

NanoMeter

The Newsletter of the Cornell NanoScale Facility
Fall 2016 • Volume 25 • Issue 2

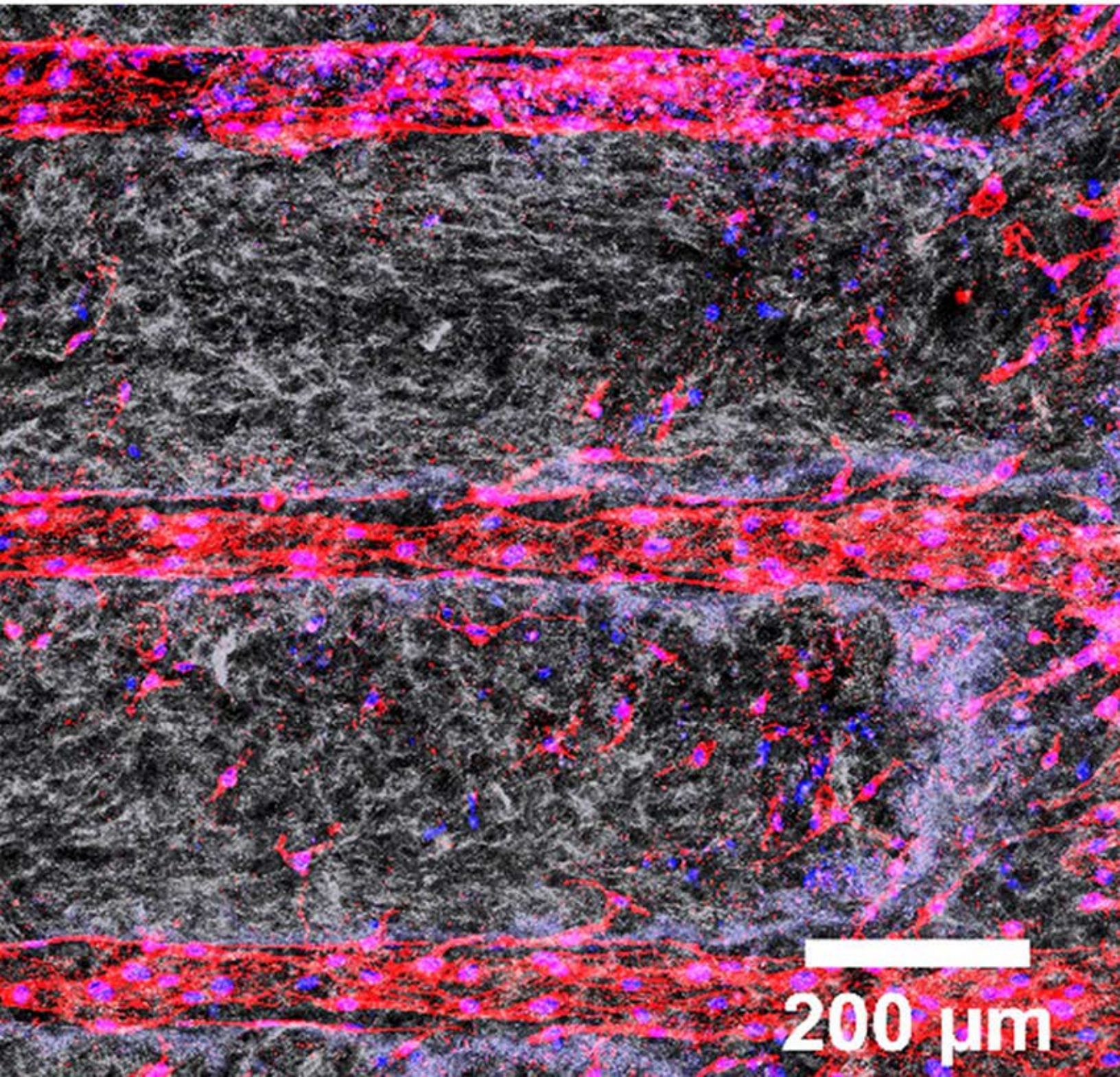


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SAVE THE DATE!

2017 CNF SHORT COURSE:
TECHNOLOGY & CHARACTERIZATION
AT THE NANOSCALE (CNF TCN)

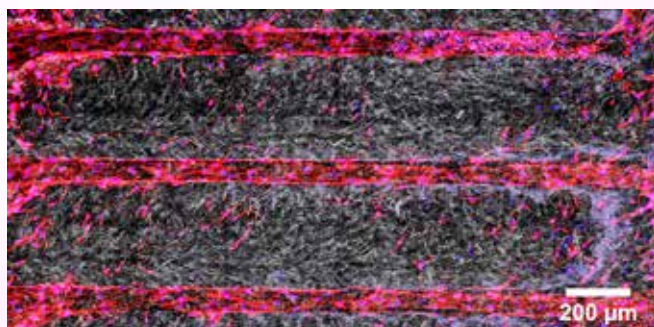
TUESDAY - FRIDAY,
JANUARY 17 - 20, 2017

[HTTP://WWW.CNF.CORNELL.EDU/
CNF_TCN_JANUARY_2017.HTML](http://WWW.CNF.CORNELL.EDU/CNF_TCN_JANUARY_2017.HTML)

Reminder to Submit to CNF User Wiki

Dear CNF Community: It has been quite awhile since our last call for updates, and clearly some of you have developed processes/recipes in that time! Please share on the CNF User Wiki.

wiki.cnfusers.cornell.edu



The cover image for this issue is from "Biomimetic Models of the Tumor Microenvironment and Angiogenesis"; CNF Project Number: 1540-07; Principal Investigators: Claudia Fischbach-Teschl, Abraham D. Stroock; Users: Peter DelNero, Lu Ling, John Morgan; Affiliation: Nancy E. and Peter C. Meinig School of Biomedical Engineering, Cornell University; Websites: ww.fischbachlab.org, www.stroockgroup.org. Figure 2: Confocal micrograph of microfluidic biomaterials using lithographically patterned collagen gels. The background for this issue is an extreme close-up of the same image!

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



Welcome to the 2016 Fall Edition of the CNF NanoMeter

In this Fall 2016 edition of the NanoMeter, we are pleased to update you on the latest news from CNF. Inside you will find greetings from the new director of CNF, research highlights, a review of our REU programs, and some exciting new results and tool updates from our staff.

Introducing Christopher Ober

As the new CNF Director, I would like to use this forum to introduce myself to the community. I am excited about the new job and about the new opportunities afforded by the creation of the National Nanotechnology Coordinated Infrastructure (NNCI), a network focused on nanoscience and nanotechnology.

As the users of CNF know, we have first-rate facilities and outstanding staff who are dedicated to helping our users achieve success in all their efforts. As a long time user of CNF myself, I am always very impressed with the enthusiasm of the staff for teaching new users and working with them to solve interesting and often difficult problems. We especially wish to thank our users for their contributions to this publication, and we hope that you will find this collection of work to be informative and impressive, both for the quality of the research and for the breadth of fields in which the tools of nanotechnology are enabling new breakthroughs.

CNF is now supported by the National Science Foundation through its funding of the NNCI, an integrated network of sixteen university-based user facilities established in September 2015 to serve the needs of researchers in the fields of nanoscale science, engineering and technology. NNCI provides users from across the nation—from academia, small and large industry, and government — with open access to leading edge tools and processes for nanofabrication, synthesis, characterization, design, simulation, and device integration. I especially want to thank Dan Ralph for steering the CNF on its course for the last few years and for leading us to a successful membership in NNCI.

NNCI Network Kick-off Meeting

As my first activity as CNF director, I attended the kick off meeting for the NNCI in Salt Lake City. We have a combination of schools from the old network and many new schools bringing a new set of skills to the new network. I am impressed by the energy and excitement of the NNCI and look forward to its future successes.

We welcome inquiries from all researchers about CNF's capabilities and the new network, especially those with no previous experience in nanofabrication, since the outstanding staff members at CNF are highly skilled at teaching new users and working with them to plan new projects.



New Equipment and Processes at CNF

The CNF continued to upgrade its capabilities since the spring edition. New tools have been acquired and new processes developed represent a significant investment in renewing and enhancing lab capabilities. Please see the CNF web site for the names of the staff members to contact for further information or training.

- Everbeing International Corp has donated a new EB-6 electrical probe station. The new system will replace our old probe system and will supply better vibration isolation, a dark box, and we purchased a new heated chuck to replace our current set up. (See page 25 for article.)
- A Metricon Prism Coupler system with five wavelength sources was added to the lab this year to allow high precision measurement of index of refraction for a wide range of dielectrics. The system also can measure waveguide losses and is already helping groups to develop novel waveguide stacks.
- A new KLA-Tencor P7 stylus profilometer has arrived and training is underway to get all our users up to speed quickly on the new system. (See page 25 for article.)
- In the deep etch area, CNF staff have worked with researchers at CHESS to optimize a modified deep silicon etch to achieve deep etching of germanium wafers in the PT Versaline Deep Etcher.
- Read on in this issue to find more information on other tools and successful processes.

Education and Outreach Events

The CNF participates in numerous educational outreach activities while also operating both a national and an international version of the NSF Research Experience for Undergraduates (REU) Program. The CNF REU Program brings in undergraduate students from across the United States and exposes them to CNF's state-of-the-art facility and our world class staff. In addition to the five students who stayed at Cornell during this year's ten-week summer REU program focused on research in micro and nanotechnology, a second group of six interns spent the summer in Japan as part of our international (iREU) program.

See the articles in this issue to learn more about the REU and iREU intern programs (pages 17-19).

We are grateful to the National Science Foundation for its continued funding for the REU activities, but we also seek corporate funds to augment this program. Please contact Dr. Lynn Rathbun, NNIN Program Manager, to discuss corporate sponsorship options (rathbun@cnf.comell.edu).





CNF continues to host many educational tours, workshops and special events at Cornell. These include our short course, “Technology & Characterization at the Nanoscale” (CNF TCN; see SAVE THE DATE on page 2), open to participants from academia, industry, and government. The TCN includes lectures and demonstrations, and also hands-on lab activities in the cleanroom. The next short course will be offered in January 2017.

Over the past year, CNF has hosted visits and tours and staffed events for over 3700 participants; from prospective graduate students and new faculty members, to visiting dignitaries and corporate executives, public events, and visit groups. These include over 124 distinct visits and events. Led by Dr. Elizabeth Rhoades, we hosted a new signature outreach event, 4H Career Explorations, introducing 4H members to the nano-world we live in.

We look forward to working with the NNCI network of facilities. Under the NNCI, CNF will continue to serve as a national resource, to meet your research and commercialization needs. We welcome your comments as well as your suggestions for improvement.

Chris Ober

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Photograph Credits: Page 3; Top, Christopher Ober by University Photography. The Farewell / Hello Luncheon for Dan Ralph and Chris Ober, by Sam Wright, (middle) Chris and Don, (bottom) Dan Ralph, Bob Buhrman, Chris Ober, Beth Rhoades, and Don Tennant. Page 4; Middle, The 2016 iREU interns, selfie by Emilie Benson. Bottom row, The Farewell / Hello Luncheon for Dan Ralph and Chris Ober, by Sam Wright, CNF Staff. Page 5; Top and middle, Dan Ralph and Beth Rhoades participate in youth outreach, by Don Tennant. Bottom row, The Farewell / Hello Luncheon for Dan Ralph and Chris Ober, by Sam Wright, CNF Staff.



NIH Provides \$2.3M Grant for FeverPhone Development

By Blaine Friedlander
June 21, 2016
Cornell Chronicle

The National Institutes of Health's (NIH) National Institute of Biomedical Imaging and Bioengineering has awarded to Cornell a four-year, \$2.3 million grant to develop FeverPhone, which will diagnose six febrile diseases in the field: dengue, malaria, chikungunya, typhoid fever, leptospirosis and Chagas' disease. Faculty members David Erickson and Saurabh Mehta will lead the team.

U.S. Sens. Charles Schumer, D-N.Y., and Kirsten Gillibrand, D-N.Y., announced the first year of the federal grant (\$611,617) June 20.

Once developed, in part using the research tools at the Cornell NanoScale Facility, the FeverPhone — hardware and software, working in combination with a smartphone or tablet — will provide a real-time, rapid and accurate diagnosis using a drop of blood to differentiate and identify specific pathogens. This represents a shift from basing field decisions on apparent syndromes or clinical judgments.

"As we face an alarming rise in dangerous illnesses like Zika, both in the U.S. and around the world, it is crucial that our medical professionals have the best tools at their disposal to track, treat and prevent disease. These cutting-edge scientists at Cornell University are on the cusp of transforming our medical industry by developing the mobile technology that can provide health care workers the most up-to-date diagnosis information at their fingertips," Schumer said.

Gillibrand said: "These funds are a critical investment that would help advance the scope of medical analysis — identifying and diagnosing the causes of serious illnesses and diseases. This collaboration in medical research would help increase response time and provide personalized treatment options for patients. Cornell



Figure 1: An early prototype of the FeverPhone, for which the NIH has provided a four-year, \$2.3 million grant to Cornell for development. Provided.

University is at the forefront of medical research and development, and its cutting-edge programs help expand health care access to families in need of health services."

Dr. Saurabh Mehta, associate professor of global health, epidemiology and nutrition in the Division of Nutritional Sciences in the College of Human Ecology, and a principal investigator on the grant, explained its global importance: "Acute febrile illnesses — such as malaria and dengue — are respon-

sible for substantial morbidity and mortality around the world, and this problem carries imposing economic cost, primarily in developing countries. The FeverPhone will help diagnose common causes of fever from a drop of blood in a few minutes to enable appropriate management and treatment."

David Erickson, professor in Cornell's Sibley School of Mechanical and Aerospace Engineering, in collaboration with Mehta will create the FeverPhone, and test it in Ecuador partnering with Washington B. Cárdenas, head of the biomedicine laboratory at the Escuela Superior Politécnica del Litoral (ESPOL) in Ecuador, and Dr. Timothy Endy, professor of medicine at SUNY Upstate Medical University.

The team will develop an app for a smartphone or tablet to work in conjunction with a small blood tester — called Tidbit — that looks similar to a countertop coffee maker and transmits its data wirelessly to the smartphone for analysis.

"Imagine a glucose tester for your smartphone, where you can test for dengue instead of measure glucose," said Erickson. "Hospitals traditionally require as much as 24 hours to get test results. With FeverPhone, we will have an actionable diagnosis in about 15 minutes."

The research team will perform a field validation at an existing infectious diseases monitoring site in Guayaquil, Ecuador, and the system will be validated and ready for FDA approval when the research is complete.

“A common feature of neglected tropical diseases, such as dengue, malaria, chikungunya, Zika and other viral and non-viral diseases, is its disproportionate burden on resource-limited countries — where technology for surveillance, basic biomedical research, diagnosis and treatment are constrained,” said Cárdenas.

While the Zika virus was not included in this specific grant, as the application was submitted before the current outbreak, the technology potentially can be expanded to include it, said Mehta.

“We’re at a really important time in the convergence of mobile and health care technologies,” said Erickson. “It’s this type of research funding that can enable the multidisciplinary collaborations between engineers and experts in infectious disease that can really move things forward and have long-term impacts on human health.”

Tech Tools to Tackle Global Health Problems

Cornell technologies such as FeverPhone and NutriPhone rely on ubiquitous, easy-to-use devices to solve nutritional and health challenges in places where the resources are sparse.

Seeking collaborations, faculty members Saurabh Mehta and David Erickson have reached across disciplines to launch the Institute for Nutritional Sciences, Global Health and Technology (INSiGHT), a project supported by Cornell’s Division of Nutritional Sciences and College of Engineering.

INSiGHT aims to develop advanced diagnostic tools to allow health workers, researchers and policymakers with minimal resources to address public health problems.

Erickson said: “Our goal with INSiGHT is to provide a clearing house to make more of these interdisciplinary efforts a reality.”

Cancer Cells’ Ability to Self-Repair May Spawn New Treatments

*By Tom Fleischman
March 24, 2016
Cornell Chronicle*

Because they have narrow bodies and no collarbones, mice are able to squeeze through holes as small as a quarter-inch in diameter. Cancer cells similarly are able to migrate through extremely tight quarters but with a major difference: The journey often comes at a price — the deformation and, in some cases, rupture of the outer lining of a cell’s nucleus.

A research group headed by Jan Lammerding, associate professor of biomedical engineering, has been studying this phenomenon in hope of using it to develop both treatment and diagnostic solutions for the millions of people who deal with cancer every day. Lammerding’s group reports on this research in a paper published online March 24 in *First Release*, from the journal *Science*. His group’s paper is being published simultaneously with research by a French group, which found similar results in immune cells.

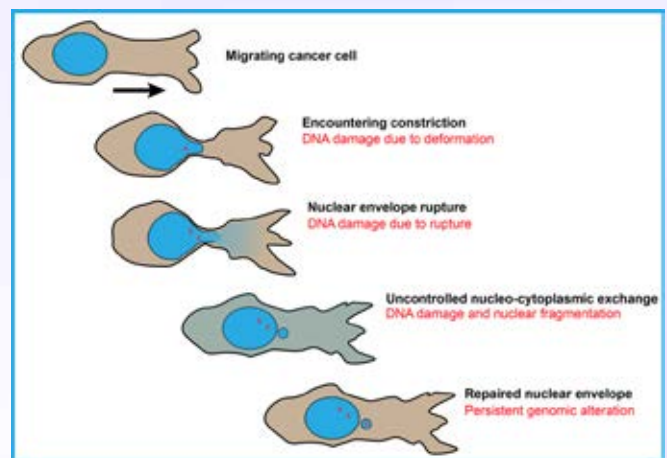


Figure 1: A cancer cell that squeezes through a constricted space undergoes deformation and, occasionally, rupture of the nuclear envelope, which can have consequences on the cell’s genomic integrity. Lammerding Lab, Provided.

Continued on page 8

While deformation and rupture can sometimes lead to apoptosis (cell death), the cell also has the ability to repair itself. "I think most cell biologists would probably say that these cells will not do very well after deformation and rupture," said group member Philipp Isermann, a visiting scholar in biomedical engineering. "And it was quite surprising that about 90% of these ruptured cells survived."

Added post-doctoral researcher Celine Denais: "You would think that, as with a balloon, at some point it will pop. We've been amazed with how these cells can handle this deformation."

There is also the possibility that a ruptured cell could mutate into a more aggressive form of cancer. "You have so many migrating cells," Lammerding said, "that even if a small fraction of them picks up a mutation, that is bad because it means the cancer is evolving."

"The good part is, this rupturing also makes the cancer cell vulnerable," he said. "Most cells in the body stay in place, and it's presumably mostly cancer cells that are moving around. So if we can block the mechanisms that allow them to repair themselves, then we potentially could target metastatic cancer cells."

Lammerding began his work in this area while teaching at Harvard Medical School. Part of the reason he came to Cornell in 2011, he said, was to take advantage of the fabrication capabilities at the Cornell NanoScale Science and Technology Facility, where the model environments used in the study were built. "They work very well and have become very popular," he said. "Every time I go to a meeting and present this work, people come up to me and say, 'Can we get some of these models?'"

The group looked at two factors in the cell's migration process: the rupturing of the nuclear envelope, which they tracked using green and red fluorescent proteins normally localized to the cell nuclei, but that spill into the cell body when the nucleus ruptures; and damage to the cell's DNA.

"We're still trying to find out if there are differences between cells, and a lot of what we see is very similar between normal cells and cancer cells," he said, adding that by trying to identify potentially unique deformation-and-repair properties of cancer cells, treatments that are minimally deleterious to healthy cells may be developed.

"Now that we kind of know what we're looking for, now that we know the molecular pathways involved in the repair," he said, "could we then specifically target invasive cancer cells and not have the sledgehammer that hits everything?"

Other contributors to the paper, "Nuclear envelope rupture and repair during cancer cell migration," included: Rachel Gilbert, former undergraduate and master's student in biological engineering; Alexandra McGregor, Cornell graduate student in biomedical engineering; and former postdoctoral fellow Patricia Davidson, now at the Institut Curie in Paris. The group was also assisted with *in vitro* and *in vivo* experimentation by Katarina Wolf and Peter Friedl of Radboud University Medical Center in the Netherlands.

This work was supported by grants from the National Institutes of Health, the Department of Defense Breast Cancer Research Program, the National Cancer Institute and the National Science Foundation.

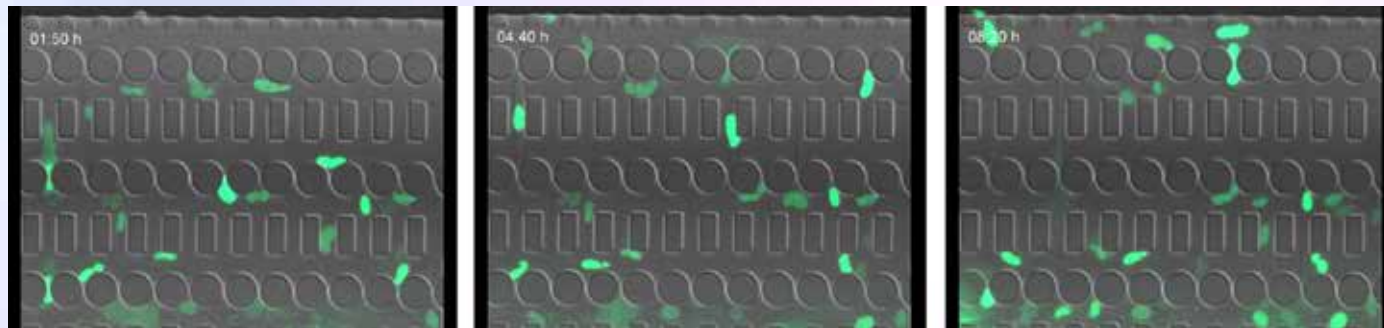


Figure 2: Breast cancer cells exhibit nuclear envelope rupture while migrating through a microfluidic device. The research done by associate professor Jan Lammerding's biomedical engineering group is being published online March 25 in the journal *Cancer Cell*.

Video captures from Lammerding Lab Video, <http://www.news.cornell.edu/stories/2016/03/cancer-cells-ability-self-repair-may-spawn-new-treatments>

Researcher's Chiral Graphene Stacks Break New Ground

By Tom Fleischman
February 22, 2016
Cornell Chronicle

Hands and feet are two examples of chiral objects — non-superimposable mirror images of each other. One image is distinctly “left-handed,” while the other is “right-handed.” A simple drinking glass and a ball are achiral, meaning the object and its mirror image look exactly the same.

In science, chirality is a fundamental concept in a number of disciplines, including medicine. In the 1950s and early '60s, pregnant women were prescribed the sedative thalidomide, but the drug produced horrific birth defects in thousands of children around the world. The reason: The thalidomide molecule is chiral, and while the left-hand molecule was indeed a sedative, the right-hand one was found later to produce fetal abnormalities.

Until very recently, similar “handedness” in large area films with atomic scale precision hadn't been investigated. The research team of Cornell's Jiwoong Park has broken new ground in this area, developing a chiral atomically thin film only 2-atoms-thick, through circular stacking of graphene. This material is of interest in the fields of polarization optics, stereochemistry, optoelectronics and spin transport electronics, or spintronics.

“I would say that we've been curious about this for a long time, whether we can make this material,” said Park, associate professor of chemistry and chemical biology and an executive member of the Kavli Institute at Cornell for Nanoscale Science.

The Park group's paper, “Chiral Atomically Thin Films,” was published Feb. 22 in *Nature Nanotechnology*. Park and Cheol-Joo Kim, a postdoctoral researcher in chemistry and chemical biology, designed and conducted the experiments and co-wrote the paper.

Contributors include Zachary Ziegler '17, an engineering physics major; former Cornell postdoc Yui Ogawa; and Cecilia Noguez of the Instituto de Fisica, Universidad Nacional Autonoma de Mexico. Noguez is one of the world's leading computational physicists, and she helped calculate the Park group's results.

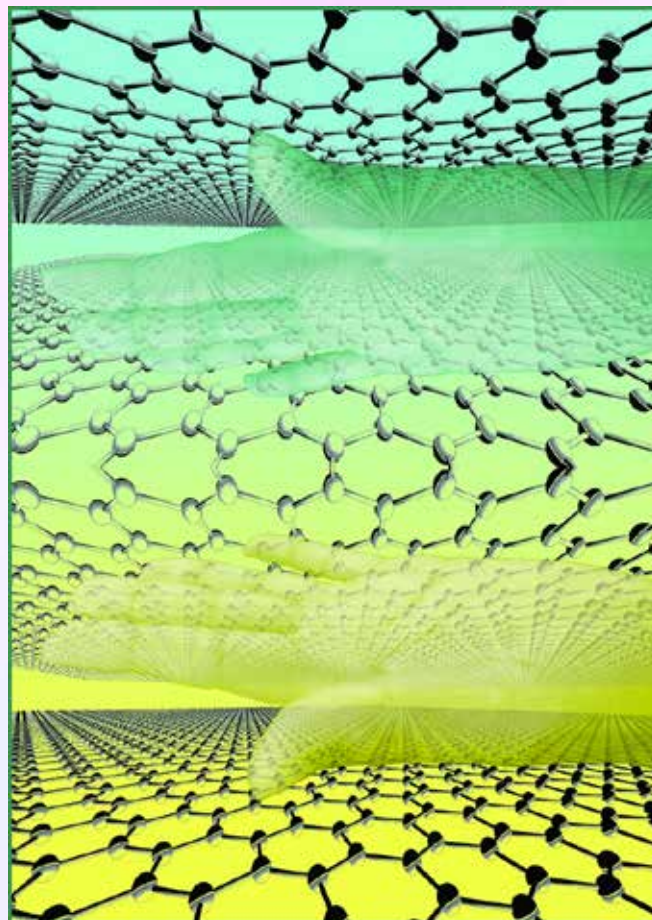


Figure 1: An artist rendering of right- and left-handed stacks of two-atoms-thick graphene, connected by a mirror plane in the middle. Provided by Kim and Ziegler.

“This discovery and its confirmation may have a lot of implications in both pure and applied science,” Noguez said. “This may be applied for sensing biomolecules, and to induce and control asymmetric catalysis, among others. I am sure this discovery opens new research directions for other 2-D materials.”

For the experiment, Kim and Ogawa grew graphene sheets on copper, then cut them into multiple sheets. Those sheets were then stacked, with each sheet rotated slightly before being placed on the one below it. The rotation went

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clockwise on one stack and counter-clockwise on the other to form right-handed and left-handed stacks.

Circularly polarized light — alternating left-handed and right-handed beams — were shone onto the stacks, and circular dichroism (or CD, the differential absorption of left- and right-handed light), was measured. It's the circular dichroism of 3-D glasses that allows you to see a movie in three dimensions.

The special graphene film's CD was stronger than the group anticipated. After months of hard work and some setbacks, that discovery came around Thanksgiving 2014, and "that was when the whole process accelerated," Kim said.

But after achieving this atomic-scale breakthrough, the group had to quantify its results, so it turned to Noguez. "It's one of those rare cases where we knew exactly what we wanted, so we

knew what quantity had to be calculated," Park said. "It's not an easy calculation, and we did a lot of research and realized that Cecilia is the best person to do this."

Noguez admitted her group was initially surprised by Park's findings, but in analyzing them further realized the research made sense.

"We predicted a long time ago a similar behavior for single-wall carbon nanotubes and more recently in ligand-protected metal nanoparticles," she said. "So in the end, those results made sense to me."

The project was supported by the National Science Foundation, through the Cornell Center for Materials Research, and the Air Force Office of Scientific Research. Sample fabrication was performed at the Cornell NanoScale Facility, which is supported by the NSF.

Graphene Used as a Frequency Mixer in Cornell-Led Research

By Tom Fleischman
June 28, 2016
Cornell Chronicle

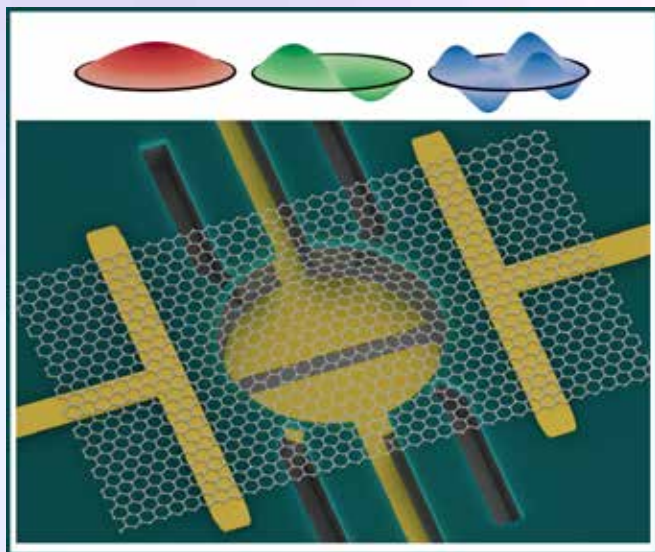


Figure 1: Top; Three vibrational modes excitable in circular drums. In graphene, these modes are coupled to one another and can exchange energy. Bottom; An artist's depiction of a graphene drum. The graphene vibrates above a circular trench on a silicon chip. T-shaped metal electrodes contact the graphene's bottom surface, while central electrodes apply electric forces from below to drive the motion. Provided by Roberto De Alba.

A professor, a postdoctoral researcher and a graduate student hop onto a trampoline.

No, it's not the opening line of a joke. It's a setup for the explanation of new Cornell-led research involving the wonder material graphene. A group led by Roberto De Alba, graduate student in physics, and Jeevak Parpia, professor and department chair of physics, has published a paper in *Nature Nanotechnology* regarding yet another application for the versatile, super-strong, super-light material.

Their paper, "Tunable phonon-cavity coupling in graphene membranes," was published June 13 and describes the ability to use the graphene's tension as a sort of mediator between vibrational modes, allowing for direct energy transfer from one frequency to another. De Alba was lead author.

Now, back to the trampoline. Let's establish that the professor jumps at a slow rate, the postdoc at

a medium rate and the grad student at a fast rate. They represent the natural modes of the trampoline, which represents the graphene.

If the professor initiates his slow jumping first, followed by the grad student at a much faster rate, the postdoc — by virtue of the jumping that is already going on — is forced into jumping, at his own rate. What's more, the professor's jumps become much higher than they were initially, as energy is transferred to him from the faster jumpers. This scenario won't actually play out in your backyard, but it takes place in graphene because of its high "elastic modulus" — a material property that means any vibrations will cause large changes to the membrane's tension.

In applying this concept, the group fabricated graphene "drums" with diameters ranging from 5 to 20 μm . Those drums can be set in motion either by an alternating electric field or by the random thermal vibrations of their constituent atoms (the same atomic vibrations that define an object's temperature); the movement is detected through laser interferometry, a method devised several years ago at Cornell in Harold Craighead's group. Craighead is the Charles W. Lake Jr. Professor of Engineering and a collaborator on this work. External voltage applied to the graphene membrane acts as a sort of "tuning peg" to control the membrane tension and engineer the coupling needed to control one oscillation mode by exciting the other.

"We've shown that there is an effect that will convert energy from one mechanical mode to another mechanical mode," De Alba said. "It allows us to either damp out or amplify vibrations of one mode by activating the other mode."

"You're able to change the fundamental frequency of this object's motion ... essentially its thermal motion, by simply applying voltage," Parpia said.

De Alba said the term "phonon cavity" was chosen because the mechanical effect is similar to that of an optical cavity, which can be used to convert energy from laser light into mechanical motion. Phonons are quasi-particles used to describe vibrations in the same way that photons are particles of light.

This discovery paves the way for the application of graphene mechanical resonators in telecommunication applications — for instance, as frequency mixers.

"And because graphene is only a single atom thick, it has such a low mass that it makes a very good force sensor, gas sensor or pressure sensor," De Alba said. "It could be used in research labs to study ultra-weak forces."

In addition, when cooled to near absolute zero, these resonators can play a key role in detection of the faintest quantum signals and in identifying and developing new, secure telecommunication technologies.

Other contributors included Paul McEuen, the John A. Newman Professor of Physical Science and director of the Kavli Institute at Cornell for Nanoscale Science; former McEuen group member Isaac Storch, M.S. '13, Ph.D. '15; Than-niyil S. Abhilash, postdoctoral researcher in physics; and Aaron Hui '15, now a graduate student in applied and engineering physics.

This work was supported by the Cornell Center for Materials Research with funding from the National Science Foundation's Materials Research Science and Engineering Center program. Fabrication was performed in part at the Cornell NanoScale Facility, a member of the National Nanotechnology Coordinated Infrastructure, which is supported by the NSF.



CNF Picnic, by Rebecca Vliet

Surface Mutation Lets Canine Parvovirus Jump to Other Species

By Tom Fleischman
April 14, 2016
Cornell Chronicle

Canine parvovirus, or CPV, emerged as a deadly threat to dogs in the late 1970s, most likely the result of the direct transfer of feline panleukopenia or a similar virus from domesticated cats. CPV has since spread to wild forest-dwelling animals, including raccoons, and the transfer of the virus from domesticated to wild carnivores has been something of a mystery.

“The underlying issue is, how do viruses jump from one animal to another and what controls viral host range?” said Colin Parrish, the John M. Olin Professor of Virology and director of the Baker Institute for Animal Health at Cornell.

With a major assist from the Cornell NanoScale Science and Technology Facility (CNF), a multi-disciplinary team of researchers has identified a mutation in CPV that can profoundly alter transferrin receptor (TfR) binding and infectivity of the virus. The methodology used in this research could blaze a trail for future research into other viruses, including influenza.

Parrish co-authored a research paper, published in the *Journal of Virology*, with Susan Daniel,

associate professor in Cornell’s Robert Frederick Smith School of Chemical and Biomolecular Engineering, which contends that a key mutation in the protein shell of CPV — a single amino acid substitution — plays a major role in the virus’ ability to infect hosts of different species.

“That was a critical step,” he said. “It took a lot of changes to allow that to happen.” He said another key factor in CPV’s infectivity is adhesion strengthening during TfR binding. “There’s an initial attachment, which is probably relatively weak,” he said. “The thing just grabs on and holds on a little bit, sort of like using your fingertips. And then it looks like there’s a second attachment that is much stronger, where it’s like you grab on and hold on with both hands and won’t let go.

“We think that the second event, this structural interaction that occurs in a small proportion of the binding cases, seems to be critical,” he said. “We think that it actually causes a change in the virus, that it triggers a small shift in the virus that actually makes it able to infect successfully.”

One of Daniel’s specialties is the investigation of chemically patterned surfaces that interact with soft matter, including biological materials such as cells, viruses, proteins and lipids. Her lab has pioneered a method called single-particle tracking — placing artificial cell membranes into microfluidics devices, fabricated at the CNF, to study the effect of single virus particles on a variety of membrane host receptors, in this case from both dogs and raccoons.

“The nice thing about these materials is that we can design them to have all different kinds of chemistries,” she said. “So in this particular study, we can put the receptor of interest in there, isolated from everything else so we can look at the specific effect of that receptor on a particular virus interaction.”

Daniel’s lab also developed the precision imaging devices used in the study.

“Another piece of this paper is how the parvovirus actually sits down and binds even stronger over

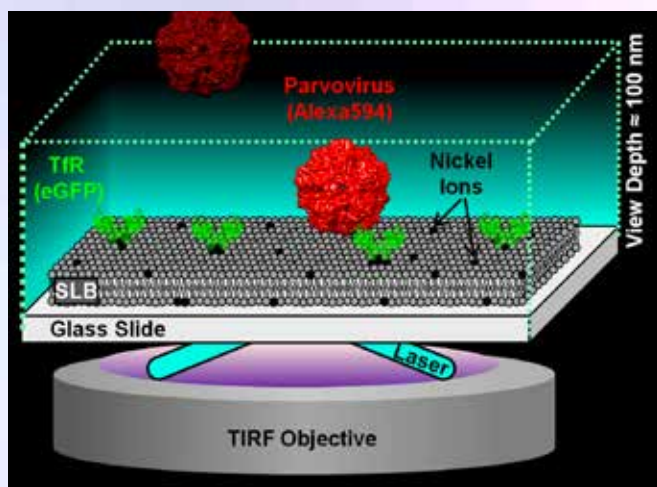


Figure 1: A schematic of the single-particle tracking binding assay used in the research into parvovirus, conducted by Colin Parrish of the Baker Institute for Animal Health and Susan Daniel from the Robert Frederick Smith School of Chemical and Biomolecular Engineering. Provided by Susan Daniel/Colin Parrish.

time with that receptor,” Daniel said. “That was kind of a new result that came out of the technique itself, being able to look at individual binding events.”

Parrish has Australian cattle dogs and Daniel has Jack Russell terriers, so this research hits home for both of them.

“When this virus infects a young animal, it can be fatal,” Parrish said. “It’s very unpleasant, and if you own a puppy or a kitten, that’s why you should vaccinate.”

Other contributors to the paper included Donald Lee, a graduate student in the field of chemical and biomolecular engineering; Andrew Allison, a postdoctoral associate at the Baker Institute; and Kaitlyn Bacon '15. Daniel in particular credited Lee and Allison with bringing their individual strengths together in a collaborative way “to make this study happen.”

This work was funded by grants from the NSF — which also funds the CNF, a member of the National Nanotechnology Infrastructure Network — and the National Institutes of Health.



Ollie! Susan Daniel's Jack Russell terrier, Ollie. Provided.

Electrical Properties of Superconductor Altered by ‘Stretching’

*By Tom Fleischman
May 26, 2016
Cornell Chronicle*

In the early 1970s, in the basement of Clark Hall, the Cornell team of professors David Lee and Robert Richardson, along with then-graduate student Douglas Osheroff, first observed superfluid helium-3. For that breakthrough, the catalyst for further research into low-temperature physics, the trio was awarded the 1996 Nobel Prize in physics.

Twenty years later, another Cornell-led team — working in that same building — has made an important discovery regarding the superconductor strontium ruthenate (Sr_2RuO_4 , or SRO), often described as a crystalline analog of superfluid helium-3. What ties them together is the

unusual way the electrons are paired together in SRO, and how the helium atoms are paired in the superfluid. That quality makes SRO intriguing for possible applications in quantum computation.

A team led by Kyle Shen, associate professor of physics, and Darrell Schlom, the Herbert Fisk Johnson Professor of Industrial Chemistry, both members of the Kavli Institute for Nanoscale Science at Cornell, has shown the ability to alter the electrical properties of the unique material through the application of strain — stretching thin films of SRO on top of a single-crystal substrate.

Continued on page 14

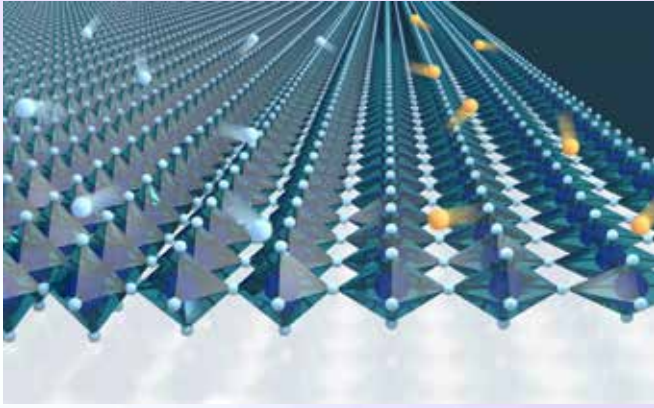


Figure 1: An artist's rendering of strontium ruthenate, a superconductor whose electrical properties can be altered by strain, or stretching, of the template on which the thin film of the material is placed. Bulat Burganov/Provided.

The group's paper, "Strain Control of Fermiology and Many-Body Interactions in Two-Dimensional Ruthenates," was published May 13 in *Physical Review Letters*. Collaborators included researchers from Stanford University, the University of St. Andrews, Scotland, and Max Planck institutes in Stuttgart and Dresden, Germany.

"You can pick different kinds of single crystals [of a substrate] where the atomic bond lengths are a little different, a little longer or shorter," Shen said. "And when you deposit the SRO film on these crystals, they take on that length that was set by the substrate. And when you change these bond lengths in the SRO film, you can really dramatically alter its properties."

The technique is used in silicon, to speed up the flow of current in a device. Shen and Schlom have published work on the use of "knobs" to tune, or control, material properties.

What the group was able to observe by photoemission spectroscopy and was able to graphically depict, was that the electrical charge carrier in the material switched from an electron (negative charge) to a hole (positive charge). An electron hole is the absence of an electron in a particular place in an atom.

"We had an idea that this might happen, but now you can really see it directly using photoemission," Shen said. "You pull on the material, stretch it out, and when you do that, these charge carriers convert from one sign to another. And actually when you measure the flow of electricity

in here, you find that, yes, one acts as if the charge carriers are electrons, and the other acts as if the charge carriers are holes."

The challenge with superconducting is temperature. The record for high-temperature superconductivity is -94 degrees Fahrenheit; most superconductors work best at near absolute zero (0°K, or -459.67 degrees). The transition temperature for SRO — the temperature at which it's a superconductor — is around 1.5°K.

There are still many challenges to overcome, but Shen is encouraged.

"It's kind of a proof of principle, that we can see this change of the electrical behavior," he said. "The next step is to boost up the superconducting transition temperature to a much higher temperature than 1.5°K, which would be amazing."

Contributors to this work included current and former physics graduate students Bulat Burganov, John Harter and Daniel Shai; former postdoctoral researcher Carolina Adamo, Department of Materials Science and Engineering (now at Stanford); graduate student Andrew Mulder, School of Applied and Engineering Physics; former physics postdoctoral researchers Masaki Uchida and Phil King; and associate professor Craig Fennie, School of Applied and Engineering Physics.

This research was supported by grants from the Air Force Office of Scientific Research and the National Science Foundation, which supports the Cornell Center for Materials Research. Part of the work was done at the Cornell NanoScale Science and Technology Facility, which is also supported by the NSF.



CNF Picnic, by Rebecca Vilet

A Miniaturized Sensor That Can Measure Chemistry On A Chip

By Bill Steele
August 16, 2016
Cornell Chronicle

By combining expertise in photonics — manipulating light beams in nanoscale waveguides on a chip — and materials science, Cornell researchers have laid the groundwork for a chemical sensor on a chip that could be used in small portable devices to analyze samples in a lab, monitor air and water quality in the field and perhaps even detect explosives.

The researchers use a phenomenon called “Raman scattering” — when a laser strikes a molecule it kicks back the laser energy as photons of light at a variety of wavelengths that depend on the structure and composition of the molecule.

To allow this phenomenon to occur on a chip, researchers fire a laser into a waveguide — a strip of transparent material made of titanium dioxide, where the light bounces off the inside surfaces and becomes confined to the waveguide. Because a waveguide is only a few nanometers high, the light waves spread out beyond the waveguide, creating a so-called “evanescent field” above the surface of the chip.

The pumping laser can induce Raman scattering in the space above the chip, or in a drop of liquid placed on its surface for analysis, while still confining the light wave to the chip. Light kicked back by the excited molecules also follows the waveguide; a prism at the end of the wave-

guide can spread that light into a spectrum that is a “fingerprint” identifying the molecule that produced it.

“If you need a chemical sensor in the lab, that is not a problem,” said Jin Suntivich, assistant professor of materials science and engineering. “But when you are outside, finding a chemical sensor that you can take with you is a challenge. We want to develop a technology that is small enough for a phone, such that your personal electronics can constantly monitor the world around you, and the moment you see something out of the ordinary, the sensor can tell you what it is.”

Sensors based on Raman scattering have been made before, using silicon nitride waveguides. The Cornell researchers have come up with a design that could make a sensor more sensitive and small enough to be used in the field by using a new material, titanium dioxide.

“We’re not the first but we’re the best,” said Christopher Evans, a Kavli Postdoctoral Fellow in the Laboratory of Atomic and Solid State Physics and the Kavli Institute at Cornell for Nanoscale Science. Evans is first author of paper describing the new approach published in the July 14 online edition of the American Chemical Society journal *ACS Photonics*. Co-authors are Suntivich and Chengyu Liu, a doctoral student in the School of Applied and Engineering Physics.

Titanium dioxide has a much higher refractive index, making a greater contrast with the space above the chip, which creates a stronger evanescent field. The material is also transparent to light at visible wavelengths, a condition that allows researchers to use a laser at shorter, visible wavelengths, which induce better scattering. The researchers tested with a green laser pointer as a light source.

For a future device, a tiny laser unit can be built into a chip, as can a component that can spread out the wavelengths of the kicked off light onto a photosensitive device to read the spectrum. One possibility is to read the spectrum with the camera in a phone.

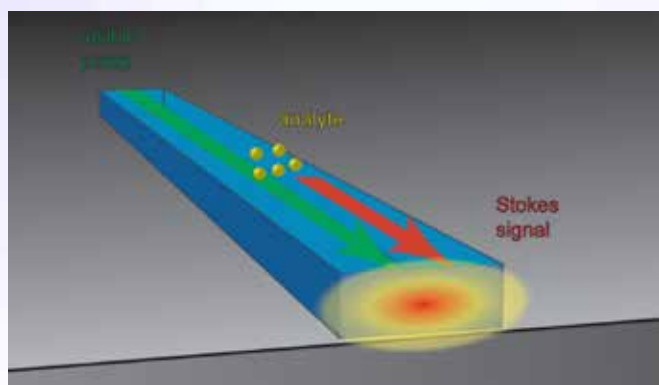


Figure 1: Light traveling through a nanoscale waveguide on a chip spreads beyond the waveguide and can interact with molecules above the surface of the chip. Provided.

Continued on page 16

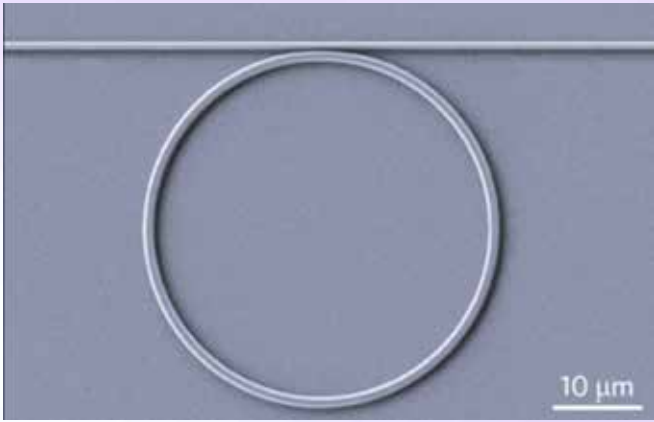


Figure 2: A circular waveguide tangent to a straight guide causes light to circulate around and around, giving it more time to interact with material above the chip. The ring is about the diameter of a human hair. Provided.

Interaction of the pumping laser with the material above the chip increases with the length of the waveguide. But the researchers also offer a way to increase the interaction without having to make the chip larger. The solution is a “ring resonator.” When a circular waveguide is set tangent to a straight guide, some of the light will enter the

ring and continue to circle around it, letting the light interact continually with the material above the chip many times.

The circumference of the ring can be adjusted to resonate with the wavelength of the light, intensifying the effect. “We have shown that we can increase the amount of peak signal from our sensors by an order of magnitude (or more), while simultaneously reducing the device footprint down to the cross-section of a human hair,” Evans said.

Potential applications include portable sensors to monitor air and water quality or conduct laboratory tests in the field. Chemists could and observe chemical reactions while they occur.

The work was supported in part by the Cornell Center for Materials Research and used the Cornell NanoScale Facility, both funded by the National Science Foundation. Additional support was provided by the Samsung Advanced Institute of Technology and the Kavli Institute at Cornell for Nanoscale Science.

StartUp CNF

CNF loves to help launch new companies and create high tech jobs! We know that the costs associated with moving your processing work to a new fab can be a barrier.

As an incentive for US-based small businesses (<10 employees) — including Small Business Innovation Research (SBIR) Awardees — to explore the use of the Cornell NanoScale Facility, **StartUP CNF** provides up to \$3,000 of (1:1) matching funds that can be applied towards the first use of the CNF Shared Facility*.

If you want to know more, get in touch!

http://www.cnf.cornell.edu/cnf_foundry_partners.html

**This program is made possible through a grant from the Empire State Development Division of Science, Technology and Innovation.*

StartUp CNF Application 2016

As an incentive for US-based small businesses (<10 employees) including Small Business Innovation Research (SBIR) Awardees to explore the use of the Cornell NanoScale Facility (CNF), StartUP CNF provides up to \$3000 of matching funds that can be applied towards the first use of the CNF Shared Facility. This program is made possible through a grant from the Empire State Development Division of Science, Technology and Innovation.

Terms and Conditions:

- This is a limited offer of one matching credit per company for the first use of the Cornell NanoScale Facility. Subsequent years and projects are not eligible for further programmatic funding.
- The credit will match 1:1 the company contribution up to \$3000 and can be used to offset the cost of equipment lease or housing when company employees or customers begin working on their project.
- The credit must be used during a three-month period commencing with first use.
- Offer valid from January 1, 2016 through December 31, 2016. CNF will offer up to five company awards per calendar year, contingent upon funding availability.

Application Process:

- ✓ Prior to the first facility use, contact a CNF facility staff member to discuss your needs: http://www.cnf.cornell.edu/cnf_foundry_partners.html
- ✓ Prepare an estimated budget for the proposed work.
- ✓ Complete the Project Proposal and New User Application.
- ✓ Submit completed application and a copy of the written estimate.

US-based Company name: _____
 Company Address: _____
 Number of employees in your company: _____
 Their name(s): _____

I, _____, work to apply for the StartUp CNF program and agree to the terms and conditions above.
 Signed: _____

(Authorized Company Representative)

Name: _____ Title: _____ Date: _____

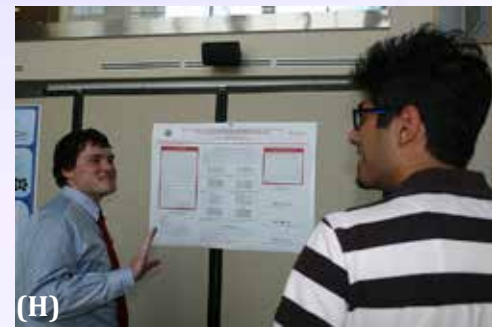
If you require assistance contact:
 Don Tauson, Director of Operations, tauson@cnf.cornell.edu
 Mike Sivak, User Program Manager, mksivak@cnf.cornell.edu
 Chris Alpha, User Program Manager, alpha@cnf.cornell.edu
 Office Use Only:
 Project Number: _____
 User GUIDs: _____

2016 CNF & PARADIM REU PROGRAMS

This year's Cornell NanoScale Science & Technology Facility Research Experience for Undergraduates (CNF REU) Program was unusual for two reasons. For the first time since 1996, the CNF was not part of a network program, and yet, just in time to join the fun, NSF created the Platform for the Accelerated Realization, Analysis, and Discovery of Interface Materials (PARADIM) at Cornell — and PARADIM joined us in our summer REU program planning! CNF hired five REU interns and PARADIM hired four. We shared schedules, many presentations, and many more meals. We even shared one intern when Betty Hu, PARADIM REU, became a CNF User!

On this page are photographs of the REUs who used the CNF cleanroom (taken by Don Tennant), and the three PARADIM REUs who did not, but did participate in the joint 2016 CNF & PARADIM REU Nano-Convocation (taken by Sam Wright) — held Thursday, August 11th. The intern presentations are online at http://www.cnf.cornell.edu/cnf5_reuprogram.html. Watch any time and see for yourself how our first shared PARADIM and CNF summer program REU researchers fared.

Also, check our website for information on the 2017 CNF & PARADIM REU Programs!



- Mr. Ryan Branch (CNF REU, A)
- Ms. Wagma Caravan (CNF REU, B)
- Ms. Ana Sofia de Olazarra (CNF REU, C)
- Ms. Betty Hu (PARADIM REU, D)
- Mr. Mark Marsalis (PARADIM REU, E)
- Ms. Maya Martirosyan (CNF REU, F)
- Mr. Arthur McCray (PARADIM REU, G)
- Mr. Cameron Ruhl (PARADIM REU, H)
- Ms. Allison Smith (CNF REU, I)

CNF Receives Additional NSF Award to Develop Globally Aware Scientists

Dr. Lynn Rathbun

Scientists and engineers, whether in industry or academia, must be able to operate effectively in a multicultural environment. Communication is about much more than language. While science itself is universal, the methods by which scientists communicate, collaborate, make joint decisions, and set priorities are not. Cultural norms such as “power” of seniority, gender roles, and individualism vs. the collective can affect how science is done on a daily basis. Unfortunately, most United States science and engineering students complete undergraduate and graduate education without benefitting from direct exposure to a “foreign” engineering environment.



*A few of the very first 2008 iREU Program Interns in Japan!
Photographs provided by 2008 iREU intern, Courtney Bergstein.*

To help bridge this gap, CNF has conducted an international research (iREU) program since 2008 for a select group of undergraduates. With this program, conducted for NNIN, we chose the best of our REU students and sent them for a second summer, more advanced research experience, in an international laboratory. Over the years, this program has been conducted in conjunction with our international partners

at: the National Institute for Materials Science (NIMS), Tsukuba, Ibaraki, Japan; Interuniversity Microelectronics Center (imec), Leuven, Belgium; Delft University of Technology (TU Delft), Netherlands; Institut Für Bio- Und Nanosysteme (IBN), Forschungszentrum, Jülich, Germany; and Centre Microélectronique de Provence, Ecole Nationale Supérieure des Mines de Saint Etienne, France.

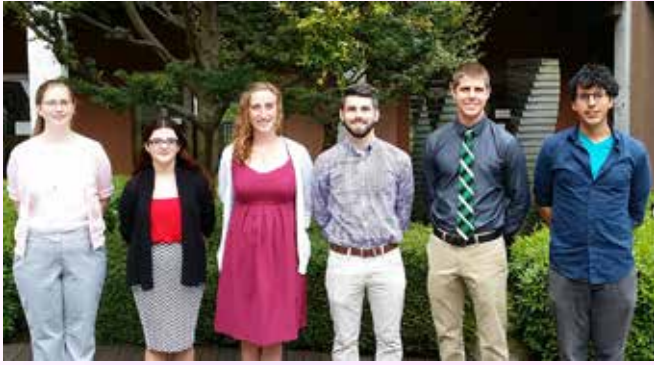
One hundred fifteen students have participated in this program in the last nine years. It has been highly successful with both the participants and our foreign partners well pleased with the program.

With the end of NNIN, this excellent program was in jeopardy. In order to assure that it would continue, Dr. Lynn Rathbun, CNF Laboratory Manager, wrote a proposal to the National Science Foundation under the International Research for Students (IRES) solicitation to continue our interaction with NIMS Japan. IRES had previously supported part of our iREU effort.

In March 2016, we were notified that that this proposal would be fully funded at the maximum amount, sufficient to support 5-6 students for three summers. Although it was late, we quickly solicited applications and assembled a cadre of six excellent students from across the country, all participants in the 2015 NNIN REU program.

Dr. Rathbun accompanied the students to Japan on May 31 and they have just completed their 10 week research experience, working on projects ranging from biomedical applications of nanotechnology to electronic materials. We are pleased to be able to continue this program and are grateful for support from the NSF International Division. As we have the established infrastructure and a good supply of excellent students, we are looking for opportunities (i.e., funding) expand from our currently funded six students, by sending additional students to Japan or by reestablishing our interactions in Europe.

Dr. Rathbun would welcome the opportunity to talk with companies who have an interest in development of globally aware scientists and engineers about supporting this stellar program.



The 2016 iREU Interns in Japan, left to right; Caroline Zellhofer, Abigail Magee, Emilie Benson, Michael Statt, Joshua Alden, and Raul Flores. Photo provided by Rathbun.



These three photos were provided by Emilie Benson!



Hey Lynn!

Great to hear the Japan program is back on its feet, even if the local REU needs some help. Like I've said before, NNIN was huge for me, especially that international experience.

As for me, I participated in one final REU, this one at MIT as part of their MIT Summer Research Program, in which I worked with Dr. Roger Kamm.

I will now graduate Magna Cum Laude with a BS in Mechanical Engineering from University of Puerto Rico-Mayaguez, and will start a Ph.D. in Mechanical Engineering in the Fall at the University of California-Berkeley in Dr. Grace O'Connell's lab. I was also awarded the NSF GRFP Fellowship, which will fund me for most of my graduate studies. I was also awarded the College of Engineering Fellowship at UC Berkeley for a year.

I am attaching a nice picture of me and a picture of me at an outreach activity for high school students that my lab participated in.

Best of luck! Gabriel

17 May 2016

Gabriel R. López Marcial
Mechanical Engineering
University of Puerto Rico at Mayaguez



2015 CNF Whetten Memorial Award Winner: Kathryn L. McGill

Kathryn's love of physics emerged in high school, the inevitable outgrowth of her childhood passion for math and general curiosity about the workings of the physical world.

Though Kathryn discovered that she wanted to be a physics major her junior year of high school, it took her until the end of her bachelor's degree at the University of California, Santa Barbara to choose one of physics' many sub-disciplines as a focus for graduate school research.

Her first foray into physics research took place within the astrophysics world. (Astrophysics was, in fact, what she thought she might want to pursue in grad school.) Through publishing her first paper under the guidance of Prof. Tommaso Treu, she discovered that she really liked learning about what *other* people discovered in astrophysics research, but wasn't as interested in doing the discovering *herself*. (Too much desk work.)



Figure 1: Kathryn L. McGill experimenting with selfies in the CNF cleanroom.

This realization led Kathryn to explore a number of lab-focused research opportunities throughout the rest of her undergraduate degree. Among these various experiences, Kathryn spent a summer in the United Kingdom working at the Oxford University Department of Materials for Dr. Andrew Watt. Kathryn got a great taste of the ups and downs of graduate-level research while studying polymer photovoltaic cells, and the experience confirmed her suspicion that she wanted to pursue some kind of experimental physics research in grad school.

The Cornell Department of Physics “just felt right” when Kathryn visited to learn more about its graduate program, and she has never regretted her decision to pursue her PhD here. Ironically enough, Kathryn's dream at the beginning of her education to explore the enormity of the universe morphed into an intense interest in the micro- and nanoscopically small by the time she started her Ph.D. with Prof. Paul McEuen. The McEuen Group is interested in “anything, as long as it's small”, making the Cornell NanoScale Science & Technology Facility (CNF) the group's second home on campus. (See Figure 1.)

In addition to extensively fabricating devices in the CNF for her research, Kathryn was also fortunate to intern with members of the CNF staff as a CNF Fellow, learning about the developing technique of nanoimprinting.

Kathryn's research focuses on two-dimensional materials. Her first full project in the lab, under the guidance of now-Prof. Kin Fai Mak, a postdoc at the time, explored the unusual properties of a single, three-atom-thick layer of molybdenum disulfide (MoS_2).

As visualized in Figure 2, circularly polarized light (of the proper wavelength) incident on a MoS_2 device reveals a third “valley” degree of freedom for the electron, in addition to charge and spin. Kathryn gained valuable insight into the scientific process by assisting Dr. Mak in the

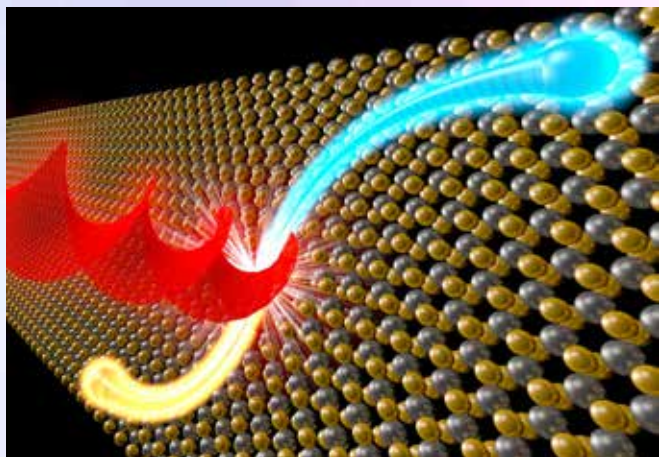


Figure 2: The valley Hall effect in MoS_2 : Atoms of molybdenum (gray) and sulfur (yellow) are shown in a two-dimensional crystal formation. A circularly polarized laser beam hits the surface, causing a valley current carried by an electron-hole pair to move through the crystal.

successful demonstration, measurement, and publication of the valley Hall effect in MoS₂ transistors (Mak, et al., Science 344, 2014). Ultimately, however, Kathryn jumped ship to (the similarly two-dimensional) graphene, and she joined other group members in studying the paper-like possibilities of manipulating graphene freely in three dimensions.

More recently, Kathryn has been combining this novel mechanical method for manipulating graphene with its ability to conduct electricity. Working with an eye towards developing flexible electrical sensors for biological systems, Kathryn has enjoyed contemplating the interdisciplinary possibilities of this project.

Figure 3 shows the electrical characteristics of a sample graphene transistor patterned to reversibly stretch and retract.

In addition to her research, Kathryn maintains a side interest in science communication. Her past projects include creating and hosting The Physics Factor YouTube channel, participating in a science communication workshop known as ComSciCon, answering student questions for Sigma Pi Sigma's Adopt-a-Physicist program, and blogging for the Kavli Foundation's Curious Stardust website.

Nellie Whetten, in her "commitment to scientific excellence, interdisciplinary collaboration, professional and personal courtesy and exuberance for life," left the sort of personal and professional legacy to which Kathryn aspires. Kathryn was overwhelmingly surprised upon learning that she was chosen for the award, and she thanks

her advisor, Prof. Paul McEuen, her research group, the CNF staff, and her family for their guidance and support throughout her graduate studies thus far.

Kathryn obtained her Master's degree in 2014 and is currently working on her Ph.D. thesis research.

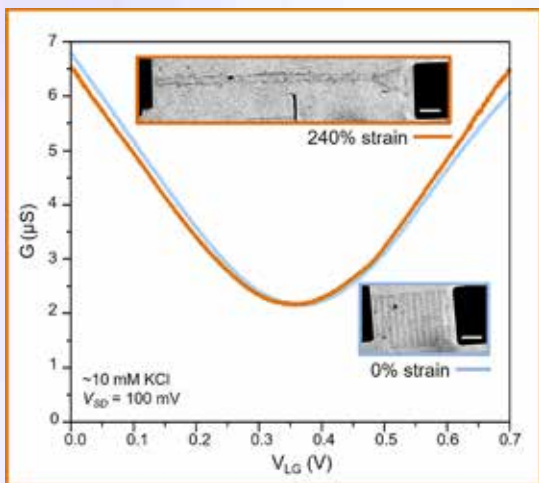


Figure 3: Electrical properties of a graphene transistor spring: The electrical conductance G is plotted against the liquid-gate voltage V_{LG} at a bias V_{SD} of 100 mV for the graphene in a ~ 10 mM KCl solution in its initial, unstretched state (blue) and after it is stretched by $\sim 240\%$ (orange). Scale bars 10 μm . (Blees, et al., Nature 524, 2015)



Photograph provided by Tim Whetten

Nellie Yeh-Poh Lin Whetten; CNF Memorial Award

This award is given in fond memory of Nellie Whetten (pictured above) — a CNF staff member from 1984 to 1987 who died March 24, 1989. This award recognizes outstanding young women in science and engineering whose research was conducted in the CNF, and whose work and professional lives exemplify Nellie's commitment to scientific excellence, interdisciplinary collaboration, professional and personal courtesy and exuberance for life.

In the words of her husband, Dr. Timothy Whetten,

- "The award should remind us to find out what it is like for people different from us to live and work in the same community. For men, to try to appreciate what it is like to be a woman scientist. For Caucasians, to try to feel what it is to be Asian or Black. For members of racial minorities and women, to try to understand what it is like to be a white male. And finally, the award should stimulate each of us to reach out and encourage women scientists who, like Nellie have the brilliance, stubbornness, and cheerfulness to succeed."

http://www.cnf.cornell.edu/cnf_whetten.html
lists all the CNF Whetten
Memorial Award Winners

CNF Ambassador Outreach Program Starts Strong

Part of the CNF's duties is to share nanoscale science with the general public. Our outreach programs reached over 2,700 people in 2015. We especially look forward to sharing science and technology with the younger crowd from middle and high schools.



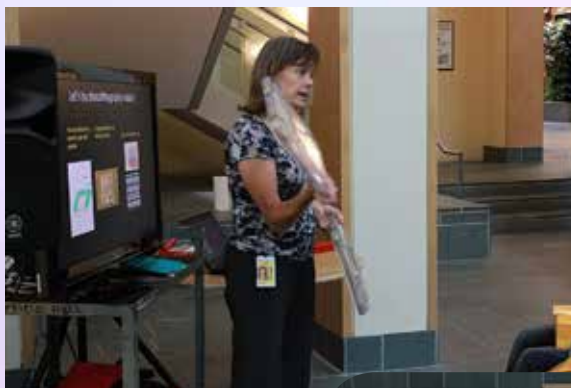
To help with this undertaking, we invited users with an inclination for outreach to join our CNF Ambassador Outreach Program. There was strong interest, and we inducted 12 CNF users. We promptly put them to work interacting with youth in outreach events.

We started in April at the NanoDays event at the ScienCenter. Over 100 families stopped by to see Lynn Rathbun's hamburger batteries and to make molecular models or ultraviolet bead bracelets. We also hosted the entire 6th grade from Dewitt Middle School. This large event spanned two days, and it was a success due to the help of many Ambassadors. They demonstrated what can be seen through light microscopes and electron microscopes.

Another large event was the annual 4H Career Explorations event in July with over 75 middle school-aged 4Her's. The Ambassadors

helped with a photolithography and circuitry lab which included a new interactive video tour of the clean room. It allowed students who were too young to enter the clean room to see how chips are patterned and developed in the clean room. The groups also had a chance to join staffer, Tom Pennell, in singing Sponge Bob Square Pants while waiting for their chips to expose. What a treat!

We are looking for more CNF users with an interest in outreach. we will send out a call for more Ambassadors in the Fall. It looks great on your CV and it is fun. Contact Beth Rhoades or Melanie-Claire Mallison for information on how to get involved.



Every year, the Center for Excellence in Youth Education (CEYE) at the Icahn School of Medicine at Mount Sinai offers an "Introduction to Nanotechnology Course" for underrepresented minorities and economically disadvantaged NYC high school students. This course is designed to introduce students to the world of nanotechnology and its biomedical applications. It takes the form of four one-week units: Nanoscale, Nanotools, Nanotechnology in Nature, and Nanotechnology in Medicine. Each week, students listen to a guest lecturer / demo on the given unit in addition to a field component.

The Cornell NanoScale Facility is pleased to be a field component for this amazing course and on Thursday, July 21st, 16 high school students attended the annual trip to Cornell for a successful day in our nano-world!

Photographs used with permission of CEYE participants.





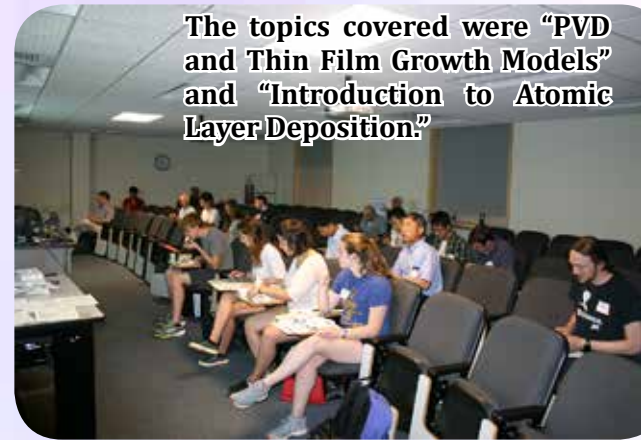
On Tuesday March 1, 2016, the students in the New Visions Engineering program at OAOC, Otsego Area Occupational Center, and NCOC, Northern Catskills Occupational Center, visited Cornell University. While on campus, the students were taken on multiple tours in some of Cornell's most impressive engineering facilities, as well as through the facilities of their engineering teams. The tours brought students face-to-face with CHESS (Cornell High Energy Synchrotron Source), the ASL (Autonomous Systems Lab), SKYNET, the VIOLET Satellite team, the Formula SAE and Baja team project area, and CNF (Cornell NanoScale Facility). Students were also able to interact directly with the students of the Mars Rover team, where they were able to ask questions and see the Rover in action. The tours provided a comprehensive inside look at the opportunities at Cornell.

High Energy Synchrotron Source), the ASL (Autonomous Systems Lab), SKYNET, the VIOLET Satellite team, the Formula SAE and Baja team project area, and CNF (Cornell NanoScale Facility). Students were also able to interact directly with the students of the Mars Rover team, where they were able to ask questions and see the Rover in action. The tours provided a comprehensive inside look at the opportunities at Cornell.



On July 6th, J.R. Gaines, Jr., Technical Director of Education at the Kurt J. Lesker Company, offered a "Lesker University" workshop at Cornell University, most especially for our summer interns, but the Cornell / CNF community was invited and forty people joined in.

The topics covered were "PVD and Thin Film Growth Models" and "Introduction to Atomic Layer Deposition."



Scenes from a Cornell Center for Materials Research (CCMR) / CNF Outreach Ambassador Event!





Robert Buhrman (RSCH) and Provost Michael Kotlikoff tour CNF. Credit: Robert Barker (MKTG), University Photography.



Hi Melanie-Claire, I graduated last August with a background in Experimental Condensed Matter Physics, and I was able to switch fields and land a job as a Data Scientist at an advertising technology (ad tech) company called OpenX, which is in Pasadena, CA. I have been working there since January, and so far, I have been enjoying it. Compared to academia, I like working on smaller projects and having a short feedback loop between research and implementation. In the software industry, it's much easier to quantify one's success. :-)

Also, we get pampered with things like free catered lunches from some of the best restaurants in LA, snacks, a game room, monthly company events, unlimited PTO, a nice benefits package... OpenX is a mid-size company with about 500 employees and has been around for about eight years. We process 10s of billions of digital advertising transactions per day, which is a massive amount of data to analyze. Our Data Science team is small, but everyone is incredibly smart and fun to work with.

-Isaac Storch

Provost Michael Kotlikoff tours the Cornell NanoScale Facility

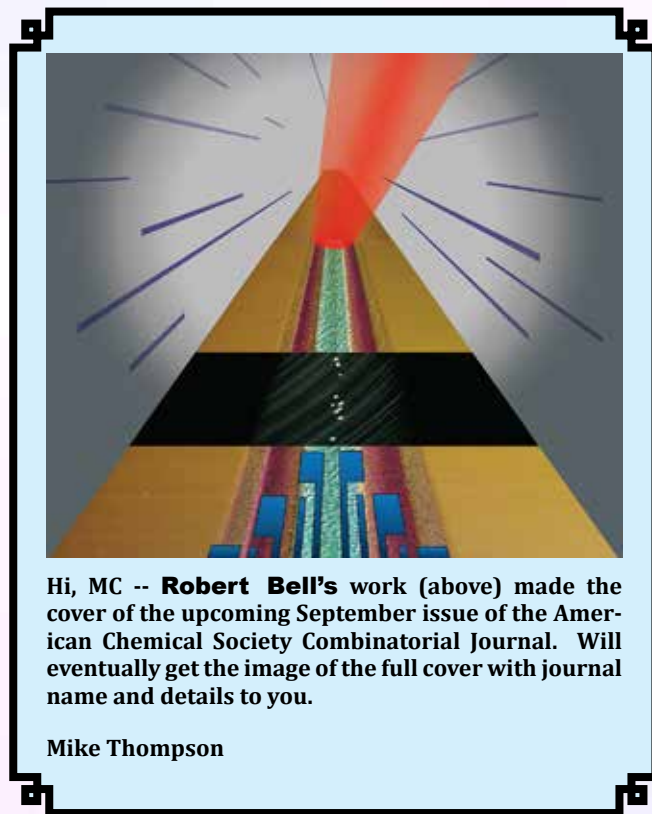
Michael I. Kotlikoff, professor of molecular physiology, became the 16th provost of Cornell University on August 1, 2015, and soon after, toured the Cornell NanoScale Facility (CNF) along with Robert Buhrman, Senior Vice Provost for Research. A member of the Cornell faculty since 2000, Kotlikoff most recently served as the Austin O. Hooey Dean of Veterinary Medicine. The Kotlikoff research laboratory, which has been continuously funded by the NIH for over 30 years, is internationally recognized in the area of cardiovascular biology. As provost, Kotlikoff continues to maintain his laboratory. Cornell Research, <https://research.cornell.edu/>



Corinne E. Isaac (Graduate Student, Marohn Group, Department of Chemistry and Chemical Biology; CNF Project # 2125-12) was awarded a prestigious Summer Fellowship from the Analytical Division of the American Chemical Society.



Philip Gordon, Electrical & Computer Engineering, defended his thesis in May, and has taken a position as Project Engineer at Diversified Technologies Inc. (Philip was a CNF User with Edwin Kan, working on "Microelectrodes for Chip-to-Chip Microfluidic Integration.")



Hi, MC -- **Robert Bell's** work (above) made the cover of the upcoming September issue of the American Chemical Society Combinatorial Journal. Will eventually get the image of the full cover with journal name and details to you.

Mike Thompson



Minglin Ma, assistant professor of biological and environmental engineering, was recently named a Young Innovator Award winner by the journal Cellular and Molecular Bioengineering. Ma was one of 10 researchers from across the country to receive the honor.

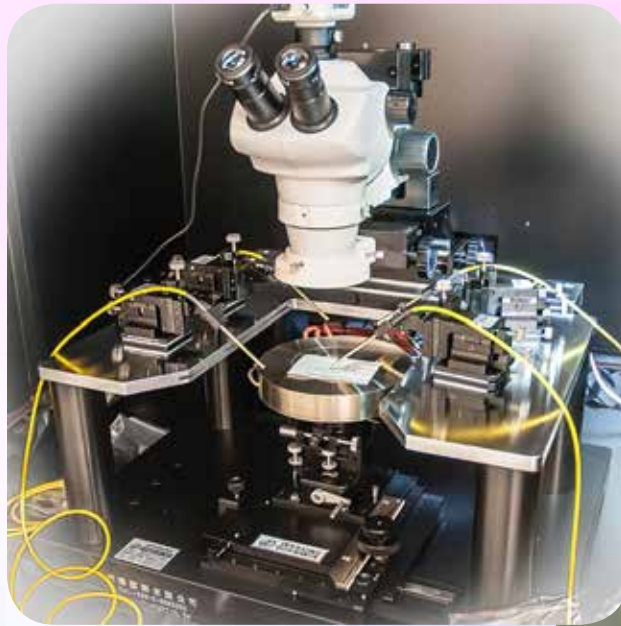
New Probe Station Donation from Everbeing International

CNF has received a donation of a probe station from Everbeing International (<http://www.probestation.tw/>), a Taiwan based manufacturer of probing equipment. Everbeing is a leading supplier of probe stations in the world market. They have, however, had a more limited presence in the USA.

In January, CNF was contacted by Everbeing to explore the possibility of their donating a new probe station to Cornell. They were attracted by the large user base at CNF and the quality of its supporting instruments and staff. This was opportune for CNF as our existing probe station equipment was well aged.

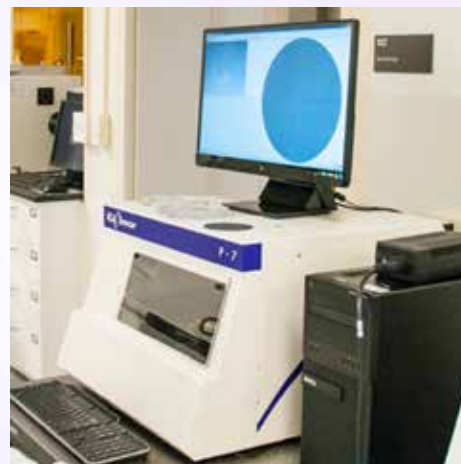
After some discussion and evaluation, we were pleased to accept the donation of a 150 mm manual probe station, high precision probe manipulators, an air table, and a dark box, as well as a separate manual 4-point probe. This donation was recently installed and we look forward to it serving the CNF community for many years to come. Contact Phil Infante for training.

Thank you, Everbeing International!



CNF Installs New KLA-Tencor P-7 Stylus Profilometer

Stylus profilometers are one of those work horse instruments that you don't think about except when they don't work. CNF has relied on two P-10 Tencor (KLA) profilometers for about 20 years, well past their productive life. In June, we purchased a new P-7 profilometer from KLA-Tencor, much to the delight of CNF staff and users. It was installed at the beginning of August and is being made available to the users community immediately. Contact Jerry Drumheller for training!



New Micromolding Capabilities with SU-8-Based Materials are Available

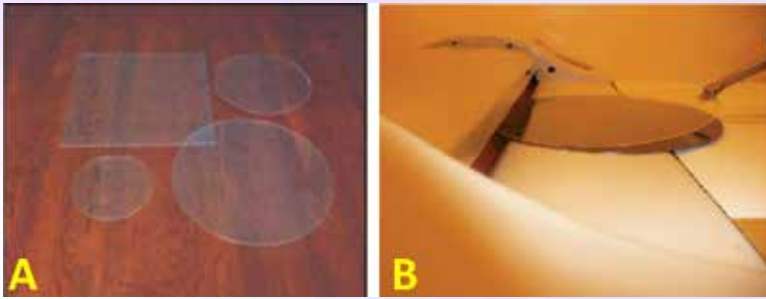


Figure 1: SUEX photosensitive SU-8 hybrid resin from DJ DevCorp. A) Pre-cast, dried sheets of SUEX are sandwiched between PET backings for easy handling. Sheets are cut for different wafers or glass slides. B) After removing the lower backing, a sheet of SUEX is adhered to a 4-inch wafer by passing through an office laminator at 65-75 °C. The process takes less than three minutes, and the wafer is ready to be exposed.

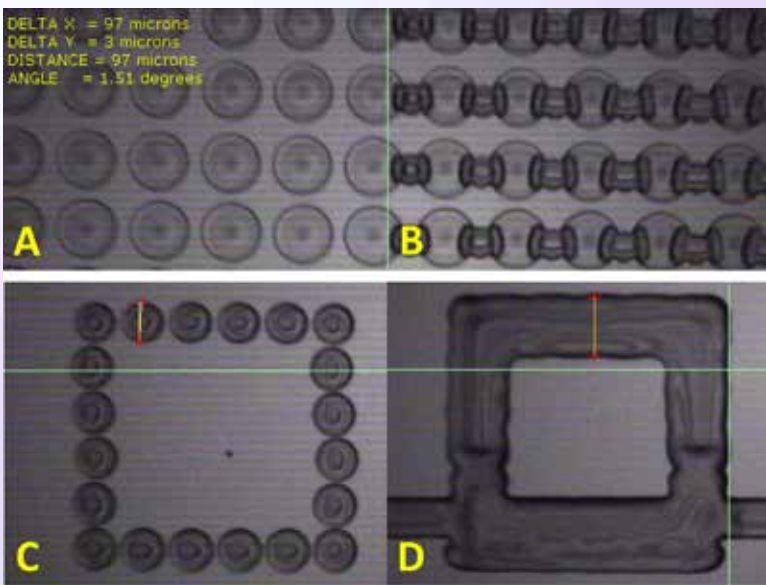


Figure 2: Jettable XP PreELEX® SU-8 1.0 on bare silicon. A) First layer of 80 µm-diameter drops spaced at 100 µm. B) Second layer of connecting drops registered and printed atop the first layer. C) 70 µm drops printed at 90 µm drop spacing for discrete drops. D) Two layers of 70 µm drops printed at 50 µm drop spacing for complete coverage.

Casting silicone (PDMS) over SU-8 master molds is a standard method for creating microfluidic devices. There are several challenges for creating thick layers or rounded features. We have added new materials to address these challenges. To overcome issues with the uniformity of layers over 100 microns thick, we stock pre-cast, pre-cut sheets of SUEX, a SU-8/photoresin hybrid from DJ DevCorp. The sheets are available in 100-, 200- and 500-µm thicknesses that can be used alone or combined to make multi-step devices or even thicker layers on 4-inch wafers. Other thicknesses and shapes are available from the company. The sheets are laminated onto a substrate with an optional 20-minute pre-bake, a fraction of the time spent on the thick SU-8 2000 series. The completed devices can be used as PDMS molds or as the actual device. Patterned SUEX can be sandwiched between two layers of acrylic, for instance, for a microfluidic device or quick prototype.

Creating rounded channels for creating collapsible PDMS valves or patterning SU-8 on flexible substrates are other challenges. We now stock ink-jettable XP Pre-Elex® SU-8 1.0 from MicroChem that print on our FUJIFILM Dimatix DMP printer. The material can be used for maskless lithography, rapid prototyping or non-contact printing in single or multiple layers.

The drop volumes are 10-pL, and drops spread to 40 to 120 µm diameters on bare silicon depending on wettability of the substrate. The jettable SU-8 cures between 125°C to 175°C, or it can be exposed to UV and post-baked at a lower temperature for substrates that don't withstand high temperatures.

Contact Beth Rhoades for more information or training on these new SU-8-based materials!

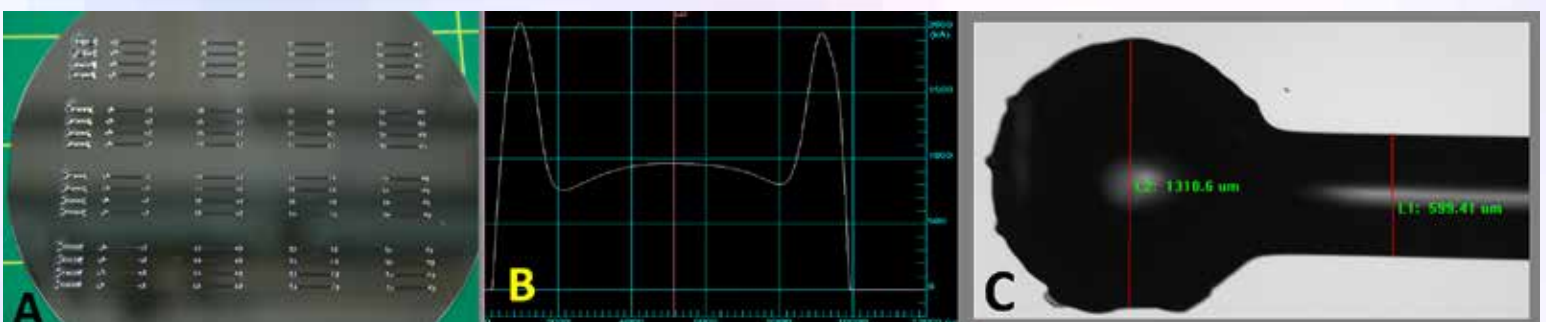


Figure 3: Channel molds printed from jettable XP PreELEX® SU-8 1.0 on bare silicon. A) Milliscale rounded channels (10 mm length) printed on bare silicon. B) Surface profile of a channel that was printed in 30-layers. Tallest features were 2 mm at the apex of the bells and 0.95 mm at the apex of the channel. C) Widths of the channel features were 1.31 mm for dumbbells and 0.6 mm for the channel.

Electron-Beam Evaporator Upgrades



Many hands touch the lab equipment in any academic, multi-user facility and there is no better example of this than the Cornell NanoScale Facility. We currently have over eight hundred active users and well over one hundred nanofabrication tools that range from our thirty-seven year old CHA thermal evaporator to our brand new KLA-Tencor P-7 profilometer. As a staff member, I can assure you that we pride ourselves in maintaining this equipment for our diverse user population, but, as any used car enthusiast will tell you, nothing lasts forever. Same goes with electronics — and as the problem reports start to pile up, we eventually have to decide to either replace or upgrade our equipment.

Case in point was with our electron-beam evaporators. Both systems still worked, but thirty-plus years of use (and abuse) had really taken a toll on the equipment. So two years ago, the CNF addressed the issue by replacing the power supplies and sweep controls for both electron beam evaporators.

The new Telemark TT-10 power supplies have proven to be robust and so far very reliable. Less power is now needed to evaporate platinum and other high temperature materials. When purchasing the power supplies, we decided to forgo the handheld joystick sweep controls and instead, spent a little more for programmable, digital systems. Honestly, I was against it at first, but it turned out to be a great idea.

The Telemark Cheetah sweep controllers give us the capability of creating a source specific sweep recipes library that we can fine tune over time. Even our novice users are now able to deposit thin films with reproducible thicknesses, steadier deposition rates and less spitting. We are also capable of having alternate recipes with

different sweep patterns. So far our users have found the spiral or circular sweep pattern to be better for nickel and other magnetic materials.

If you are interested in electron-beam evaporation or have any questions, please contact Aaron Windsor (ajw49@cornell.edu).



CNF Picnic, by Rebecca Vitet

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Please send your request via email to: information@cnf.cornell.edu.
You will also find the NanoMeter in PDF online at: <http://www.cnf.cornell.edu>