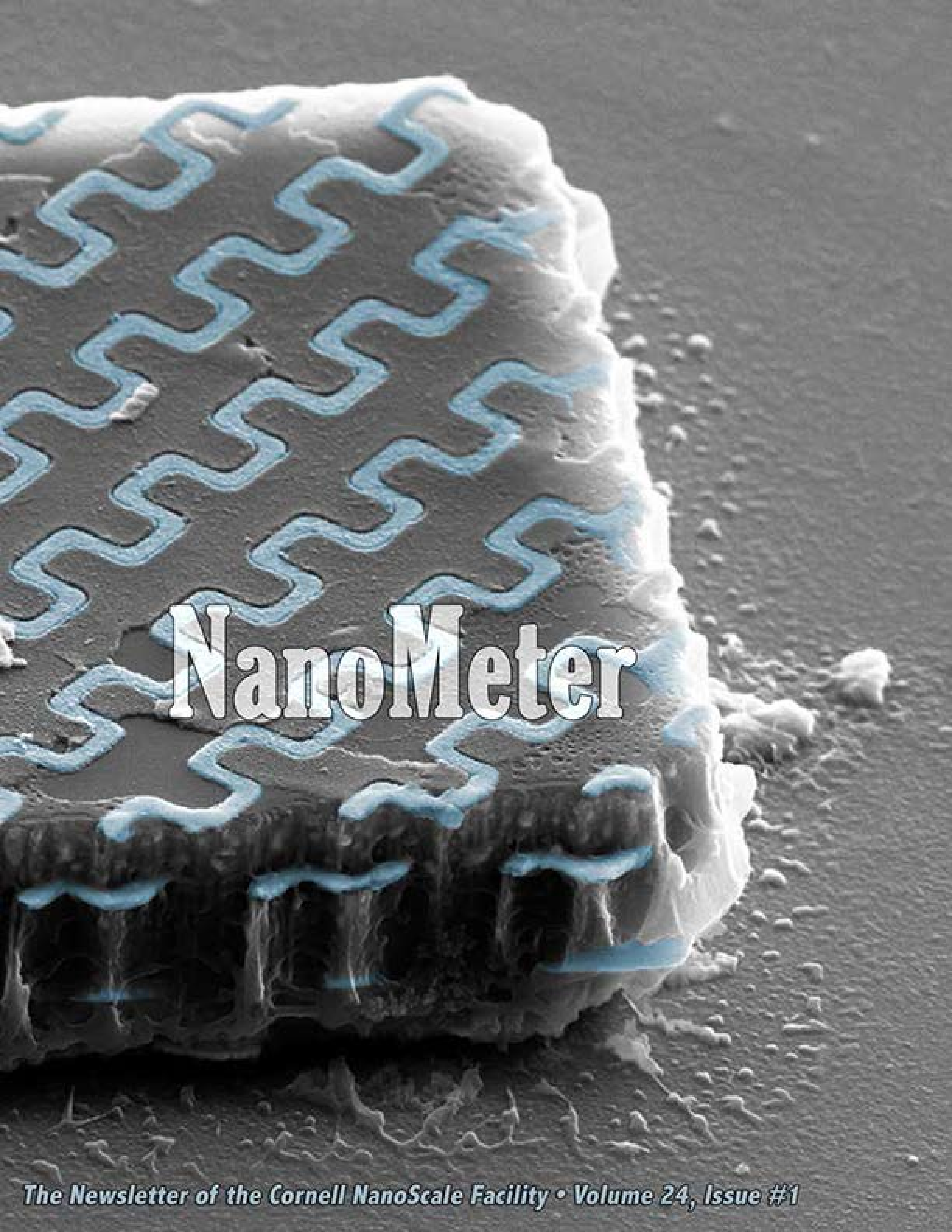


NanoMeter

The Newsletter of the Cornell NanoScale Facility • Volume 24, Issue #1

Table of Contents

Profiles

SAVE THE DATE!

The 2015 CNF Annual Meeting will be held on TUESDAY, SEPTEMBER 15th.

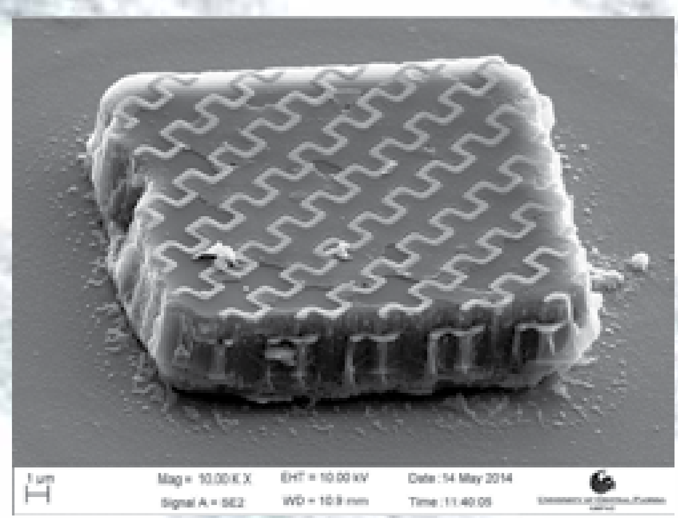
NOTE THAT THIS IS NOT OUR USUAL DAY!!

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

PHOTO & FORMAT CREDITS

Most photographs in this issue were provided by the author, researcher, or as noted. The annual meeting photographs were taken by University Photography and CNF Staff. The New Staff photographs were taken by Don Tennant.

The NanoMeter is formatted by Melanie-Claire Mallison. She welcomes your comments and corrections at mallison@cnf.cornell.edu



The NanoMeter cover image is from CNF Project 2252-13, Circular Polarizer Infrared Device (CPIR), Principal Investigators: David Shelton, James Ginn, CNF Users: Pedro Figueiredo, Andrew Warren, Christopher Long, Affiliation: Plasmonics, Inc., Website: http://www.plasmonics-inc.com/

See the full technical report in the 2013-2014 CNF Research Accomplishments, pages 164-165. http://www.cnf.cornell.edu/cnf_2014ra.html

CNF IN THE NEWS:

Defying Physics, Engineers Prove a Magnetic Field for Light

By Anne Ju
Cornell Chronicle
September 10, 2014

In electronics, changing the path of electrons and manipulating how they flow is as easy as applying a magnetic field.

Not so for light. "We don't have such a thing for light," said Michal Lipson, professor of electrical and computer engineering. "For the majority of materials, there is no such thing as something I can turn on, and apply this magic field to change the path of light."

Until now. Lipson, a leader in the emerging field of silicon photonics — sending light through waveguides instead of currents through wires — and colleagues have shown that an equivalent field for light does exist. Experiments led by graduate student Lawrence Tzuang, in collaboration with Paulo Nussenzveig of University of Sao Paulo and Kejie Fang and Shanhui Fan from Stanford University, are described in a recent issue of Nature Photonics.

This effective magnetic field has to do with the light's phase, which is a measure of a particular point in a light wave's cycle, quantified as an angle in degrees.

The researchers demonstrated the existence of this field with an experimental interferometer, a micron-scale device with two modulators that send light waves back and forth between them.

When a light wave travels under normal conditions, its phase is proportional to how far it traveled, but it is unaffected by what path it has taken. Just like a magnetic field causes a current to switch direction, the researchers showed that by modulating the light with their device, they could make the phase of the light change not only as a function of distance traveled, but also by the shape of its path.

An array of such modulators would be powerful enough to create a field for light that is equivalent to the magnetic field for electrons; phases of light could be controlled arbitrarily by each of the modulators. This means that the phase of transmitted light could depend on the path it has taken from point A to point B, Lipson explained.

"That puts us very close to what electrons do in a magnetic field; they experience exactly that in a magnetic field: The phase accumulated in their trajectory depends on the exact path they have taken," Lipson added.

Lipson and colleagues dream of controlling light at the smallest scales and in the most fundamental ways, using optics instead of wires on circuits to revolutionize electronics. Reaching this goal depends on the ability to propagate and control light in nontraditional ways, of which the Nature Photonics work is an example.

"One could in principle make fabrics of similar devices that would imprint phase and control the path of light in ways you couldn't conceive of before," Lipson said.

Supporters of the research include the National Science Foundation and the Kavli Institute at Cornell for Nanoscale Science. The interferometer was fabricated at the Cornell NanoScale Science and Technology Facility, also supported by the National Science Foundation.

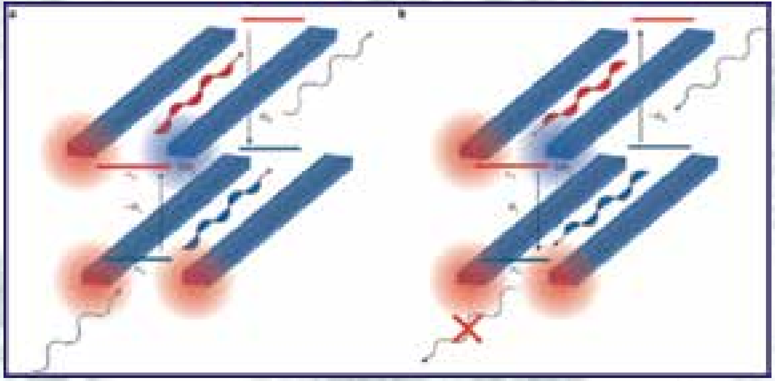


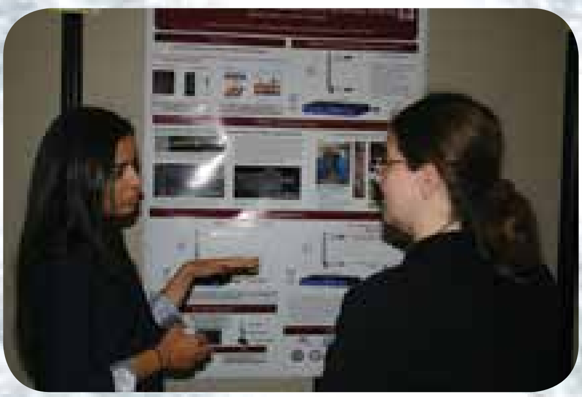
Figure 1: An illustration of the nonreciprocity of the dynamics of light propagating in the forward (a) and the backward (b) direction. Image provided by Tzuang.

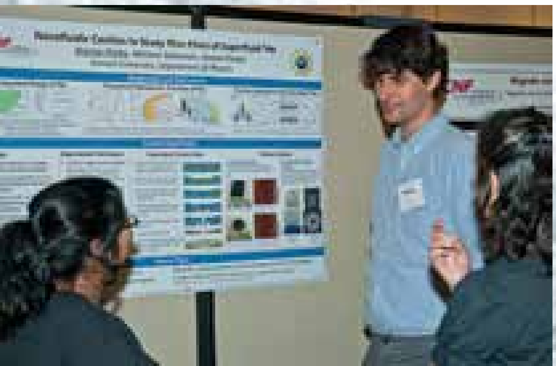


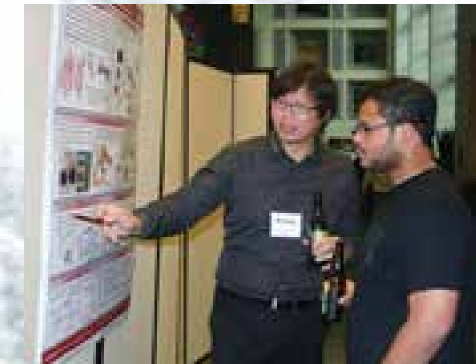
Scenes from the 2014 CNF Annual Meeting









We are grateful for sponsorships from the following corporations:

AJA International

Applied Materials

ASML

Corning Incorporated

Ebara Technlogies

GenISys

Heidelberg Instruments

Hitachi High Technologies America

JEOL USA, INC

Kurt J. Lesker Company

Leica Microsystems

Nanonex Corporation

Oxford Instruments

Plasma-Therm, LLC

Pozzetta, Inc.

Raith America, Inc.

ReynoldsTech Fabricators

RTS Technologies

SPTS Technologies

SUSS MicroTec

Tousimis Research Corporation

The CNF Student Awards were sponsored by:

Applied Materials
Corning Incorporated
Bob Scruton
Timothy Whetten

Best User Posters, top right:

Eugene Choi
Andrea Katz
Pamela Nasr

Best User Presenters, bottom right:

Arthur Barnard
Dakota O'Dell

Whetten Memorial Awards:, below

Andrea Katz
Nini Munoz

2014 CNF Whetten Memorial Award Winner:
Andrea Katz

Andrea Katz is a fourth year graduate student in Applied Physics at Cornell and, along with Nini Munoz, is one of the recipients of the 2014 CNF Nellie Yeh-Poh Lin Whetten Memorial Award.

Andrea received her bachelor's degree in Physics and Astronomy from Trinity University in 2011. While at Trinity, she researched carbon abundance in the Crab Nebula and engaged in public science outreach through star parties. A desire to work on something more hands-on and immediately relevant brought her to Cornell's School of Applied and Engineering Physics for her graduate studies.

She joined Lois Pollack's research group and began developing new methods for using small angle x-ray scattering (SAXS) on frozen solutions of biological molecules, such as proteins, RNA or DNA. Since the function of these biomolecules is related to their shape, structural studies are important. SAXS provides structural information about molecules in solution, and importantly can follow shape changes as the molecules function. However, its application is limited by radiation damage, which can cause aggregation or otherwise change the structure of the molecules on typical experimental timescales. Most SAXS experimenters avoid this problem by flowing large volumes (30 microliters) of sample through the x-ray beam to spread out the radiation dose, but this can be costly and make the study of rare molecules difficult.

A novel solution to the radiation damage problem is to perform SAXS experiments on frozen samples (cryoSAXS). CryoSAXS presents its own set of issues: the samples must be vitrified to avoid large disruptive scattering from crystalline ice, and the frozen samples must have a constant x-ray path length to allow for subtraction of the scatter from the buffer. At CNF, Andrea, along with her collaborator Jesse Hopkins, fabricated fixed path length sample holders for cryoSAXS to enable more straightforward data acquisition and analysis.

Silicon is an ideal material for these sample holders for several reasons. It is rigid, which prevents a change in path length upon freezing. It also has low x-ray absorption, and the availability of high aspect ratio fabrication techniques allows for the production of very x-ray windows which are thin enough to have high x-ray transmission, but tall enough for the beam to pass through without clipping the edges and generating extraneous scatter. A simple parallelogram design, etched into a silicon wafer with potassium hydroxide (KOH), produced the sample holders shown in Figure 1. The walls are 30 µm thick but over 600 µm tall, which is a sufficiently high aspect ratio to allow high transmission while accommodating the entire beam. The silicon sample holders have relatively small thermal mass, allowing rapid freezing of a drop of sample in a cold gas stream. Additionally, the sample holders require a sample volume of less than 0.8 microliters, representing a huge savings compared to standard SAXS experiments.

A big challenge in fabricating these sample holders is to obtain extremely smooth surfaces, which are necessary because x-ray scattering off rough interfaces can obscure the relatively weak scattering from biological molecules. Etching the wafer at 60°C in 45% w/w KOH solution inside an ultrasonic tank broke up bubbles and resulted in very smooth surfaces. The RMS roughness is 1.27 nm over 100 µm^2 as determined from AFM analysis. These surfaces produce very small amounts of parasitic x-ray scattering, comparable to that produced by sample holder materials used in standard SAXS experiments as shown in Figure 2.

These sample holders represent a step forward in cryo-SAXS data acquisition and analysis. Eventually, these sample holders could enable scientists without access to a synchrotron at their home institution to freeze their samples in the lab and mail them in for analysis. Additionally, the smaller required sample volumes could allow the study of rare or expensive molecules that were previously off limits for SAXS experiments.

Outside of research, Andrea enjoys teaching, science outreach, and playing traditional Irish fiddle music.

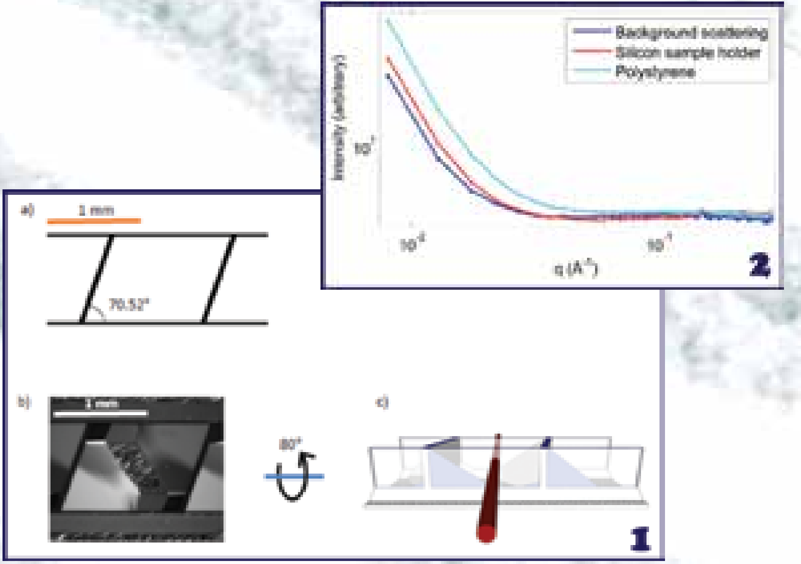


Figure 1: a) Sample holder etch mask. The horizontal lines are 30 µm thick and the slanted crossbars are 56 µm thick. This unit is tiled horizontally across a wafer to avoid the need for corner compensation. b) Top-down composite image of a sample holder. Additional features not defined in the etch mask are artefacts of the KOH etch. c) Cartoon sample holder, rotated 80° relative to the photo. The walls are semi-transparent to show the x-ray path (red cylinder).

Figure 2: Comparison of scattered intensity from different materials as a function of the momentum transfer q, which is related to the scattering angle. The scatter from a silicon sample holder is comparable to or smaller than that of a room temperature sample holder with two 25 µm thick polystyrene windows for all measured q.

2014 CNF Whetten Memorial Award Winner:
Nini Munoz

Nini Lucia Muñoz was a graduate student in the Electrical and Computer Engineering department at Cornell, and along with Andrea Katz, is one of the recipients of the 2014 CNF Nellie Yeh-Poh Lin Whetten Memorial Award.

Born and raised in Barranquilla, Colombia, Nini first came to Cornell in 2001 upon receiving a full scholarship to complete her undergraduate studies. She went on to pursue a Masters of Engineering and quickly transitioned into the Ph.D. program at Cornell, completing her studies in the summer of 2014. During her graduate career Nini became the instructor and assistant instructor for a wide range of courses — from Microelectronics and Nanofabrication, all the way to Power Switching electronics, circuit design and robotics.

“I have always upheld that the best way to learn something is to teach it — whenever I couldn’t understand something entirely or wanted to know more about it, I would sign up as an instructional assistant to teach it.”

Her graduate studies initially focused on CMOS-based sensors, but she ultimately transitioned into graphene bioelectronics, under the guidance of Dr. Michael Spencer. In his group, she fostered collaborations and friendships that defined her graduate career. Still as a graduate student, she took a job as a full-time intern for Applied Materials in their R&D department, and for about the last 17 months of her doctorate, she worked in Massachusetts while studying in Ithaca, New York. “I had to travel on a weekly basis. Sometimes I would go back and forth between the two states in a 24-hour period, to give a talk or complete a specific experiment.”

The challenges of such lifestyle proved key in overcoming any self-doubt and pushing her own academic research forward. “The industry moves much faster than academia, and expects turn-over of results at twice the rate (or perhaps even faster). Being able to design more concise and valuable experiments was one of the biggest rewards (and challenges) of working for an industry giant and it became even more important when I was able to translate that knowhow into my own academic work at Cornell.”

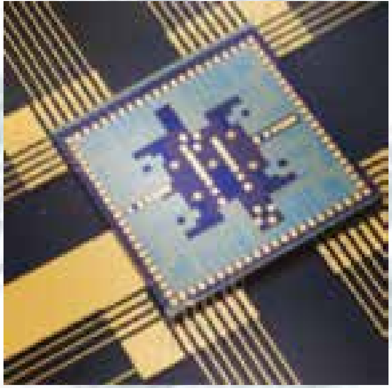


Figure 1: 1 cm x 1 cm Graphene on SiO_2 chip: 48 electrodes and 24 solution-gated transistors wire-bonded to a glass printed circuit board.

The end of Moore’s Law is real, and even though the industry is still focused on silicon-based electronics, the interest in newer materials, such as wide bandgap semiconductors for power electronics and novel 2D channel materials such as graphene, is awakened.

“It is a compelling time for the semiconductor industry. The requirements for faster switching devices and higher current densities are getting stricter, and due to quantum effects, it is becoming increasingly harder to comply by these. My interest in graphene was like of that of any other scientist or physicist — it is the wonder material that could prove key in achieving faster electronics than silicon ever could.”

Graphene has also gained much attention as a biosensing material since its discovery and characterization due to its highly sensitive electronic properties. Reported work on graphene as a biological sensor has focused on solution-gated graphene transistors (SGGFETs) that can measure the perturbed channel conductivity in response to environmental changes in the proximity of the graphene surface. Electrodes present a simpler method of biological detection, both from the operation and the fabrication standpoint.

Her work at the Cornell NanoScale Facility consisted of designing, implementing and characterizing a process flow for graphene microelectrode arrays made with a variety of graphitic materials that exhibit differences in the number of layers, domain size, defects and substrate. A typical chip can be observed in Figure 1. In her work, Nini examined, for the first time, the electrochemical properties of Van der Waals chemical vapor deposited (CVD) graphene grown on sapphire substrates and electrode arrays made on epitaxial graphene grown on silicon carbide. No significant performance differences with mono-, bi- and multilayer graphene were observed, but microelectrode edge effects did become more dominant in multilayer devices as they are scaled down. CVD graphene on sapphire, with domain sizes as small as 100-200 nm, show higher sensitivity and epitaxial electrodes display the lowest detection limit (1 µM) and fastest electron transfer kinetics, with the latter presumed to be effect of the high degree of corrugation in the material and consistent with reports that higher curvature leads to faster kinetics.

To further examine the effect of the edges, Nini patterned electrodes of the same area varying only the perimeter. For clean electrodes, the perimeter to area ratio had little effect on the electrode sensitivity. However, after exposure to a low-power 30-second ozone plasma, the electrode sensitivity and electron kinetics improved, increasing by almost by two-fold with increasing electrode length. This result is consistent with the graphene edges becoming more electroactive through functionalization and result implies that graphene electrode sensitivity can be increased by functionalization and optimization of the electrode geometry. The electrode voltammogram response can be seen in Figure 2, with increasing current response with electrode length.

Nini has continued to work at Applied Materials after graduation. Her work consists of facilitating new nano-fabrication processes to sustain the demands of the semi industry, designing new fabrication protocols for future applications and examining new materials.

In her free time, Nini participates in outreach education programs in the local community, enjoys cooking, climbing and running outdoors.

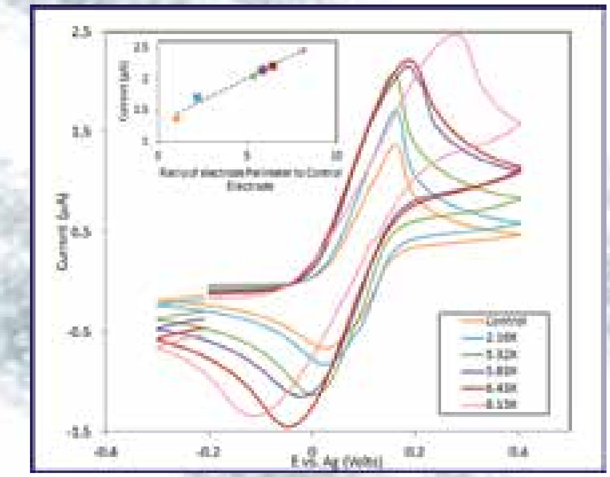


Figure 2: Voltammogram behaviors of serpentine ladder electrodes in 500 µM of FcMeOH in 0.2 KNO3 at 200 mV/s. The inset shows the peak current versus the ratio of the electrode to a control electrode.

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

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."

Photograph provided by Gourdon

Delphine Gourdon, assistant professor of Materials Science and Engineering, at Cornell, received a Faculty Early Career Development award from the National Science Foundation in May 2014.

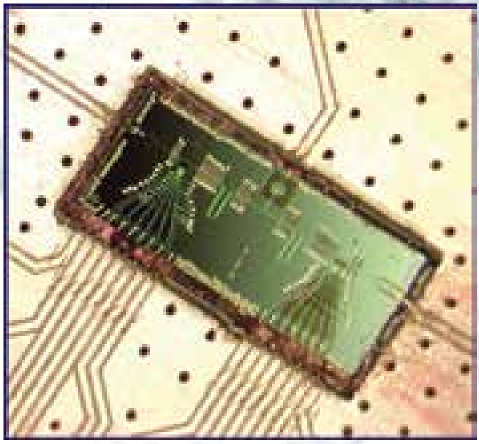
Gourdon will receive $485,000 over five years from the NSF's Division of Materials Research (within the Biomaterials Program) to support her project titled "Biologically inspired platforms: Finding the tricks worth mimicking in the extracellular matrix."

Living cells sense and respond to their microenvironment through chemical and physical interactions determined by the adjacent cells and by the surrounding extracellular matrix (ECM) fibrillar network. Gourdon will investigate both structural and mechanical properties of the two major proteins of ECM structures (fibronectin and collagen) from the single molecule to the cellular/tissue level. A relevant part of the project will make use of facilities at Cornell such as CNF.

The strength of such a project lies in the interdisciplinary approach that combines Gourdon's demonstrated expertise in FRET (Fluorescence Resonance Energy Transfer) protein conformation mapping, and mechanical characterization of biomaterials at the nano-, and the microscopic scales. Combining these efforts will not only generate a fundamental understanding of the regulatory mechanisms governing ECM composition, conformation and mechanics, but also enable the design of 2D and 3D cell culture platforms with controlled mechanobiological properties for investigating vascularization mechanisms in physiological and pathological (cancer) environments.

Gourdon's research at Cornell focuses on understanding and controlling the mechanobiology and tribology of natural and synthetic biomaterials. More specifically, her group studies (i) the mechanobiology of the extracellular matrix in breast cancer, (ii) the lubrication and adhesion of biopolymers, and (iii) the characterization and mimicking of the mineral-protein interface in inflammation.

Gourdon's proposal was one of ten selected from circa 200 submissions in 2013. Gourdon website: https://sites.google.com/site/gourdongroup/



Jason Petta is now an associate physics professor at Princeton University. His research group has come up with a device that they think could be a "major step forward" for the technology of shrinking the scale of semiconductor materials. Petta says they have created the smallest laser possible powered by single electrons that burrow through quantum dots. Read more about "REGARD our TINY but POWERFUL LASER, suitable for very SMALL sharks. Or indeed, more seriously, for quantum computing" online at The Register, http://www.theregister.co.uk/2015/01/17/princeton_builds_single_grain_of_rice_laser/

Devin Wakefield's research is on the cover of the recent issue of the Biophysical Journal! Below is the cover image, and following is the paper reference and a short description of the image:

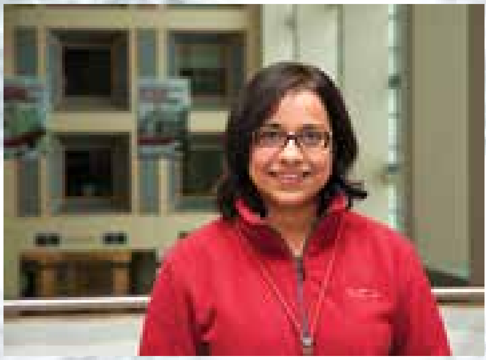
A. Singhai, D.L. Wakefield, K.L. Bryant, S.R. Hammes, D. Holowka, B. Baird, Spatially Defined EGF Receptor Activation Reveals an F-Actin-Dependent Phospho-Erk Signaling Complex, Biophysical Journal. 107 (2014) 2639-2651. This confocal fluorescence image shows a single cell attached to micron-sized patterns labeled with red fluorescence (immobilized streptavidin).

These patterns present attached epidermal growth factor (EGF), which engages EGF receptors expressed at the cell surface. A consequence of this engagement is stimulated phosphorylation of tyrosine residues at the patterned features, detected as blue fluorescence with an anti-phosphotyrosine antibody. Most interesting is the concentration of the beta1 subunit of an integrin in green. The striated labeling around the more peripheral EGF features suggests that focal adhesion complexes are formed at these sites.

More details on this image can be found here:

https://biophysicalsociety.wordpress.com

Introducing New CNF Staff!



My name is ***Amrita Banerjee****, and I have recently joined CNF as a Research Associate. I am an electrical engineer with backgrounds in nanotechnology, optoelectronics, bio-electronics, and material science. I graduated with a Ph.D. degree in 2012 from the Department of Electrical and Computer Engineering at the New Jersey Institute of Technology (NJIT). During my graduate studies, I made significant contributions in developing graphene deposition methodologies and its applications in diverse fields of optoelectronics, electrochemistry and bioelectronics. I performed my post-doctoral research at Rutgers University and in collaboration with CFN at Brook Haven National Laboratory. My primary research goal during my post-doctoral work was to design, fabricate and characterize multi-layer optical interconnects using e-beam lithography. I am fortunate enough to have a vast interdisciplinary research background and it led to the publication of twenty peer reviewed articles and two patents. I got my first opportunity to work in a cleanroom environment when I was a master's student at NJIT. During that time, I fabricated and characterized array of CMOS photodiodes in collaboration with Jet Propulsion Laboratory (JLP). That was the first time I got fascinated by the idea of working in a cleanroom and a user facility. Time passed by and this aspiration of becoming a part of a user facility turned out to be much stronger. Later, it helped me choose to bring my career here to CNF. The main focus of my effort at CNF is to assist CNF users and support different interdisciplinary projects based on e-beam lithography and spectroscopic tools.*

The background image used for this NanoMeter is a "Blast from the Past" spherical lens device found amongst many old photographs and slides from the early years of the CNF / NNF!

Tom Pennell*, a long time CNF user, comes to the facility from Transonics and started in December 2014. Tom earned an MS in Mechanical Engineering from the University of Buffalo and has lots of experience in microfluidics and SU-8 processing, semiconductor packaging, and MEMS fabrication.*

Tom is also involved in medical research in the field of neurosurgery as part of his work related to flow sensor development at Transonic Systems Inc. In his free time, Tom enjoys snowmobiling, building things, Legos, collecting comic books and toys, and making people laugh. Tom joins the CNF as a Research Support Specialist and is eager to work with users and expand into new areas of technology.

New CNF Capabilities & Tools

Analog Switch Box for Driving Fluids with Air Pressure

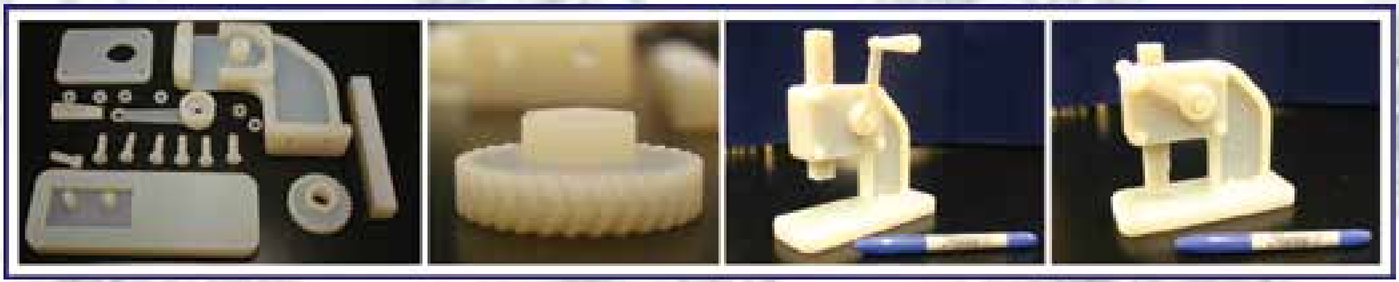
This simple controller has a regulator to deliver gas (nitrogen) pressures between 0 to 40 PSI. There are 24 solenoid switches to apply the pressure to up to 24 separate lines. The lines can be attached to fluidic devices via 24-gauge stainless steel connectors, Luer-lock fittings and Tygon tubing. This box is part of a new system to integrate Quake-style pneumatic control valves into PDMS-based microfluidic devices. It can be integrated into the CorSolutions Fluidic Probe Station to test and document the function of microfluidic devices. Users are invited to set a time with Beth Rhoades to learn about PDMS-based valves and control systems. If you are interested, Beth can also show you how to build your own control system.

Microfluidic Gradient Generator

This microfluidic gradient generator is a sample of the devices that can be attached to the pneumatic control system. In this case, the fluid is being driven by the nitrogen pressure. The lines are attached to the device via stainless steel pins that are inserted and epoxied into throughports. One line is delivering yellow dye and the other is delivering blue dye. Outputs are various mixtures (green).

3D-Printed Old-School Arbor Press

Here is a fun example of things that can be printed on our ObJet30 Pro 3D printer. 20 pieces, including screws, were printed in Durus White polymer. The gears and screws had threads that functioned in the final device. This press could be scaled down for a custom-built approach. Contact Beth Rhoades if you are interested in printing. We can train you, or take advantage of our printing service. Just send a file and some simple instructions! For more details, click on the 3D printing button on our main at http://www.cnf.cornell.edu.










Scenes from the 2015 CNF Junior FIRST® LEGO® League Expo!






Photographs by Don Tennant






In the 2015-2016 WASTE WISE(SM) Challenge, children will look at trash in a whole new way. From reducing, to reusing, to recycling, and beyond, find out what making trash really means. Prepare to become Waste Wise!

The 2014 National Nanotechnology Infrastructure Network Research Experience for Undergraduates (NNIN REU) Program

has been successfully completed! Our summer program brings undergraduates from colleges and universities across the U.S. into some of the nation's leading academic nanofabrication laboratories for an intensive ten-week research experience. The 58 interns hired in 2014 were trained in safe laboratory practices, learned the essential scientific background for their project, and performed independent research in nanotechnology, under the guidance of their mentor. Finally, they all submitted a summary report, which are online at http://www.nnin.org/reu/past-years/

Also, during the summer of 2014, eleven students from our 2013 NNIN REU Program were selected to participate in NNIN's International Research Experience for Undergraduates (iREU) Program in France and Japan. Finally, five graduate students from Japan participated in our NNIN International Experience for Graduates (iREG) Program.

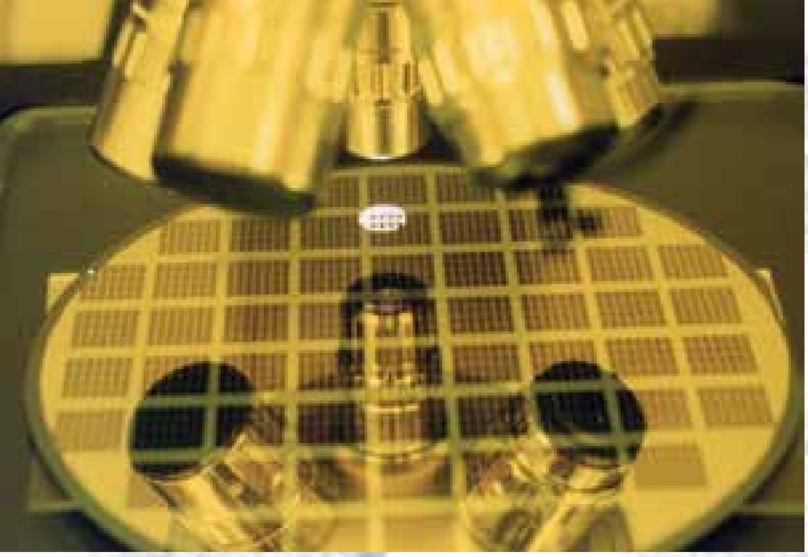
We wish all of our program participants the very best for their future careers, whether in science, engineering, or other disciplines. And personally, I hope to hear from them often over the coming years!

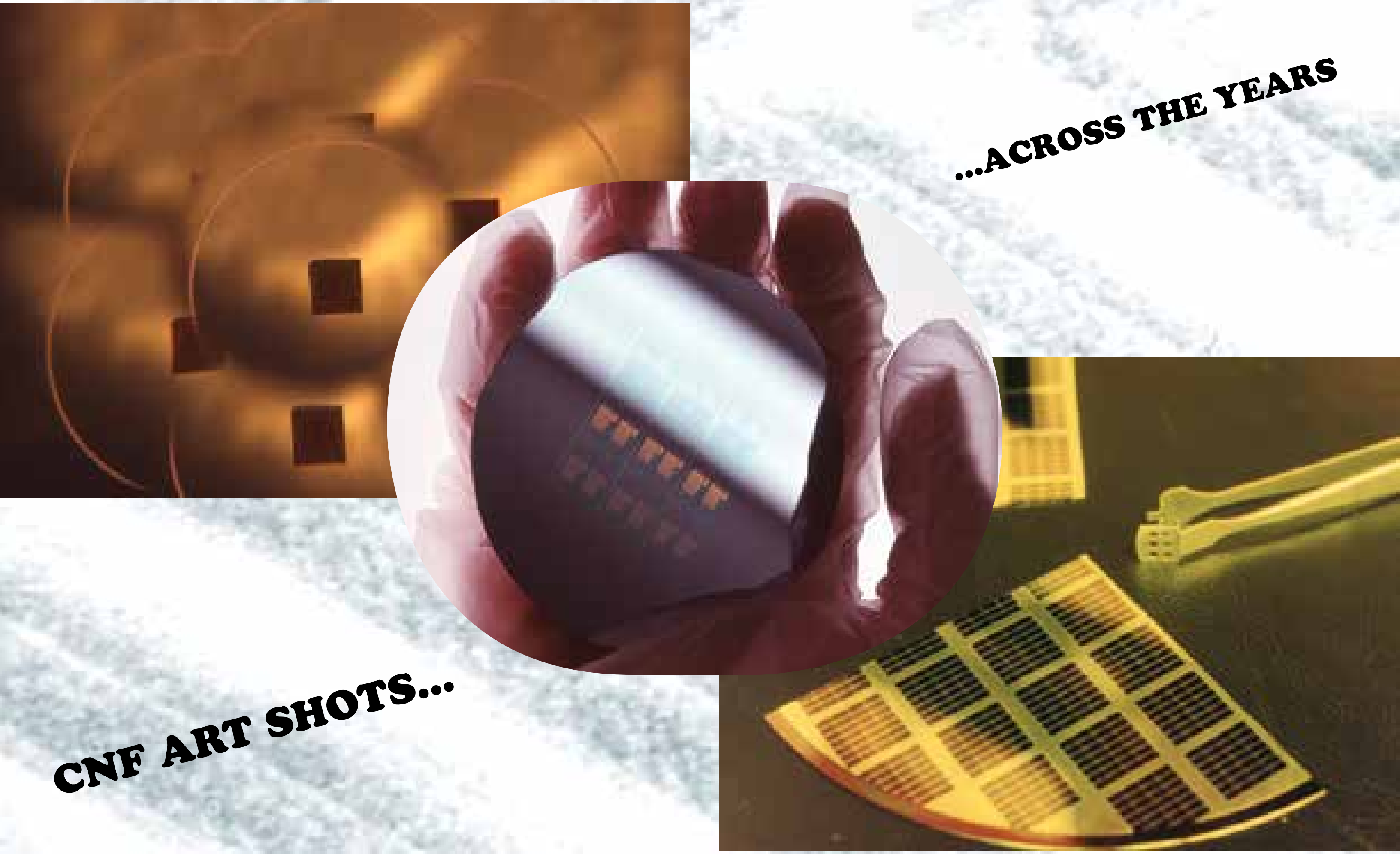
Melanie-Claire Mallison
NNIN REU Program Assistant
& CNF REU Program Coordinator

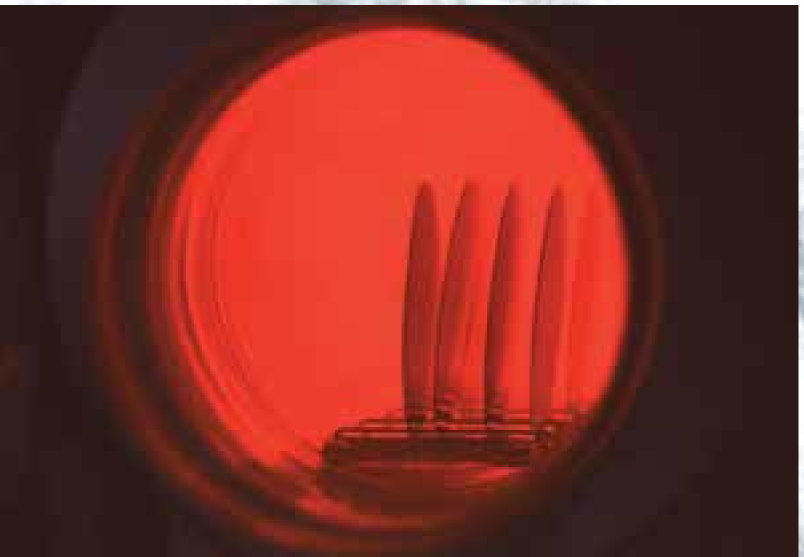
The top photograph of the 2014 NNIN REU Interns was taken by Melanie-Claire at the network-wide convocation held at Georgia Tech in August 2014.

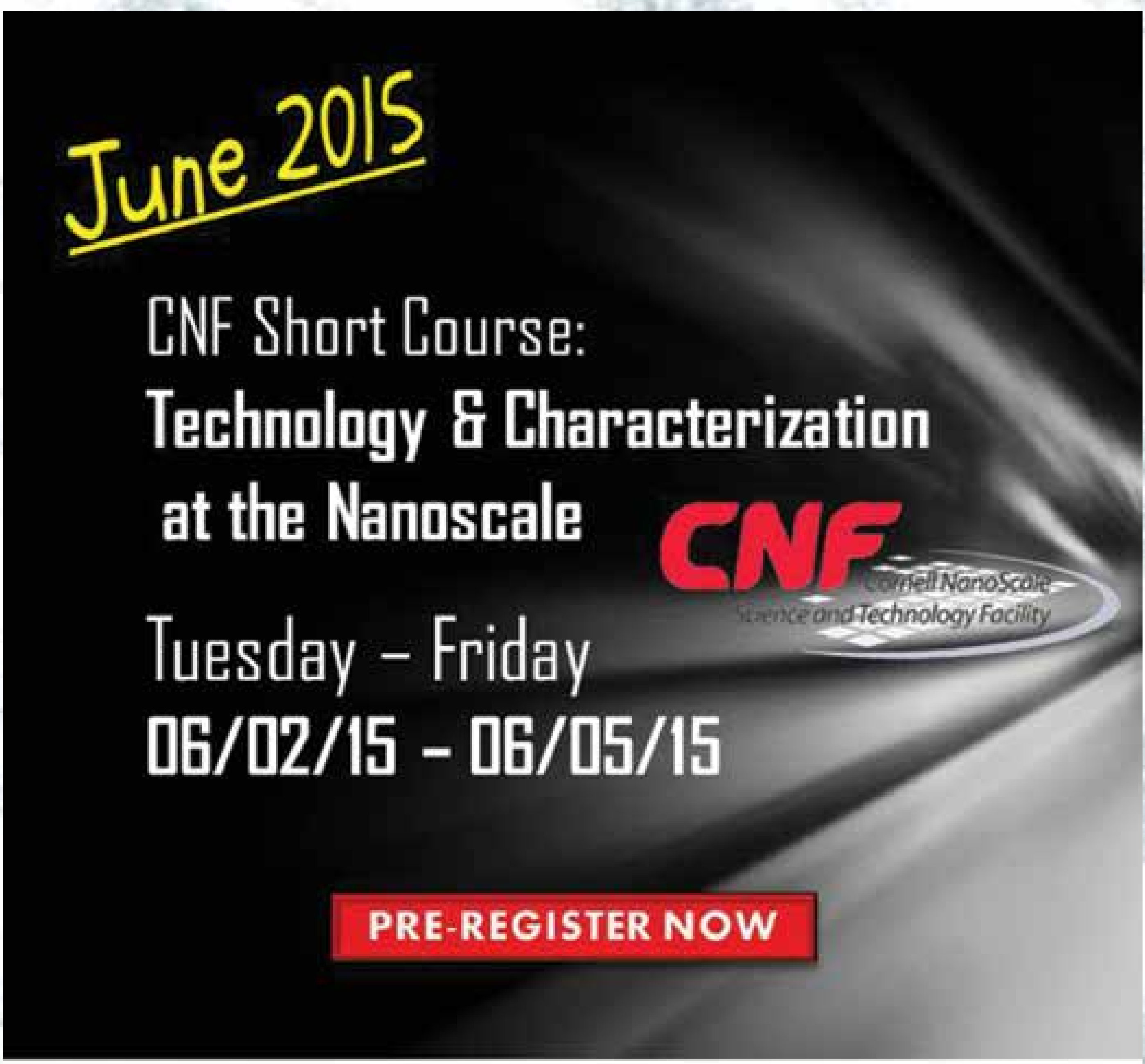
At right are a series of photographs of the CNF REU and iREG interns, taken by Don Tennant in Duffield Hall Atrium, Cornell University campus.

CNF ART SHOTS... ...ACROSS THE YEARS









June 2015

CNF Short Course:
Technology & Characterization at the Nanoscale

CNF
Cornell NanoScale Science and Technology Facility

Tuesday – Friday
06/02/15 – 06/05/15

PRE-REGISTER NOW

This intensive 3.5 day short course offered by the Cornell NanoScale Science & Technology Facility, combines lectures and laboratory demonstrations designed to impart a broad understanding of the science and technology required to undertake research in nanoscience. TCN is an ideal way for faculty, graduate students, post docs and staff members to rapidly come up to speed in many of the technologies that users of the CNF need to employ. Members of the high tech business community will also find it an effective way to learn best practices for success in a nanofab environment. Attendance is open to the general scientific community.

http://www.cnf.cornell.edu/cnf_tcn_june_2015.html

Cornell NanoScale Facility
250 Duffield Hall
343 Campus Road
Ithaca NY 14853-2700

information@cnf.cornell.edu
http://www.cnf.cornell.edu

2015 CNF NanoMeter
Volume 24, Issue 1

30% post-consumer content • soy based ink • reduce, reuse, recycle • your comments are welcome!