; Charlie Mulligan, MBA '11, CEO and co-founder of GiveGab; and Scott Allen, Ph.D. '04, co-founder of Novomer.



Electron Spins Controlled Using Sound Waves

By Anne Ju
March 6, 2015
Cornell Chronicle

The ability to control the intrinsic angular momentum of individual electrons — their “spins” — could lead to a world of new technologies that involve storing and processing information. Cornell applied physicists have demonstrated an unprecedented method of control over electron spins using extremely high-frequency sound waves. A research team led by Greg Fuchs, assistant professor of applied and engineering physics, previously had demonstrated electron spin control using a mechanical oscillator, which creates gigahertz-frequency sound waves (audible in the kilohertz range). According to a new paper published March 5 by the Optical Society’s new journal *Optica*, they’ve taken it a step further: They not only created spin transitions with sound, but they also used sound to coherently control the quantum state of the spin. As the driven mechanical oscillator interacts with the electron spins inside, energy flows back and forth in between. This marks a huge step forward in understanding electron spin.



University Photography

Electron spins typically are controlled by applying a magnetic field to flip the spins up or down — the same way nuclear spins are influenced in magnetic resonance imaging technology. But Fuchs’ group flips the spins a different way: They use sound waves from a resonator made out of a diamond. In particular, they study electron spins stored in defects in the diamond crystal called nitrogen-vacancy centers, the study of which is a promising platform for the growing field of spintronics. “A big part of what our group does is to figure out what all the knobs are and how we turn them,” Fuchs said.

Here’s another way of looking at the accomplishment: Electron spin is a quantum phenomenon — something that happens at the atomic scale. Fuchs’ group demonstrates control of a quantum phenomenon using classical vibrations. It’s like reaching through a portal between two branches of physics, exerting force from one side to control something just on the other side.

“We’re coherently interacting this quantum thing, this spin, with something that’s big and mechanical, a thing you can see with your naked eye, and that actually vibrates,” Fuchs said.

The resonator is on the scale of hundreds of microns — easily visible. The acoustical vibrations are the same things that cause a wine glass to break in response to a high note.

So what’s this good for? At the moment, the researchers are still working out all the physics. But some of the technologies mechanical spin control could lead to include magnetic field sensing, inertial motion sensing and quantum information processing.

The paper is called “Coherent Control of Nitrogen-Vacancy Center Spin Ensemble With a Diamond Mechanical Resonator,” and its first author is Evan MacQuarrie, a graduate student in Fuchs’ lab. As with the previous work, Fuchs’ group collaborated with Sunil Bhawe, associate professor of electrical and computer engineering, and his graduate student Tanay Gosavi.

The Office of Naval Research and the Department of Energy Office of Science Graduate Fellowship Program supported the research, as did the National Science Foundation (NSF)-supported Cornell Center for Materials Research (CCMR). Device fabrication was performed at CNF and CCMR.



Precision Gas Sensor Could Fit On A Chip

By Anne Ju
February 26, 2015
Cornell Chronicle

Using their expertise in silicon optics, Cornell engineers have miniaturized a light source in the elusive mid-infrared (mid-IR) spectrum, effectively squeezing the capabilities of a large, tabletop laser onto a 1-millimeter silicon chip. The breakthrough could lead to highly sensitive, handheld gas sensors for anything from atmospheric research to disaster-recovery missions.

This miniaturized mid-IR light source is called a frequency comb, and hails jointly from the labs of Michal Lipson, previously in the School of Electrical and Computer Engineering, and Alexander Gaeta, previously in the School of Applied and Engineering Physics. It is described online Feb. 24 in *Nature Communications*.

An optical frequency comb, in part the subject of research that was awarded the 2005 Nobel Prize in physics, is a light source made of very short, equally spaced pulses, which can be visualized like the teeth of a comb. Mid-IR frequency combs are of widespread interest for gas sensing applications, because in this wavelength, many different gases absorb in a strong way. Engineers want to exploit this wavelength range for sensitive detection of a large array of gases.

Today's most common method for gas sensing is optical spectroscopy, which identifies gas molecules by shooting light through them and detecting their unique frequencies, like a fingerprint, as the light is absorbed. But this requires a broad bandwidth of different colors of light, typically generated by a giant laser inside a laboratory.

The Cornell researchers solved some long-standing puzzles in order to shrink this mid-IR frequency comb onto a chip. First, they fabricated the silicon structure with a special thermal oxidation process that makes the surfaces very smooth, leading to reduced optical losses compared with typical silicon optics.

Second, they solved the problem of silicon building up too much charge at high optical powers. They placed a diode on the device that swept out built-up electrical charges so that the light source did not "feel" the few charges that were left.

The experiments detailed in the paper, "Silicon-Chip Mid-Infrared Frequency Comb Generation," were carried out by first author Austin Griffith, a graduate student in Lipson's lab. The devices were fabricated at the National Science Foundation-supported Cornell NanoScale Science and Technology Facility. The research was supported by the Defense Advanced Research Projects Agency and the Air Force Office of Scientific Research.

Tumor Cells Prefer Easy Way Out, Study Shows

April 23, 2015
By Anne Ju
Cornell Chronicle

Tumor cells become lethal when they spread. Researchers have thought they might migrate by brute force, actively pushing through tissue in their way, but it turns out tumor cells may be more methodical. Cornell biomedical engineers report in a new study that tumor cells take advantage of already-cleared paths to migrate unimpeded.

"We are looking for novel ways of preventing cancer cells of the primary tumor from spreading to other parts of the body," said Cynthia Reinhart-King, associate professor of biomedical engineering and senior author on the study published in the *American Journal of Physiology — Cell Physiology*. "Our study points to potential therapeutic targets that could be inhibited to halt tumor cell movement."

The body's tissue is full of small gaps between proteins and cells. Much of the tumor cell migration research, however, has represented tissue as a solid gel. While this model has been useful in understanding how tumor cells invade, Reinhart-King and colleagues are using a more accurate model of the tissue environment consisting of a microfabricated device with cell-sized tracks.

"Ours is the first study to rebuild the native tracks and gaps that exist in tissue to investigate how cells use these as superhighways to move quickly to spread throughout the body," Reinhart-King said. The researchers found that when working through an environment with no pre-existing tracks, tumor cells had to actively stick to the tissue, break it down and then move themselves forward. In contrast, moving through tissue with paths was much easier because once the cells found the tunnels, they could avoid their tissue-clearing processes and pass through unhampered.

The findings support the idea that tumor cells prefer preformed tunnels for migration. The study also suggests that targeting the machinery that makes cells mobile, rather than targeting the tissue-clearing process — which has been tested in patients with little success — may be a better treatment strategy to stop cancers from spreading.

The article, "Comparative mechanisms of cancer cell migration through 3D matrix and physiological microtracks," was highlighted as an April "best of the best" as part of the American Physiological Society's select program. The work was supported by the Cornell Center on the Microenvironment and Metastasis through the National Cancer Institute, as well as the National Science Foundation, and acknowledged the use of equipment and resources at the Cornell NanoScale Facility, also supported by the NSF.

Like Paper, Graphene Twists, Folds Into Nanoscale Machines

By Anne Ju
July 29, 2015
Cornell Chronicle

The art of kirigami involves cutting paper into intricate designs, like snowflakes. Cornell physicists are kirigami artists, too, but their paper is only an atom thick, and could become some of the smallest machines the world has ever known.

A research collaboration led by Paul McEuen, the John A. Newman Professor of Physical Science and director of the Kavli Institute at Cornell for Nanoscale Science (KIC), is taking kirigami down to the nanoscale. Their template is graphene, single atom-thick sheets of hexagonally bonded carbon, famous for being ultra thin, ultra strong and a perfect electron conductor. In the journal *Nature* July 29, they demonstrate the application of kirigami on 10-micron sheets of graphene, which they can cut, fold, twist and bend, just like paper.

Graphene and other thin materials are extremely sticky at that scale, so the researchers used an old trick to make it easier to manipulate: They suspended it in water and added surfactants to make it slippery, like soapy water. They also made gold tab “handles” so they could grab the ends of the graphene shapes. Co-author Arthur Barnard, also a Cornell physics graduate student, figured out how to manipulate the graphene this way.

The study’s first author, Melina Blees, a former physics graduate student and now a postdoctoral researcher at the University of Chicago, said she received an “enthusiastic welcome” from the Department of Art, where the researchers spent time in the library studying paper and fabric designs and dreaming up ways to translate them to graphene.

They borrowed a laser cutter from the College of Architecture, Art and Planning shop, creating paper models of their designs, before hiking over to the Cornell NanoScale Science and Technology Facility to fabricate them out of graphene.

“It was really true exploration, cutting things out of paper and playing with them, trying to imagine how a ‘hanging kirigami mobile for kids’ could become a nanoscale spring for measuring forces or interacting with cells,” Blees said.

With one sheet of graphene, for example, they made a soft spring, which works just like a very flexible transistor. The forces needed to bend such a spring would be comparable to

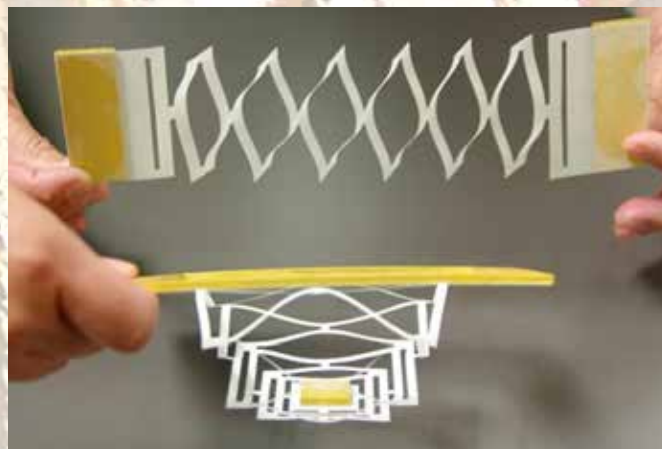


Figure 1: Graphene, like the paper models, is strong but flexible, and can be stretched or pulled with forces comparable to those exerted by motor proteins. The researchers tested their graphene kirigami designs on laser-cut paper. They found that a graphene soft spring behaved similarly to the paper model. Joe Wilensky/Cornell Chronicle

forces a motor protein might exert, McEuen said. Entering the realm of biological forces, the experiments open up a new playground of ideas for, say, flexible, nanoscale devices that could be placed around human cells or in the brain for sensing, McEuen said.

The researchers also demonstrated how well graphene bends in a simple hinge design, quantifying the forces needed. Opening and closing the hinge 10,000 times, they found that it remains perfectly intact and elastic — a potentially useful quality for foldable machines and devices at that scale.

Building on the principles from the paper, a related research team at Cornell has just received Department of Defense funding to continue developing technologies around flexible materials like graphene, using some of the kirigami principles demonstrated.

Blees added that over the course of the project, she was able to get an intuitive grasp of graphene’s properties - rare for nanoscale scientists.

“It’s one thing to read about how strong graphene is; it’s another thing entirely to crumple it up and watch it recover, or to stretch a spring dramatically without tearing the materials,” she said. “It’s not every day that you get to develop a feel for a nanoscale material, the way an artist would.”

The work, which also included David Muller, professor of applied and engineering physics and co-director of KIC, was supported by the Cornell Center for Materials Research, which is funded by the National Science Foundation; the Office of Naval Research; and the Kavli Institute at Cornell for Nanoscale Science.

See videos of “Graphene kirigami behaves like a soft spring,” and “A computer-controlled needle pushes on a graphene sheet. The graphene crumples and deforms like a sheet of tissue paper, and recovers its original shape.” at <http://www.news.cornell.edu/stories/2015/07/paper-graphene-twists-folds-nanoscale-machines>

New Tech Application Keeps Bacteria from Sticking to Surfaces

By Krishna Ramanujan
January 9, 2015
Cornell Chronicle

Just as the invention of nonstick pans was a boon for chefs, a new type of nanoscale surface that bacteria can't stick to holds promise for applications in the food processing, medical and even shipping industries.

The technology, developed collaboratively by researchers from Cornell University and Rensselaer Polytechnic Institute, uses an electrochemical process called anodization to create nanoscale pores that change the electrical charge and surface energy of a metal surface, which in turn exerts a repulsive force on bacterial cells and prevents attachment and biofilm formation. These pores can be as small as 15 nm; a sheet of paper is about 100,000 nm thick. Three distinct nano- and microscale patterns of pores were created in 200-nm-thick thermally grown silicon dioxide in the Cornell NanoScale Science and Technology Facility.

When the anodization process was applied to aluminum, it created a nanoporous surface called alumina, which proved effective in preventing surrogates of two well-known pathogens, *Escherichia coli* O157:H7 and *Listeria monocytogenes*, from attaching, according to study recently published in the journal *Biofouling* and previously in *Applied Environmental Microbiology*. The study also investigates how the size of the nanopores changes the repulsive forces on bacteria.

"It's probably one of the lowest-cost possibilities to manufacture a nanostructure on a metallic surface," said Carmen Moraru, associate professor of food science and the paper's senior author. Guoping Feng, a research associate in Moraru's lab, is the paper's first author.

Finding low-cost solutions to limiting bacterial attachments is key, especially in biomedical and food processing applications. "The food industry makes products with low profit margins," said Moraru. "Unless a technology is affordable it doesn't stand the chance of being practically applied."

Anodized metals could be used to prevent buildups of biofilms — slick communities of bacteria that adhere to surfaces and are tricky to remove — in biomedical clean rooms and in equipment parts that are hard to reach or clean, Moraru said.

There are other strategies for limiting bacterial attachment to surfaces, including chemicals and bactericides, but these have limited applications, especially when it comes to food processing, Moraru said. With food processing, surfaces

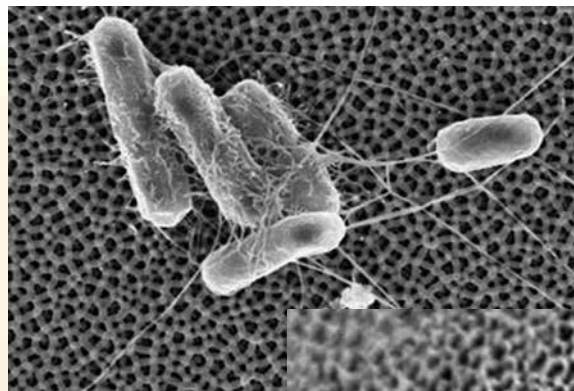
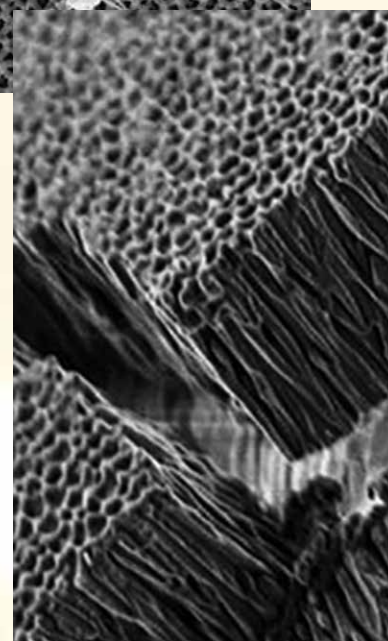


Figure 1, above: Nanoporous alumina repels *E. coli* cells. Guoping Feng

Figure 2, right: A cross-section of nanoporous alumina. Guoping Feng



must meet food safety guidelines and be inert to food that they may contact.

Anodized metal could also have marine applications, such as keeping ship hulls free of algae.

Future work will investigate the repulsive effect of these surfaces on other bacteria, and the use of other anodized materials for this purpose.

The collaborating group from Rensselaer Polytechnic Institute is led by Diana Borca-Tasciuc, associate professor of mechanical, aerospace and nuclear engineering. The authors acknowledge the use of and the help of staff at the Cornell Nanobiotechnology Center and the Cornell Center for Materials Research. The study was funded by the U.S. Department of Agriculture.

Chemists Cook Up Three Atom-Thick Electronic Sheets

By Anne Ju
April 29, 2015
Cornell Chronicle



Figure 1, above: A schematic for fabrication of molybdenum disulfide/silicon dioxide stacking using alternating metal organic chemical vapor deposition growth, device fabrication with photolithography, and silicon dioxide deposition. Kibum Kang

Making thin films out of semiconducting materials is analogous to how ice grows on a windowpane: When the conditions are just right, the semiconductor grows in flat crystals that slowly fuse together, eventually forming a continuous film.

This process of film deposition is common for traditional semiconductors like silicon or gallium arsenide — the basis of modern electronics — but Cornell scientists are pushing the limits for how thin they can go. They have demonstrated a way to create a new kind of semiconductor thin film that retains its electrical properties even when it is just atoms thick.

Three atom-thick layers of molybdenum disulfide were cooked up in the lab of Jiwoong Park, associate professor of chemistry and chemical biology and member of the Kavli Institute at Cornell for Nanoscale Science. The films were designed and grown by postdoctoral associate Kibum Kang and graduate student Saien Xie. Their work is published online in *Nature*, April 30.

“The electrical performance of our materials was comparable to that of reported results from single crystals of molybdenum disulfide, but instead of a tiny crystal, here we have a 4-inch wafer,” Park said.

Molybdenum disulfide (MoS_2), which is garnering worldwide interest for its excellent electrical properties, has previously been grown only in disjointed, “archipelago”-like single crystal formations, Park said. But making smooth, flat, ultrathin sheets, like paper, is the ultimate goal, and the bridge to actual devices.

The researchers pulled off the feat by tuning the growth conditions of their films using a technique called metal organic chemical vapor deposition (MOCVD). Already used widely in industry, but with different materials, it starts with a powdery precursor, forms a gas and sprinkles single atoms onto a substrate, one layer at a time.

Park’s group systematically optimized the technique to make the films, tweaking conditions and temperatures not unlike experimenting in the kitchen. They found that their crystals grew perfectly stitched together, but only with a little bit of hydrogen and in completely dry conditions, for example. In addition to advanced optical imaging techniques, researchers led by co-author David Muller, professor of applied and engineering physics and director of Cornell’s Kavli Institute, contributed advanced transmission electron microscopy to test and characterize the quality of the films as they went along.

The team also demonstrated their films’ efficacy when stacked layer by layer alternating with silicon dioxide and employing standard photolithography. This effectively proved that these three-atom-thick semiconducting films can be made into multi-level electronic devices of unsurpassed thinness.

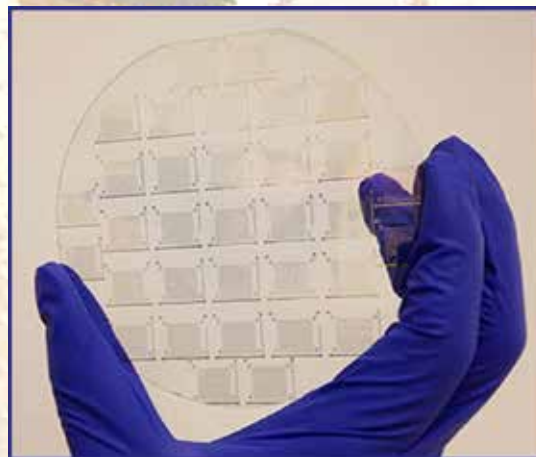


Figure 2: A MoS_2 device array on a transparent silica wafer. Kibum Kang

The MOCVD method for thin film generation is seemingly generic. The researchers showed the ability to simply change the precursor to make other films; for example, they also grew a tungsten disulfide film with different electrical properties and color. They envision perfecting the process to make atomically thin films of all varieties, like a packet of colored paper, from which new, exciting electronic and optoelectronic devices can be derived.

“These were only the first two materials, but we want to make a whole palette of materials,” Park said.

The paper is titled “High-mobility three-atom-thick semiconducting films with wafer scale homogeneity.” The work was supported by the Air Force Office of Scientific Research, the National Research Foundation of Korea and the Cornell Center for Materials Research funded by the National Science Foundation, as well as the Samsung Advanced Institute for Technology. Devices were fabricated at the Cornell NanoScale Facility, also supported by NSF.

Physicists Energized About Restart of Large Hadron Collider

By Kathy Hovis
April 1, 2015
Cornell Chronicle

When Kevin McDermott and Susan Dittmer talk about what they might discover when their particle detector goes back online in Switzerland there's a twinkle in their eyes, and it's hard to keep them from literally fidgeting in their seats. These Cornell physics graduate students have grand ideas for what they might find once their detector, the Compact Muon Solenoid at the Large Hadron Collider (LHC), begins recording data again later this year — new particles, evidence of supersymmetry, an explanation for dark matter and extra dimensions may be discovered.

"It would be great if new particles were showing up every day," McDermott said. "Even if just one of them showed up."

The LHC is the most powerful particle accelerator in the world, hosted at CERN, the European Laboratory for Particle Physics. At CERN, 21 member states collaborate to study the fundamental particles of matter. Founded in 1954 to bring European scientists together, the Geneva laboratory is perhaps best known as the place where the Higgs-Boson was discovered in 2012.

McDermott and eight other grad students are headed back there to continue their work. The students are advised by five Cornell physics faculty members, including Julia Thom-Levy, associate professor of experimental physics. The LHC has been shut down to refurbish the superconducting magnets and when it goes back online, Thom-Levy said, "It will produce particle collisions at energies that were impossible to reach before. There is again the possibility of never-before-seen physics. Many theories have been shown to work mathematically, but only the detectors make it possible to test them experimentally." The results could help answer questions about dark matter and the recently discovered Higgs-Boson, she said. Because the number of collisions created in the detector will be so large, grad students working there not only need training in particle physics but also advanced programming skills to "discover small signals in a vast background" of data, Thom-Levy added.

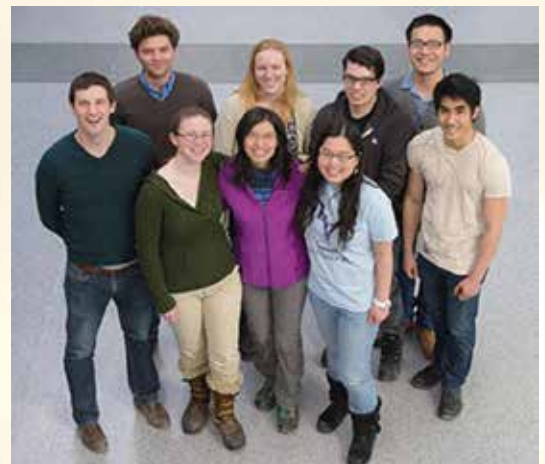
"It's a very exciting time to be going there. It's like opening up a box and you have no idea what could be in there," said grad student Margaret Zientek. "I'm also excited to meet people who I've only interacted with through emails and video."

Cornell undergraduates in physics and engineering also have been working on projects related to the Compact Muon Solenoid, Thom-Levy said, including R&D for future upgrades of the detector. Some of the students are working at the Cornell NanoScale Science and Technology Facility, creating prototypes that will inform the choice of technology for the upgraded detector. "We're lucky to have a little time before we have to deliver this new detector," Thom-Levy said.

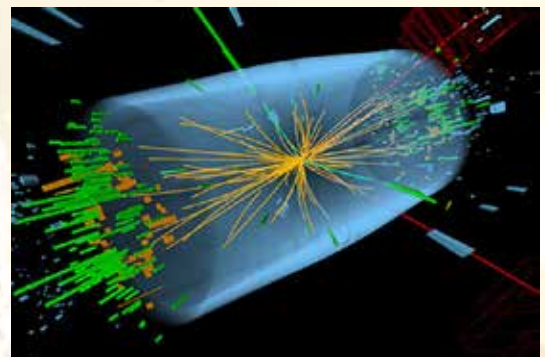
"We're in this for the long run. The upgrade isn't planned to go online until 2020, and a lot may happen before then."



Construction on the Compact Muon Solenoid detector at the Large Hadron Collider in Geneva, Switzerland. CERN



Physics grad students working at the Large Hadron Collider in Switzerland include, clockwise from left, Kevin McDermott, Nathan Mirman, Margaret Zientek, Jorge Chavez, Zhengcheng Tao, Dan Quach, Jennifer Chu, Shao Min Tan and Susan Dittmer. Provided



One of millions of proton collisions recorded in 2012. Detected are two muons and two electrons, and many other particles that are consistent with the decay products of a Higgs Boson. The blue shows the outlines of the detector components, green blocks represent energy deposited in the detector and orange represents reconstructed particle tracks. CERN

Polymer Mold Makes Perfect Silicon Nanostructures

By Anne Ju
July 2, 2015
Cornell Chronicle

Using molds to shape things is as old as humanity. In the Bronze Age, the copper-tin alloy was melted and cast into weapons in ceramic molds. Today, injection and extrusion molding shape hot liquids into everything from car parts to toys. For this to work, the mold needs to be stable while the hot liquid material hardens into shape. In a breakthrough for nanoscience, Cornell polymer engineers have made such a mold for nanostructures that can shape liquid silicon out of an organic polymer material. This paves the way for perfect, 3-D, single crystal nanostructures.

The advance is from the lab of Uli Wiesner in Materials Science and Engineering (MSE), whose lab previously has led the way in the creation of novel materials made of organic polymers. With the right chemistry, organic polymers self-assemble, and the researchers used this special ability to make a mold dotted with precisely shaped and sized nanopores. The research is published in *Science* July 3.

Normally, melting amorphous silicon, which has a melting temperature of about 2,350 degrees, would destroy the delicate polymer mold, which degrades at about 600 degrees. But the scientists, in collaboration with Michael Thompson, also MSE, got around this issue by using extremely short melt periods induced by a laser. The researchers found the polymer mold holds up if the silicon is heated by laser pulses just nanoseconds long. At such short time scales, silicon can be heated to a liquid, but the melt duration is so short the polymer doesn't have time to oxidize and decompose. They essentially tricked the polymer mold into retaining its shape at temperatures above its decomposition point. When the mold was etched away, the silicon had been perfectly shaped by the mold. This could lead to making perfect, single-crystal silicon nanostructures. The researchers haven't done it yet, but their *Science* paper shows it's possible. Wiesner called the breakthrough "beautiful" and a possibly fundamental insight into studying nanoscale materials.

Most self-assembled nanostructures today are either amorphous or polycrystalline — made up of more than one piece of a material with perfect order. It's hard to judge whether their properties are due to the nanostructure itself or whether they're dominated by defects in the material. Discovery of single-crystal silicon — the semiconductor in every integrated circuit — made the electronics revolution possible. Today, nanotechnology allows incredibly detailed nanoscale etching, down to 10 nm. But nanofabrication techniques, like photolithography, hits its limits when

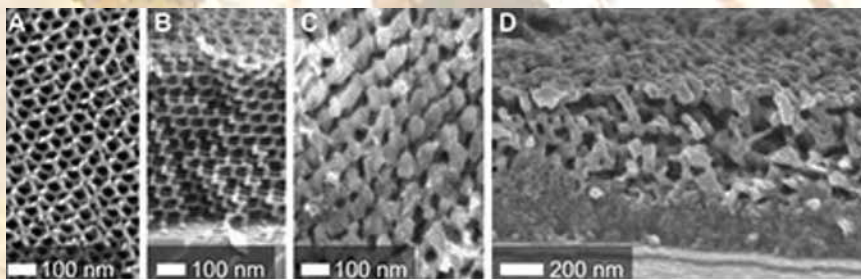


Figure 1: Scanning electron microscopy micrographs show a periodically ordered mesoporous gyroidal resin template (A and B) and the resulting laser-induced crystalline silicon nanostructure after template removal (C and D). Wiesner lab

it comes to 3-D structures. Semiconductors like silicon don't self-assemble into perfectly ordered structures like polymers do. It's almost unheard of to get a 3-D structured single crystal of a semiconductor. To make single crystal nanostructures, there are two options: multiple etching or molding. Wiesner's group now has made the mold.

The way they made the mold was itself a breakthrough. They first used a carbon dioxide laser in Thompson's lab to "write" the nanoporous materials onto a silicon wafer. A film, spin-coated on the wafer, contained a block copolymer. Writing lines in the film with the laser, the block copolymer decomposed, acting like a positive-tone resist, while the negative-tone resin was left behind to form the porous nanostructure. That became the mold.

"We demonstrated that we can use organic templates with structures as complicated as a gyroid, a periodically ordered cubic network structure, and 'imprint' it onto molten silicon, which then transforms into crystalline silicon," Wiesner said.

"Having the ability to mold the workhorse of all electronics, silicon, into intricate shapes is unprecedented," said Andy Lovinger, a program director in the materials research division at the National Science Foundation, which funded Wiesner's research. "This beautiful work shows how it could be done by taking advantage of the unique design properties offered by polymeric materials."

The paper is called "Transient Laser Heating-Induced Hierarchical Porous Structures From Block Copolymer Directed Self-Assembly," and its first author is Kwan Wee Tan, a former graduate student in the Wiesner Lab. The work was supported by the National Science Foundation, and made use of research facilities at the Cornell Center for Materials Research and the Cornell NanoScale Facility.

Novel Silicon Nitride ICP Etching Process with High Selectivity over Silicon Dioxide for Gate Spacers



The Business of Science®

Colin C. Welch¹ and Vincent J. Genova²

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A novel difluoromethane (CH₂F₂)-sulfur hexafluoride (SF₆)-nitrogen (N₂) inductively coupled plasma (ICP) was investigated with the aim of developing a silicon nitride (Si₃N₄) etching process having high selectivity over silicon dioxide (SiO₂). Such a process finds application in gate spacers.

Introduction

Gate spacers are used in metal oxide semiconductor field effect transistors (MOSFET) in order to precisely define the channel length with an abrupt junction in modern nanoscale architectures [1]. The spacer allows the benefits of a lightly doped drain (LDD) — lower capacitance and lower electric field near the gate — without the main disadvantage of higher resistance. This is because the spacer can mask a subsequent deep source-drain implant to reduce resistance away from the gate. Silicon nitride has several advantages as a spacer material [2]. However, the etching of Si₃N₄ spacers requires high selectivity to stop on ultrathin thin gates dielectrics with SiO₂ thickness typically less 6 nm in order to avoid etch damage and silicon substrate loss in source/drain regions.

Selective etching of Si₃N₄ over SiO₂ is inherently challenging because both materials are etched by standard fluorine gases such as CHF₃, CF₄, SF₆, etc. One study used CF₄ or NF₃ highly diluted in Ar/O₂ to achieve high selectivity [3]. This was more for a nitride strip application however. Another study used CF₄-CH₄ to achieve high selectivity [4], but the CH₄ is known to be a strongly polymerizing gas leading to short mean time to chamber clean. We screened several candidate chemistries and found CH₂F₂-SF₆-N₂ to be the most promising for further investigation.

Experimental

400 nm of low pressure chemical vapor deposited (LPCVD) Si₃N₄ was grown on thermally oxidized standard silicon wafers and patterned with photoresist (PR) (minimum feature sizes 1 μm). Etching experiments on 1x1 cm pieces were done in an Oxford Instruments System 100 ICP tool. This features a cylindrical ICP source, independent substrate electrode bias and option of gas introduction through a ring just above the wafer as well as through the top of the ICP source.

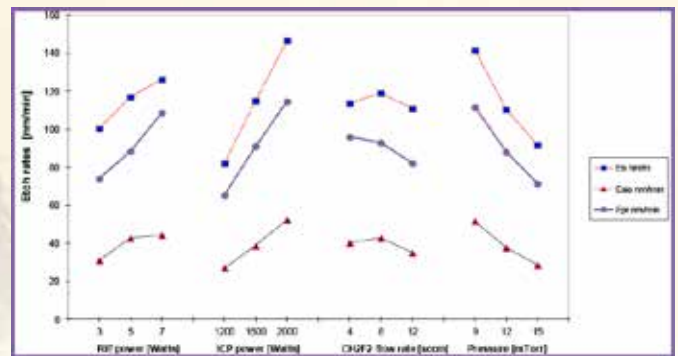


Figure 1: Etch rate trends for LPCVD Si₃N₄, thermal SiO₂ and photoresist

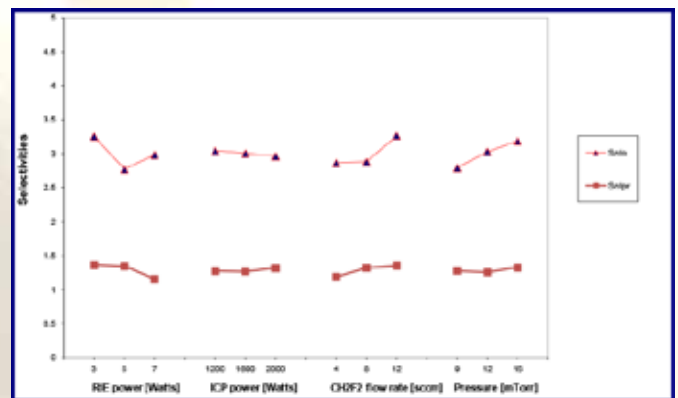


Figure 2: Selectivity trends for LPCVD Si₃N₄ over thermal SiO₂ and over PR

Experiments were formulated using a Taguchi L9 orthogonal matrix [5]. This enables a wide range of parameter space to be studied with relatively few process trials by means of an averaging procedure possible due to the symmetrical properties of the orthogonal matrix. The input parameters were CH₂F₂ flow rate, pressure, ICP source power and electrode bias (RIE) power. The output responses consisted of Si₃N₄ etch rate, selectivity over SiO₂ and selectivity over PR.

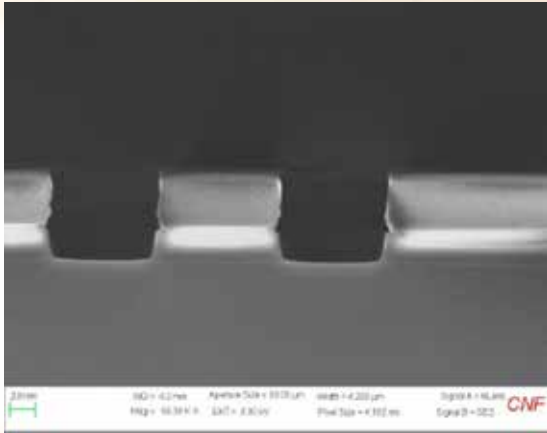


Figure 3: 400 nm LPCVD Si₃N₄ etched down to a Si substrate showing a profile of 80°



Results

The results of the L9 matrix are summarized in Figure 1 showing etch rate trends for Si₃N₄, SiO₂ and PR, and Figure 2 showing selectivity trends for Si₃N₄ over SiO₂ and over PR. It can be seen there are moderate trends to higher selectivity over SiO₂ as pressure and CH₂F₂ flow rate increase, and as ICP and RIE powers decrease. Using these trends for guidance, and introducing CH₂F₂ through the gas ring, further stepwise process development led to process with the following characteristics: Si₃N₄ etch rate 47nm/min, selectivity over SiO₂ 4.7:1 and selectivity over PR 1.5:1. Figure 3 shows the Si₃N₄ etched profile is about 80°.

Conclusion

Good initial results for selective silicon nitride etching over silicon dioxide using a novel CH₂F₂-SF₆-N₂ ICP process were presented. Further work will optimize the process for even higher selectivity and straighter etched profile, test masking with SiO₂, attempt to describe the mechanism for selectivity and, finally test topographical structures realistic to spacer structures.

References

- [1] R.A. Gottscho, K. Nojiri, and J. LaCara: *Thin Solid Films* 516, (2008), p. 3493
- [2] C. Mazure, C. Gunderson, and B. Roman: *Tech. Dig. Int. Electron Devices Meet.* (1992), p. 893
- [3] B.E.E. Kastenmeier, P. J. Matsuo, and G. S. Oehrlein: *J. Vac. Sci. Technol. A* 17(6), (Nov/Dec 1999), p. 3179
- [4] S. Lee, J. Oh, K. Lee, and H. Sohn: *J. Vac. Sci. Technol. B* 28,1 (Jan/Feb 2010), p. 131
- [5] G.Z. Yin and D.W. Jillie: *Solid State Tech* (May 1987), p. 127.

This work was performed as part of the CNF's Cooperative Development Agreement with Oxford Instruments. It is a result of a significant upgrade to the Oxford 100 ICP etch system, in which the addition of novel gas chemistries such as difluoromethane CH₂F₂, enables the development of highly selective dielectric etch processes.



Knight Laboratory Memories, submitted by past CNF User Madanagopal Kunnavakkam (Ph.D. ECE, 2001, PI Prof. Norman Tien). Madan is now at ST Microelectronics, Singapore!

Oxford PlasmaPro 100 Cobra ICP Etch System

Submitted by: Vincent Genova, CNF Research Staff

CNF is pleased to announce the full facilitation of the new PlasmaPro 100 Cobra ICP etch system from Oxford Instruments. This inductively coupled plasma (ICP) based reactive ion etch platform is configured for state of the art nanoscale etching. One of the many features of the system include a wide range temperature ($-150^{\circ}\text{C}\rightarrow 400^{\circ}\text{C}$) electrode which will greatly enhance our spectrum of materials that can be etched with volatile chemistries. Mechanical clamping along with high pressure helium backside cooling will allow for additional temperature control for longer etches with resist masking.

A low frequency (350 kHz) bias capability of the lower electrode will allow us to more effectively etch high aspect ratio features with minimum RIE-lag effects.

The system is equipped with a 12 line gas pod permitting a wide range of process gases and additives for maximum system versatility. The initial setup includes the following gases: HBr, Cl_2 , BCl_3 , CH_3OH , SF_6 , O_2 , H_2 , and Ar. Future additions may include NH_3 , CO, and C_4F_8 as process gases. The system is constructed for corrosive halogen based gases and is equipped with a loadlock for sample entry and system isolation. The tool also has an Ocean Optics optical emission spectrometer (OES) that is fully integrated to the Spectrasuite software that will allow users to monitor chamber conditions and process chemistry for critical etch termination, ie, endpoint control, and selectivity to underlying materials.

One of the main process missions of the system will be nanoscale etching of silicon with HBr based chemistry. The benefits of HBr etching of silicon have been known for many years and these include moderately fast etch rates with a highly anisotropic etch profile due to its ion enhanced etch mechanisms. HBr chemistry offers the flexibility of using

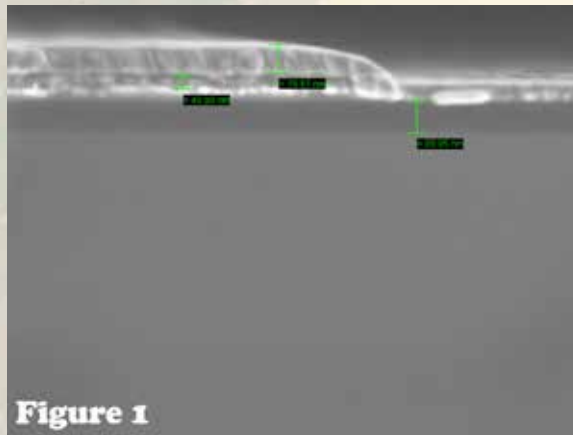


Figure 1

either resist or SiO_2 as etch masks and the ability to etch high aspect ratio nanoscale features without many of the artifacts that are present in chlorine based plasmas such as trenching. There are many differences between HBr and chlorine chemistries that induce differences in feature charging effects, selectivity, faceting of the resist, and composition of the sidewall passivation layers formed during etching.

In addition, selectivity to HSQ as a masking layer and to the buried oxide layer (BOX) can exceed 50:1 and 100:1 respectively. These process attributes will greatly enhance our capabilities to fabricate advanced silicon photonic, MEMS, and electronic devices.

The other principal process objective will be the etching of magnetic based materials. One of the most technologically important areas is the development of MRAMs, which consist of a magnetic tunnel junction (MTJ) and CMOS. One of the most challenging steps in MRAM fabrication is the etching of the MTJ stack. The stack typically contains a non-magnetic seed layer to promote proper crystalline growth (eg. Ta), an antiferromagnet such as PtMn or IrMn, an antiferromagnetically exchange based pair of ferromagnets (eg. CoFe/Ru/CoFe), the insulating tunnel barrier (e.g., Al_2O_3 or MgO), a switchable layer free layer (e.g., CoFeB/Ru/CoFeB), and a suitable hard mask such as TiN or TaN.

The problem is that magnetic materials have difficulty reacting with most chemically active plasma species to form volatile etch products, so users often have to resort to purely physical ion milling processes. However, ion milling suffers from low etch rates, low selectivity, undesirable sidewall redeposition especially for nanoscale features, and damage to the device structure itself. These magnetic materials can be etched in halogenated chemistry (i.e., Cl_2 or HBr), but often electrode temperatures must exceed 190°C to form

Disco DAD3240 Automatic Dicing Saw

volatile etch products. Recently, an alternative process using methanol (CH_3OH) and argon has shown to be effective on Co, Fe, and Ni based alloys. Methanol, as the principal plasma reactant, can form volatile carbonyl compounds (e.g., $\text{Ni}(\text{CO})_4$, $\text{Fe}(\text{CO})_5$, and $\text{Co}_2(\text{CO})_8$) at room temperature. The antiferromagnet IrMn also etches in a methanol plasma. In addition, the selectivity to common mask materials such as Al_2O_3 , Ta, Ti, TaN, and TiN is quite high, while leaving no residue on the etched devices. Earlier this year, we demonstrated successful etching of a 41 nm thick magnetic tunnel junction stack down to the tantalum under layer (see Figure 1). This device utilized a tantalum hard mask (78 nm), which demonstrates high selectivity through the formation of tantalum carbide in the methanol process.

The Cobra's capabilities will extend to the cryogenic silicon etch used for deep reactive ion etching. The electrode's low temperature range will allow the process to take place at temperatures below -100°C . While the process has been used for MEMs applications for many years, it recently has proven to be an excellent option for nanoscale silicon etching. The process uses SF_6/O_2 at -110°C to etch silicon anisotropically due to the formation of an involatile silicon oxyfluoride on the sidewalls.

The process is especially attractive for nanoscale etching since the passivation layer is thin and inorganic. Selectivity to resist masks, including e-beam resists, is greatly enhanced since the low temperature induces less chemical erosion. Furthermore, since the SF_6 and O_2 flow simultaneously, the sidewall profiles are smooth without the presence of scalloping which is characteristic of the Bosch process. This feature makes fabricating nanoscale photonic structures very attractive.

An additional capability of the new Cobra ICP is the ability to etch nanoscale polymer features at cryogenic temperatures. Using oxygen based chemistry, anisotropic high aspect ratio features can be obtained at cryogenic temperatures due to reduced reactivity of the sidewalls, eliminating the need for a separate passivant additive gas.

There is also considerable interest among the faculty to use the Cobra in facilitating the etching of single crystal diamond for the fabrication of diamond based nanophotonic and nanomechanical devices. This can be accomplished using an oxygen based ICP process. This diamond on insulator structure can be etched with a suitable metallic hard mask.

Finally with the use of an SF_6 based chemistry, we plan to develop a silicon carbide etch process utilizing the wide temperature range available on the Cobra. With the growing interest in silicon carbide devices among the user community, this will be a nice addition to our increasing etch repertoire.

For further information, please contact Vince Genova at Genova@cnf.cornell.edu.

CNF has purchased a new Disco DAD3240 Automatic Dicing Saw. This tool replaces an older ADT saw that was increasingly difficult to maintain. With the new Disco saw, users will be able to cut silicon, glass, and other substrates up to 200 mm in diameter with high precision on a high reliability platform.

The saw was installed in the CNF cleanroom and made available to users in August. Contact Sam Wright for more information and tool training, wright@cnf.cornell.edu.



Arradiance GEMStar ALD System

Submitted by: Vincent Genova, CNF Research Staff

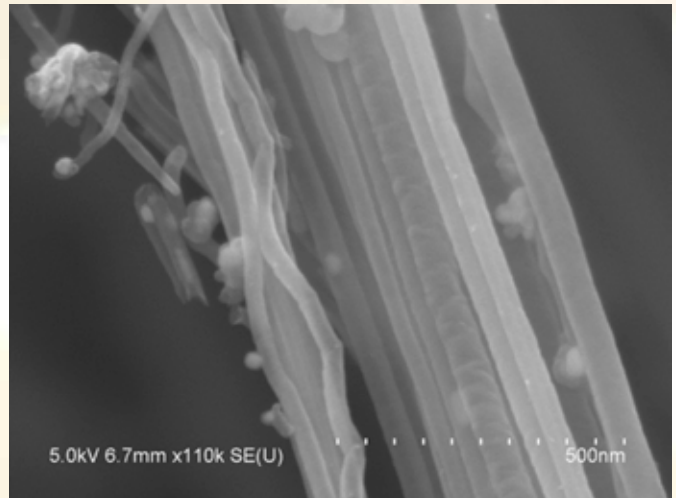


Figure 1: SEM of the coating of aluminum oxide on carbon nanotubes (CNTs), courtesy of Prof. Andy Sun, U. of Western Ontario.

CNF is pleased to announce the availability of a new Arradiance GEMStar 6 ALD system.

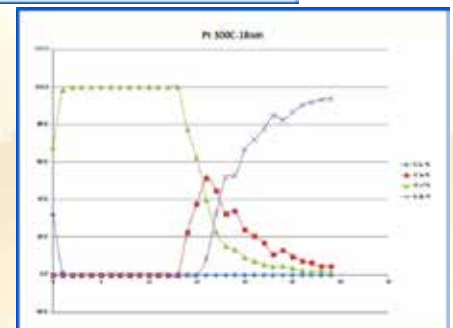
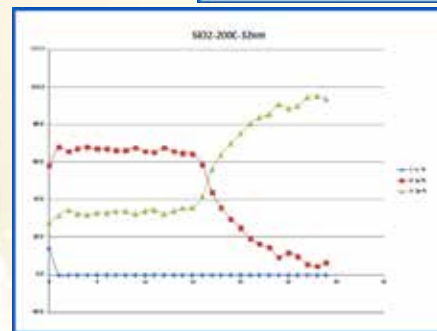
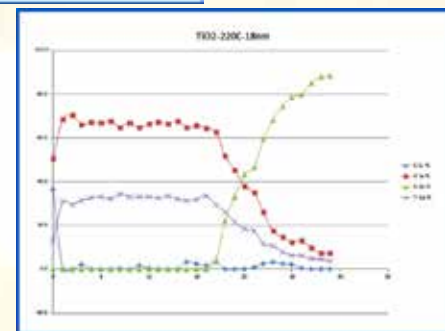
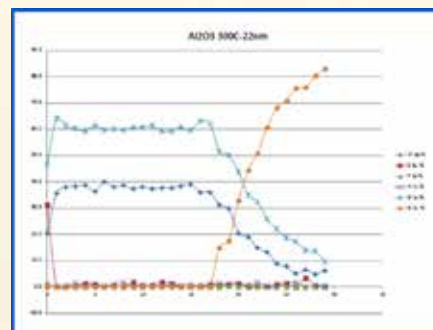
This compact table top ALD system is ideally suited for research applications in a multiuser facility. The GEMStar 6 can accommodate substrates up to 6 inches (150mm) and its unique 300°C hot wall chamber design can deposit uniform, conformal metal, and insulating ALD films on flat substrates, 3-D surfaces including high aspect ratio features, nanoparticles and nanopowders. Up to eight precursors can be run simultaneously, producing multi-component films and film stacks.

A very unique feature of the GEMStar system is the particle ALD coating option. It consists of a 2 μm particle canister filter mounted on a variable speed (5-95 rpm) 360 degree continuous rotary driven feedthrough to enable conformal coating of the suspended particles. Nanoparticles can be coated by placing them in a specified container with recipes structured to accommodate the large surface areas with a conformal coating. This system has demonstrated successful conformal Al_2O_3 coatings on 30-70 nm diameter CNTs as well as uniform TiO_2 ALD coatings of networked mesoporous polymeric and carbon films with pore sizes as small as 40 nm.

The particle ALD feature will be an invaluable asset to those research groups wishing to conformally coat nanoscale sized media for a variety of applications.

Initially the GEMStar will be configured for platinum, titanium oxide, aluminum oxide, and silicon oxide ALD films. These thermal ALD films will complement our current dielectric film capabilities on the Oxford FlexAL system. XPS analyses of our initial sample evaluations of the above four films are illustrated below and indicate precise stoichiometric and high purity films.

The versatility of the GEMStar will permit us to add additional precursors in the future to quickly meet the changing demands of the CNF user community. For further information on this system, please contact Vince Genova at Genova@cnf.cornell.edu.

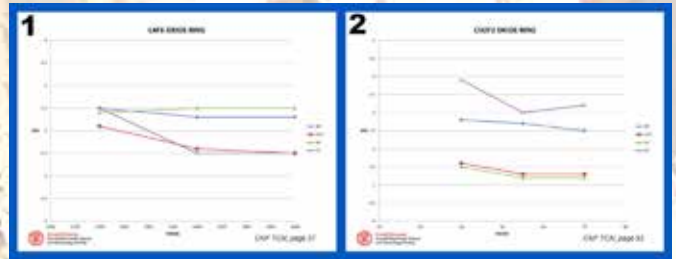


An Update on Dielectric Etching Using Advanced Polymerizing Chemistries in the Oxford 100-ICP

Submitted by: Vince Genova, CNF Research Staff

In 2014, the CNF reported on a significant upgrade to the Oxford 100 ICP regarding the installation of a gas ring manifold for delivery of highly polymerizing hexafluorobutadiene (C_4F_6) and difluoromethane (CH_2F_2) gases. This is the first Oxford Instruments RIE/ICP system with the unique gas ring configuration. The gas ring manifold is in close proximity to the substrate, and hence a greater distance from the ICP source. The degree of ionization and dissociation of the polymer precursors is distinctly different when these gases are admitted through the gas ring. This is evident in the X-ray Photoelectron Spectroscopy (XPS) analysis where the deposited polymer is not only thicker, but also has a lower fluorine/carbon (F/C) ratio indicative of a more cross-linked polymer. The chemical and physical nature of this polymer has a direct correlation with resist selectivity. Because advanced lithographic techniques such as deep UV (DUV) and electron beam lithography (EBL) require thinner and more porous resists to obtain ever shrinking nanoscale resolution, selectivity becomes paramount. With the increase in selectivity comes the ability to etch even higher aspect ratios.

Since our last report, we explored a comparison of various additive gases to C_4F_6 and CH_2F_2 . Specifically, we looked at the influence of helium (He), argon (Ar), carbon dioxide



(CO_2), and oxygen when added to either of the two polymer gases. As expected, we found a significant improvement in selectivity when using the inert gases, especially He, as opposed to the more reactive CO_2 and O_2 gases, as illustrated in Figures 1 and 2.

The thermal oxide (SiO_2) etch rates in the CH_2F_2 /He mixture exceed 150 nm/min with selectivity to DUV resist UV210 exceeding 4.4:1, as illustrated in Figures 3 and 4. Thermal SiO_2 etch rates in the C_4F_6 /He exceed 260 nm/min with selectivities to UV210 resist greater than 4.1:1. The etch profiles are illustrated in the SEM images, Figures 5 and 6.

Photonics research groups here at the CNF are using these advanced chemistries exclusively for their waveguide etches not only for more conventional silicon oxide and silicon nitride based waveguides, but for more advanced materials such as titanium dioxide (TiO_2). Professor Michelle Wang's research group has investigated TiO_2 / SiO_2 bilayer waveguide structures and has successfully etched them in C_4F_6 /He as illustrated in Figures 7 and 8, both used courtesy of Wang group.

For more information on dielectric etch capabilities in the Oxford 100, please contact Vince Genova at genova@cnf.cornell.edu.

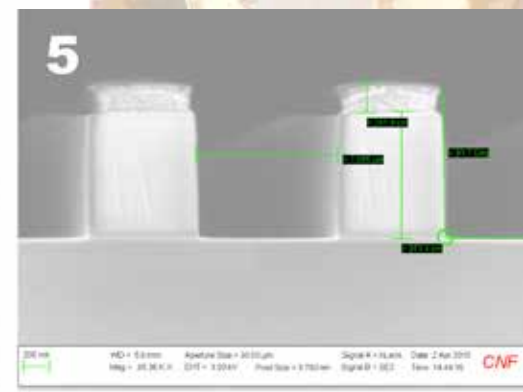
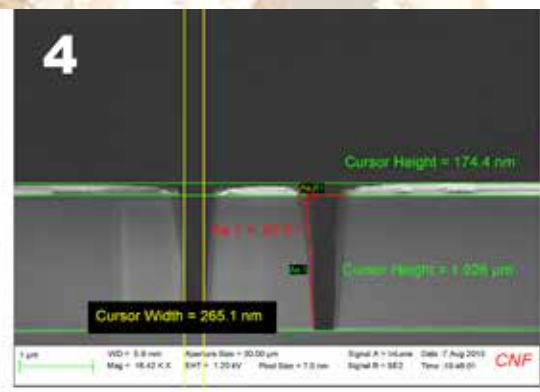
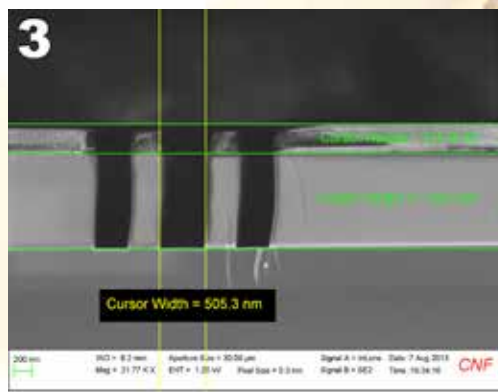


Figure 3: CH_2F_2 /He SiO_2 etch, 155 nm/min, Selectivity-4.4. Figure 4: CH_2F_2 /He SiO_2 etch, 155 nm/min, selectivity-5.8. Figure 5: C_4F_6 /He SiO_2 etch, 260 nm/min, selectivity-4.4. Figure 6: C_4F_6 /He SiO_2 etch, 260 nm/min, selectivity-4.4:1. Figure 7: TiO_2 / SiO_2 waveguide etched with C_4F_6 /He. Figure 8: TiO_2 / SiO_2 waveguide etched with C_4F_6 /He.



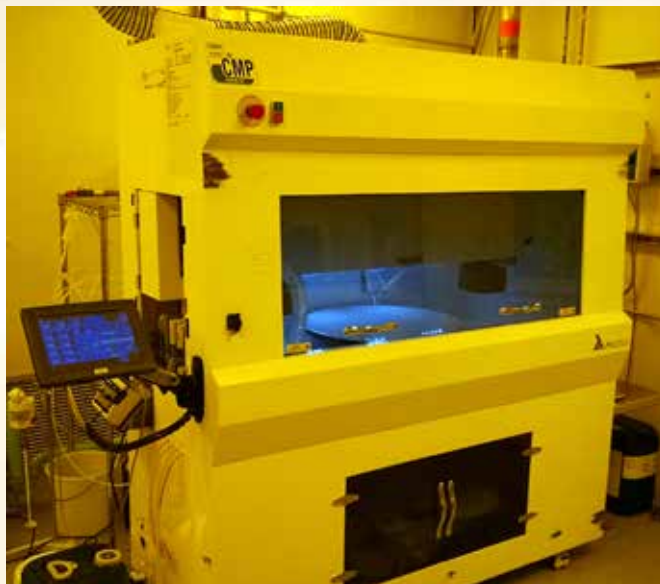
Logitech Orbis Chemical Mechanical Polisher

Out with the old, in with the new...

The Strasbaugh 6EC CMP has been moved out and the new Logitech Orbis CMP has been installed in the lab. Once characterization (and Coral-ization!) has taken place we can start training users on this new tool hopefully by the end of Septmeber. It is 4", 6" and 8" capable, as well as being unique in that custom fixturing for individual die is possible, this was previously unavailable with the 6EC.

The Logitech Orbis CMP system is a precision engineered, floor standing CMP tool ideally suited for R&D environments. Typically the Orbis is used in applications which conduct pilot production tests with optimum analytical capabilities and enhanced processing performance. This tool is ideally suited for work within the CNF in a R&D usage mode which it can closely replicate production CMP tooling.

Please contact Christopher Alpha for more information and tool training, alpha@cnf.cornell.edu.



University Photography

OVPR Summer Carnival

Submitted by Rebecca Vliet

On July 31st, 2015, CNF participated in the 6th annual Office of the Vice Provost for Research (OVPR) Summer Carnival.

CNF hosted a game booth, Five Amigos (stands with five ping pong balls and the player has six rubbers bands to shoot all five balls off). Door prize winners included CNF staff: Garry Bordonaro, five Flex permits donated by CU Transportation; Tom Pennell, one-year Science and Nature Family Membership from Museum of the Earth.

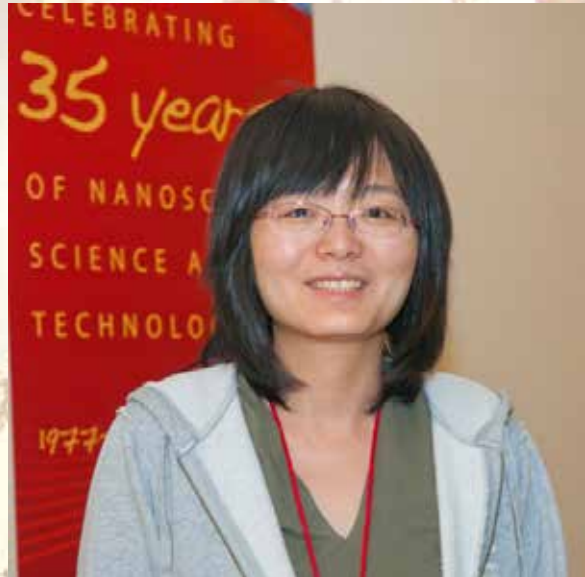


Introducing New CNF Staff!



Jeremy Clark

Jeremy Clark has spent the last seven years at Corning Incorporated in the Thin Films Research Group as a Process and Equipment Engineer. His responsibilities included specifying, installing, modifying, and maintaining process, metrology, and support equipment. He also developed and maintained a library of processes for several thermal and plasma deposition and etch systems. Before Corning he studied Microelectronic Engineering at Rochester Institute of Technology, where he was also a research assistant for the NanoPower Research Lab and the Semiconductor & Microsystems Fabrication Lab. In his free time he enjoys tinkering with 3d printers and making his kids laugh.



Xinwei Wu

Xinwei Wu joined CNF as a research associate in July 2015. Xinwei received a Ph.D. degree in Materials Science (with a minor in Applied Physics) in 2012 at Cornell. She worked in CNF for nanowire array oscillator fabrications using E-beam lithography and photolithography when performing her post-doctoral research in the Sonic MEMS group at Cornell. The main focus of Xinwei's work at CNF is to conduct research on thin film deposition and support CNF users. In her spare time, Xinwei likes gardening, hiking and photography.

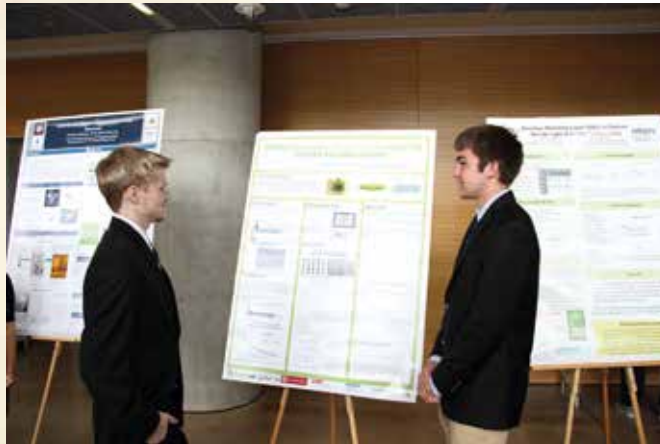


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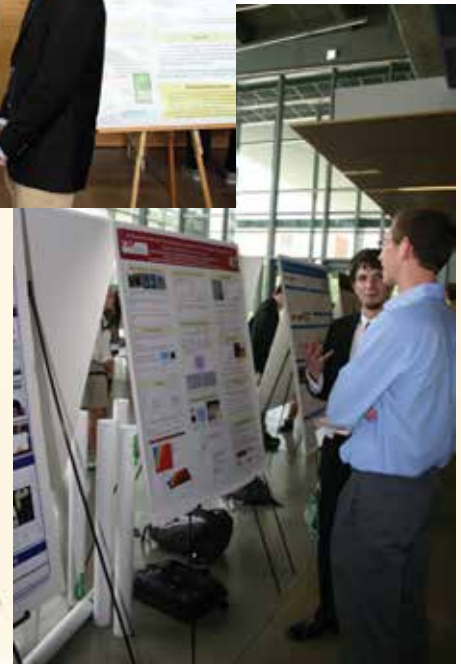
2013 CNF REU Interns Win Prestigious Awards!

Brandon Pereyra, who worked with David Erickson and Syed Ahsan, has won a Barry Goldwater scholarship, in the amount of \$7,500—an award given yearly to only 260 students in the USA! Brandon writes, “At the end of my freshman year, my research career started with the National Nanotechnology Infrastructure Network research experience for undergraduates at Cornell. I worked in Professor David Erickson’s laboratory under Dr. Syed Ahsan. Even though this was my first research experience, I was given challenging work that stimulated my interest in research. Thank you, Professor Erickson and Dr. Ahsan.”

Caleb Christianson, who worked with Derek Stewart and Saikat Mukhopadhyay, has been awarded an NSF Fellowship at \$34,000 plus cash and prizes for three years! Caleb writes, “I won the NSF [Fellowship]!!! Thank you so much for believing in me enough to let me participate in the NNIN; I know that that was a strong factor in the decision. :) Have a great week!!!” Best, Caleb



Brandon Pereyra (above right) and Caleb Christianson (below left) at the 2013 NNIN REU Convocation at Georgia Tech. Photographs by Melanie-Claire Mallison



Society of Women Engineers Member Spotlight for July 13th-19th



Provided

Allison Bosworth is currently studying Biological Engineering, with a minor in Physics, at Louisiana State University. She was a 2014 NNIN REU intern at the Cornell NanoScale Facility, and is now participating in the 2015 NNIN International REU with the National Institute for Materials Science in Tsukuba, Japan

Do you have a mentor? Please explain how they have helped, so far. I work closely with a professor and a post-doc in a mechanobiology lab. They have both mentored me on various lab techniques, including surface functionalization and cell culturing, and have introduced me to traditional Japanese foods and customs.

Of the projects you've been assigned which one have you liked, do you anticipate, or is interesting? I am now working on characterizing a migration pattern in breast cancer cells which gives rise to cancer metastasis. By studying a cellular process called epithelial-mesenchymal transition (EMT), we can pinpoint specific environmental conditions in which the process will speed up or slow down. We do this by seeding the cells on gold surfaces and analyzing migration patterns and protein expression at different time points.

Explain what you think the importance of your internship is so our younger colleagues can get a taste. Explain interview/how you met the company/how early or late you applied -- anything that you feel is something for those who potentially will be looking for internships themselves. Anyone interested in pursuing graduate school would definitely benefit from doing a summer research program like this one. Summer REU's allow you to experience graduate school firsthand through independent research, one-on-one meetings with a PI, and formal presentations of your work. Most REU applications are due between December and February depending on the organization. I qualified for the NNIN REU Program based on my prior research experience in Dr. Daniel Hayes' tissue engineering lab at LSU, however not all programs require previous research experience. In fact, I've found that most professors are eager and willing to discuss research positions with you if you show a sincere interest. A simple email is all it takes to connect with a professor and find out more about his/her research. I would advise anyone interested in graduate school to get involved in lab work early on in your college career so that you have the opportunity to travel and grow as a student/researcher through REU programs in the US and abroad.

Antonio Badolato, assistant professor at the Department of Physics, University of Rochester, received a Faculty Early Career Award 2015 from the National Science Foundation. Badolato will receive \$500,000 from the NSF Electronics, Photonics and Magnetic Devices program (No. ECCS-1454021) to support his project titled On-chip non-classical light sources in nanophotonic platforms. Badolato will study semiconductors photonic crystal nanostructures that harness quantum nonlinearities for their core operation and exploit photonic functionalities designed by a novel genetic evolution approach. The project will involve numerical modeling, nanofabrication, and laser spectroscopy.

Badolato's research group focuses on classical and quantum nanophotonics (website: <http://badolato.pas.rochester.edu>).



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Two Researchers Awarded Department of Defense Grants

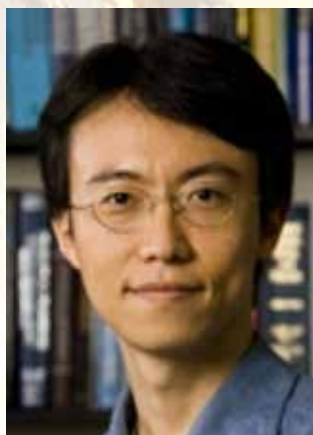
*By Anne Ju
June 10, 2015
Cornell Chronicle*

Cornell chemists William Dichtel and Jiwoong Park have received Department of Defense Multidisciplinary University Research Initiative (MURI) awards. The highly competitive program supports research teams working in more than one traditional science or engineering discipline to accelerate breakthroughs in basic research. This year, the DOD awarded 22 MURI grants totaling \$149 million over the next five years.

Dichtel, associate professor of chemistry and chemical biology, will partner with researchers from the University of California, Berkeley; Georgia Institute of Technology; and King Abdullah University of Science and Technology in Saudi Arabia to develop the Center for Advanced 2-D Networks. The center will address the long-standing challenge of making polymers with repeating two-dimensional structures, similar to the repeating nature of bathroom tile, as compared with the one-dimensional structures of many plastics used today, Dichtel said. Members of the center have pioneered ways to prepare 2-D polymers, and the center will focus on improving these techniques and understanding their unique design rules. The researchers will prepare 2-D polymers with properties including conductivity, magnetism, the ability to store charge, or the ability to interact with light in



Dichtel



Park

useful ways. They will also study mixed systems of these designed 2-D polymers with other emerging 2-D materials, such as graphene or molybdenum disulfide.

Park, associate professor of chemistry and chemical biology, will partner with researchers from Stanford University and Johns Hopkins University for a project titled "Atomically thin systems that unfold, interact and communicate at the cellular scale." The goal of the collaboration is to make transistors, photovoltaics and other devices out of ultra-flexible, ultra-thin materials including graphene, hexagonal boron nitride and transition metal dichalcogenides. The work will involve integrating devices into paper-like, atomically thin materials. For instance, Park said, the researchers envision microscale or nanoscale deployable parachutes made out of high-functioning electronics devices that could be communicated with wirelessly. The team includes Paul McEuen, professor of physics, and David A. Muller, professor of applied and engineering physics, as well as experts in thin film folding, integrated circuits and the interaction of light and devices from Stanford and Johns Hopkins.

Three Faculty Elected to American Academy of Arts and Sciences

By Anne Ju (edited for space)
 April 23, 2015
 Cornell Chronicle

The American Academy of Arts and Sciences has named three Cornell faculty members among its 197 new fellows for 2015. The fellows are among “the world’s most accomplished scholars, scientists, writers, artists and civic, business and philanthropic leaders.”

“We are honored to elect a new class of extraordinary women and men to join our distinguished membership; Joseph Halpern, professor of computer science, Paul McEuen, professor of physical Science, and Karl Niklas, professor of botany,” said Don Randel, chair of the academy’s board of directors and former Cornell provost. “Each new member is a leader in his or her field and has made a distinct contribution to the nation and the world. We look forward to engaging them in the intellectual life of this vibrant institution.”

Paul McEuen, a faculty member since 2001, is the John A. Newman Professor of Physical Science in the College of Arts and Sciences and director of the Kavli Institute at Cornell for Nanoscale Science. He leads a nanotechnology lab researching electrical, mechanical and optical properties of carbon nanotubes and graphene sheets; scanned probe microscopy of nanostructures; and applications for nanoelectronics in chemistry and biology. He is also a fellow of the American Physical Society and a member of the National Academy of Sciences.



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The fellows will be inducted at an Oct. 10 ceremony in Cambridge, Massachusetts. Members of the academy includes more than 250 Nobel laureates and more than 60 Pulitzer Prize winners.

Greg Pilgrim graduated from the University of Rochester (Chemistry) this summer and won a fellowship from the Japanese Society for the Promotion of Science (a sort of analog to our NSF) to do postdoctoral research at Kyoto University in Japan.

Greg be working on nanoscale actuators with Professor Motofumi Suzuki.



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High school students visited from the Icahn School of Medicine at Mount Sinai Center for Excellence in Youth Education (CEYE) Program. Photographs provided by students and CEYE staff.

The next CNF Short Course: Technology & Characterization at the Nanoscale (CNF TCN) will be held January 12-15, 2016. Information and registration will be available online soon! http://www.cnf.cornell.edu/cnf5_courses.html



Sam Wright

Blast from the Past

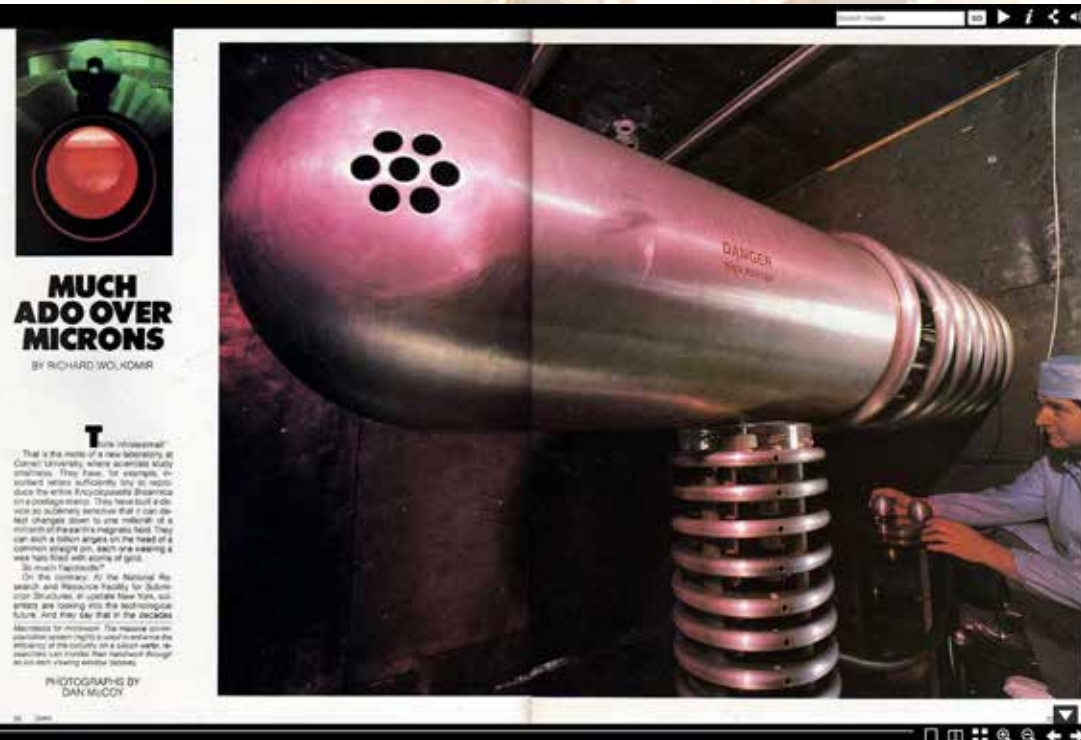
Submitted by Dan McCollister

From the December 1982 Omni magazine, a feature on the then National Research and Resource Facility for Submicron Structures.

I remember the photographer complaining that his editors always wanted something strikingly unusual about his photographs even though they were about scientific or technical subjects. As we have now come to expect, Michael Skvarla stepped up and came through. He's pictured here inside the source of his old (even then) Veeco ion implanter, holding the 300 KV terminals.

There's something you don't see every day!

The full article is at https://archive.org/stream/omni-magazine-1982-12/OMNI_1982_12#page/n27/mode/2up



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