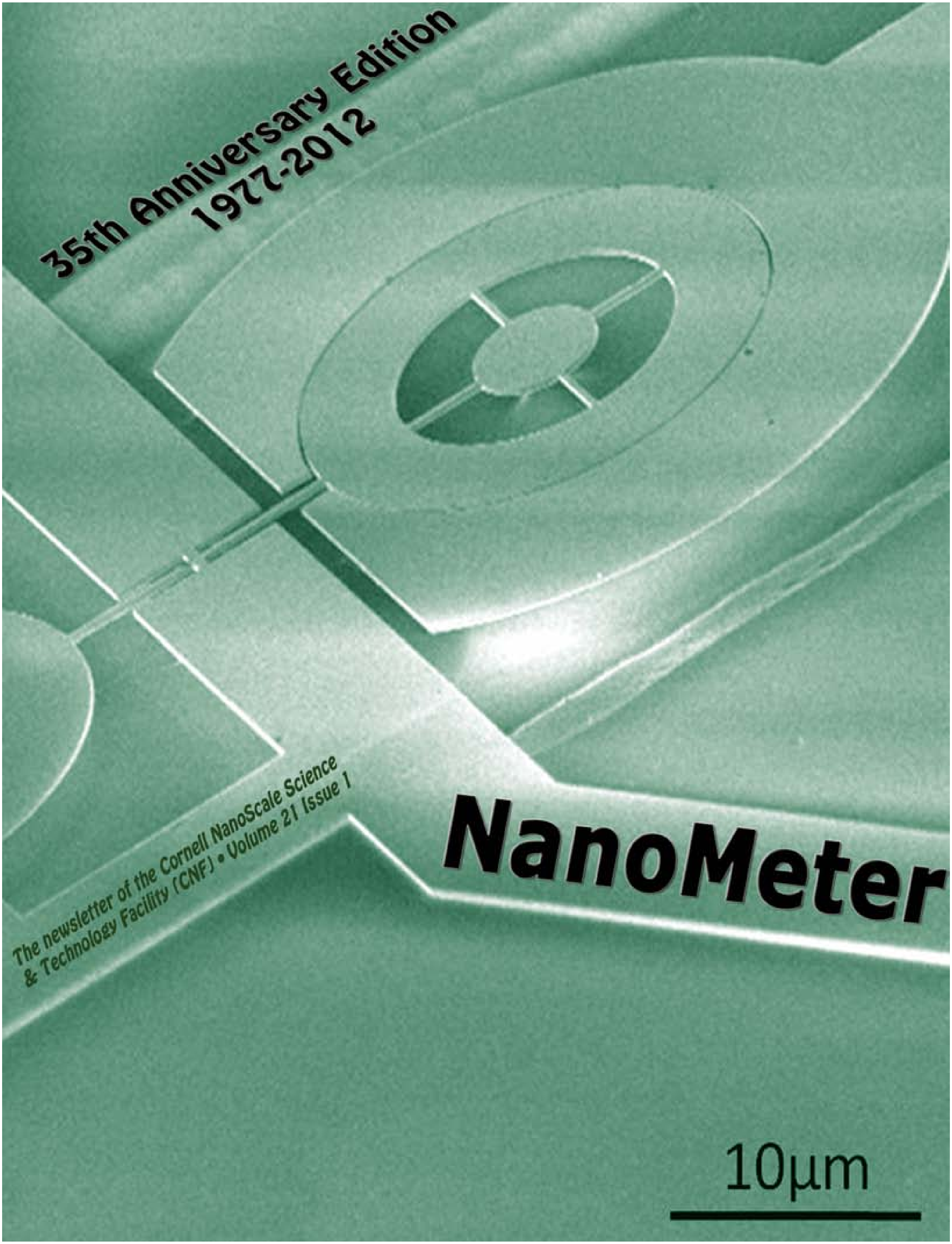

NanoMeter

35th Anniversary Edition
1977-2012

The newsletter of the Cornell NanoScale Science & Technology Facility (CNF) • Volume 21 Issue 1

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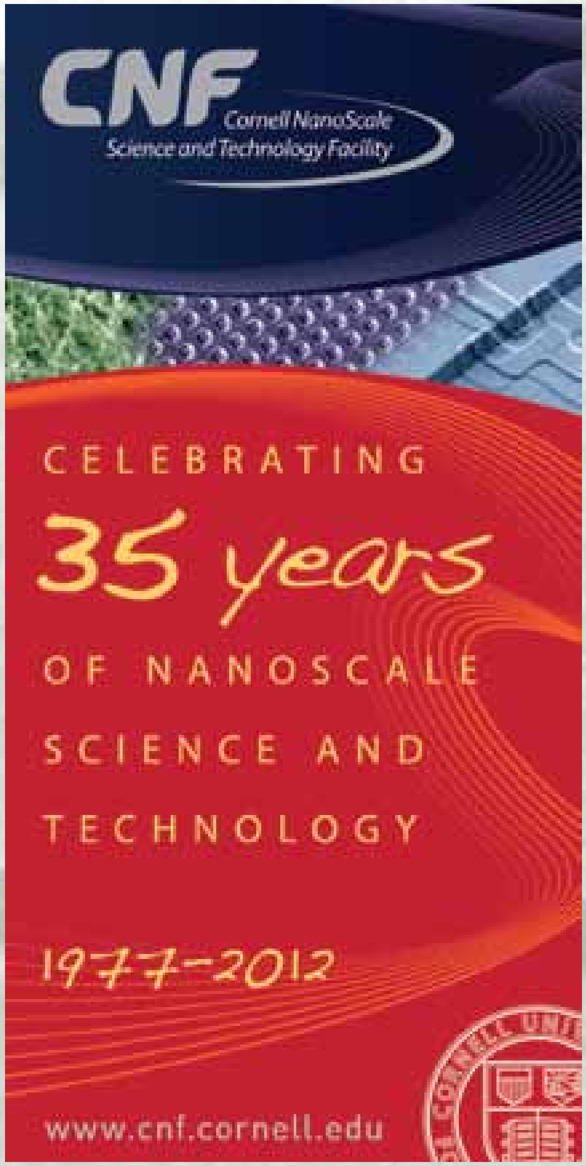
CNF 35th Anniversary Celebration & Annual Meeting • Thursday, July 19th, 2012



The CNF 35th Anniversary Logo, above, was created by Jennifer Infante Design.

The CNF 35th Memories photographs are from sources too numerous to mention! So credit is given to the CNF Staff and CNF Researchers, in general, unless otherwise noted.

Welcome to the 2012 Summer Edition of the NanoMeter

This issue is being released as part of CNF's 35th Anniversary Celebration as a national user facility. We are also approaching the ten-year recompetition for National Science Foundation (NSF) support of the National Nanotechnology Infrastructure Network (NNIN), which funds CNF — we are expecting a call for proposals from the NSF in the fall of 2012, and the assembly of our new proposal over the following months. This is therefore a time in which we are reflecting about the accomplishments of CNF and the new opportunities for science and technology that CNF can enable over the next decade. We invite you to do the same, and to share your ideas with us. In addition, over the course of the next year we will need to ask our entire user community to contribute to the proposal preparation process by sending us information about your accomplishments (even more detailed requests than usual). Demonstrating outstanding achievements by both academic and industrial users will be essential to our continued funding. We therefore ask you to please be responsive to the requests for information that you have received and will be receiving.

New Equipment: The lab is currently working on several tool upgrades that should help keep us at the leading edge of nanofabrication technology. Near the end of 2012 we expect to take delivery of the first of a new generation of electron beam lithography tools to be produced by JEOL, the JEOL 9500. This has been jointly developed in a partnership between CNF and JEOL, funded by a NSF instrumentation grant. The prototype system is currently running well in Japan, and is improved relative to current tools in nearly every category of specification: smaller spot size, larger writing fields, increased speed, dramatically improved placement accuracy and stitching, and more user-friendly software. We have also recently upgraded our Oxford 100 reactive ion etching system, expanding the number of etching gases so as to be able to tune the ratio of chemical species in the plasma. We will, over the next few months, be installing a new load-locked plasma-enhanced chemical vapor deposition system (PECVD) that should enable improved process flexibility and stress control for the deposited films. And last but not least, our ancient Flexus stress measurement system has been replaced with a brand new model! Please see Jerry Drumheller (and page 31) to get trained.

Staff News: Since the last issue of the NanoMeter, we are very pleased that Christopher Alpha has joined the CNF. Chris brings a wide range of industrial processing experience and is also a long-time CNF user himself. Read his introduction on page 30, and please help us welcome Chris into the CNF community.

Cleanroom Upgrade: Finally, we wish to give you advance warning about some future construction in the facility and an associated shutdown. When Duffield Hall was built, much of the recirculating processed cooling water system was made with black iron pipes which ever since have been rusting from the inside, clogging our tools and killing pumps. We plan to fix this problem once and for all by replacing our entire processed cooling water system and cleaning all of our existing tools. To minimize the impact on users, this work will be done in stages with the major impact scheduled for December 2012/January 2013. However, we still anticipate approximately a one-month winter shutdown of everything in the CNF — instead of our usual ten-day Christmas/New Year holiday. As we get closer to the start of this project, we will send you more details about the exact schedule by email and via postings on our website.

Please note the dates for upcoming events on the back page of this NanoMeter and check our web site often for news updates.

Dan Ralph, CNF's Lester B. Knight Director

Don Tennant, CNF's Director of Operations

University Photography

CNF in the Changing World

By Sandip Tiwari

University Photography

CNF's 35th anniversary is an auspicious moment. Indian traditions reserve the expression of gratitude and introspection for such moments. For CNF, i.e., its people and its resources folded into a culture imbued with openness, the former stems from the mark that past and current students — of Cornell and elsewhere who came into their own pursuing research using CNF — continue to make in the world. For the latter, I would like to share some thoughts: of lessons from the past and present, and a debate of the future within the world that affects us and that we perturb and occasionally disturb through our scientific and academic pursuits.

Late 1970's, when CNF came into being, was the beginning of a remarkable period. The microprocessor had just come into being, numerous mesoscale and emergent effects were being discovered (quantized Hall, interference in superconductivity, giant magneto-resistance) and applied, tools were coming together to understand miniature devices and to control them, the high frequency solid state devices were getting ready to displace slow and fast wave vacuum structures, and new controlled techniques from molecular beams and through chemical vapor phase were allowing one to imagine atomically controlled epitaxial structures. These made possible the personal computer of 80's, then the optical transmission and internet of the 90's, and the wireless phones of the past decade. It certainly would have been hard to imagine all this at the birth of CNF. It is said that practicing scientists and engineers underestimate what would happen longer term — over several decades, and overestimate what is possible near term. A reading of the original proposal to NSF follows this saying.

I started my graduate pursuit coincident with this facility's beginning, and today, I still find it very remarkable and exhilarating to think of the changes that have unfolded from the miniaturization that was its focus. Just one decade ago, we didn't have the pervasive cell phones or the GPS systems. Two decades ago, we didn't have the way by which we use computers in their various forms to access all the information — news or contents of journals through the library or to talk via Skype to our distant loved ones. Three decades ago, we would all be just at the cusp of playing simple video games that involved escaping a round object with a wedge chomping through a maze or using a paddle to hit a ball repeatedly on a brick wall.

The exhilarating part is that the research of science and engineering of the small has been so remarkably intellectually rewarding in uncovering the unknown and in using it on this small planet in the vast universe that we inhabit. Our small dimension based science and engineering instruments, in the remarkable marriage of the modern chip-based eyes and the evolution of the optics of the Dutch that launched the modern science in the Renaissance period, is now telling us that we are probably not alone in this universe — that there are plenty of exoplanets around, and that we can speculate that some are surely to be inhabited by life forms.

Our engineering, the technology and the science that underlies it, is a tremendous social force. Communications — and the moving of the information out of the control of a few — helps individuals be independent and interact as a group. The truth is out readily, rather than left to historians to uncover decades or centuries later, and tools for learning abound. And this has had a major impact around the globe — democracies are more successful, people are freer, and particularly for China and India, who between them constitute a third of humanity, a period of rapid growth following centuries of suffering.

The ability to discover, invent, use these personalized tools to help individuals locally, disseminate, organize, and learn is global. The pervasiveness of these creations of engineering has also brought about changes in the value system — what the society rewards in practice and what the young consider important and rewarding.

The modern devices — phones, thumb drives, GPS, digital cameras, laptops and tablets — are mostly made and put together in factories abroad. Apple and Google and Wall Street are the rewarding employers. Apple has a stock market value of about $600 billion out of a total USA stock market capitalization of $14 trillion. It employs 60,000 people. If all companies were as “innovative” as this, we will have a total employment of 1.4 million. Today’s total USA employment is 140 million. This is a large disconnection.

Engineering’s precious reward is a beautifully designed, aesthetically pleasing, robust, and simple object that is useful and satisfying to the user. What makes it successful is the entirety. It is not just the user interface, the feel, but the entire packaged form, the hardware, the software, the looks and the usability. The societal change in these decades that has unfolded in the United States includes the movement of much of hand-crafting or non-desk-tied tasks to outside the country. Good engineering, the technology that underlies it, the entire process that creates it, and appreciating all who do it, is lower down on the reward scale than it was thirty-five years ago. Germany has many more car manufacturers than USA and they are more successful today than they were thirty-five years ago. This is a result of the appreciation by that entire society of the precision worker — technologist as well as the designer; all engineers who are just different in where their interests lie, and an education system which, from well before high school, works towards it.

An optimization such as the current one focused on a local maximum of profit, driven by the current economic and social and cultural milieu, is brittle and primed for failure at another moment in time. Textile industry and electronics manufacturing both suffered through this in the past century. Products — physical creations useful to society — are essential for a large nation to succeed in the long term. Services that allow the flow of creation and use of the products, such as finance or communication and information delivery, are an essential aid but not a replacement for the engineering and manufacturing for creation of wealth.

USA has a robust venture and angel funding system, one that funds at nearly $50B to $100B per year creation of start-ups and of their expansion. However, much of this funding goes to the service-like functions. Apps are a form of service, so are most financial instruments or insurance. The small business investment grants that do support the physical creation are a few billion dollars, a very small fraction of the total funding for entrepreneurship that is so valued in the society.

New directions for successes in engineering and of inventions also require continuing leading discoveries. Forty-two of the three science Nobel Prizes were awarded in the prior six year periods, thirty-five years ago (1972-77) and today (2006-11). In these, the share of non-USA born researchers increased in percentage from 50% to 64.3% and the numbers of awardees working outside USA increased from 35.7% to 45.2%. NSF’s latest complete statistics (of year 2006) show that only 18.2% of the doctorate awards in engineering are to natives. Among university faculty, in engineering, 25.7% and in computer science, 36.8% are non-USA born, a near tripling from 35 years ago.

In short, this world of 2012 is very significantly different from 1977, its center of gravity steadily shifting towards the east. The national culture has changed. The environment of USA, in academic research, and how it is supported and fostered by the government, is still very close to the form that came about following World War II. In this new competitive landscape, what we value and reward as a community needs rethinking.

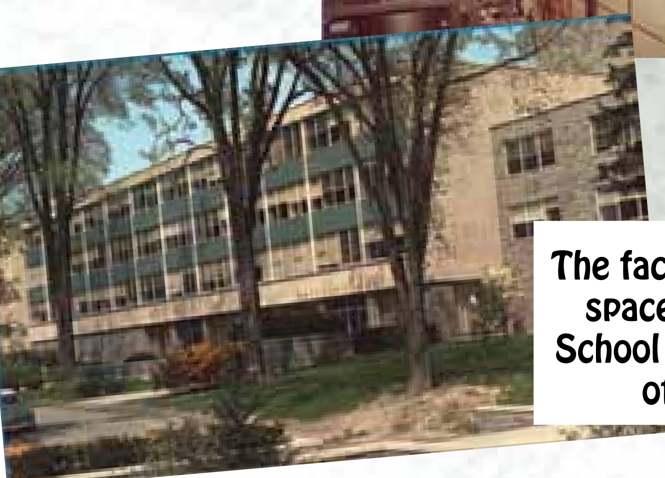
The approaches to opportunity for all, rewarding excellence, while employing precious resources effectively through openness, as practiced in CNF from its earliest days, are more important now than ever.

Prof. Sandip Tiwari recently retired as the director of the National Nanotechnology Infrastructure Network (NNIN), having held that title since 1999. Prof. Tiwari was also the CNF’s Lester B. Knight Director from 1999 till 2005.

Edward Wolf, Noel MacDonald, Jeff Lehman, Joseph Ballentyne, Sandip Tiwari, Harold Craighead; at CNF’s 25th Anniversary Celebration. Five CNF Directors and One Cornell President! University Photography.

"The CNF had its beginnings within the National Science Foundation (NSF) during the mid-1970s."

"The winning proposal was promoted and coordinated by Prof. Joseph M. Ballantyne, School of Electrical Engineering."



The facility was to be located in renovated space within Phillips Hall, home of the School of Electrical Engineering, at a cost of about 600 thousand dollars.

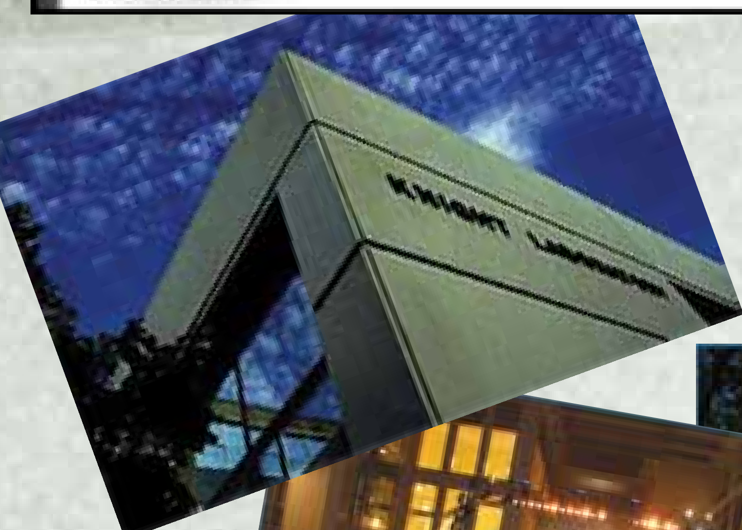
"We changed from individual faculty to staff responsibility for equipment operation and repair and from a renovated 4th-floor space in Phillips Hall to a new site on ground level for the new lab."


SCIENCE

Exploring the Microworld

MOLECULAR DEVICES

"The new Kinght Laboratory allowed local Class 10 processing in a Class 500 ambient with very low electromagnetic fields and mechanical vibration, and its construction was endowed by Lester B. Knight (Cornell '29)."

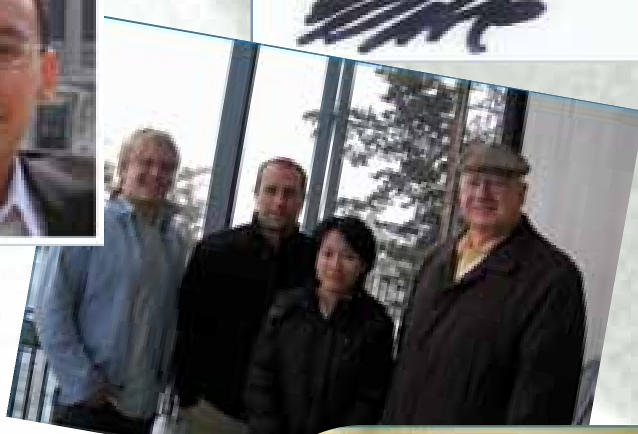


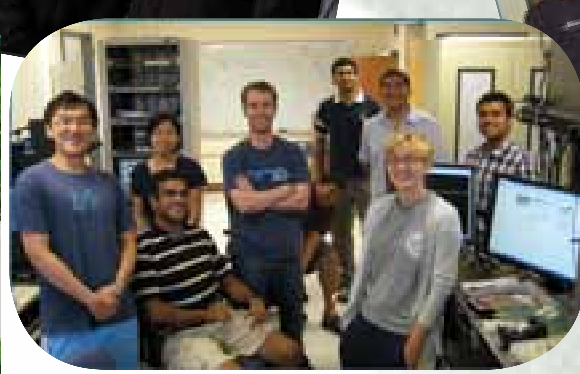
Charles Harrington Photography

"Duffield Hall, named for Cornell Engineering alumnus David Duffield '62 EE, is one of the country's most sophisticated research and teaching facilities for nanoscale science and engineering. It supports research and instruction in electronic and photonic devices, microelectromechanical devices, advanced materials processing, and biotechnology devices."
Duffield Hall Web Site

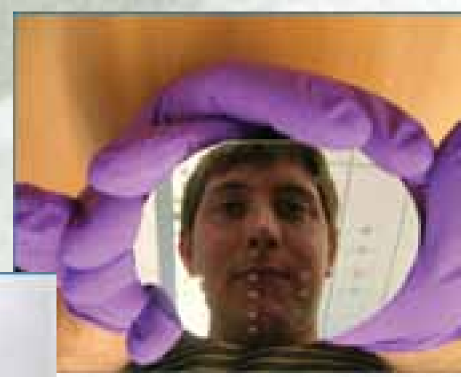
35^{th} memories

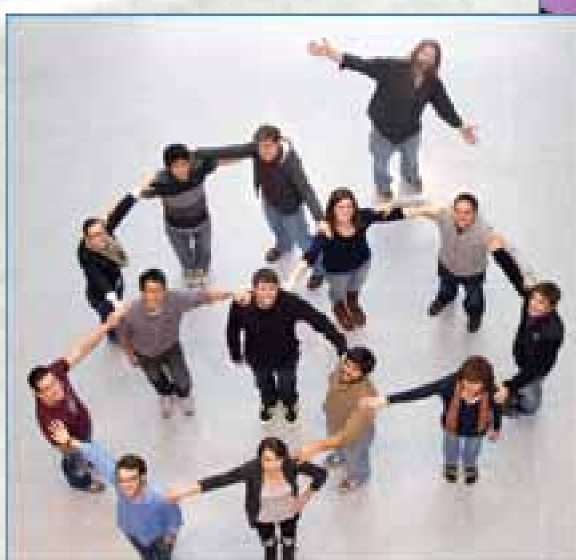
University Photography

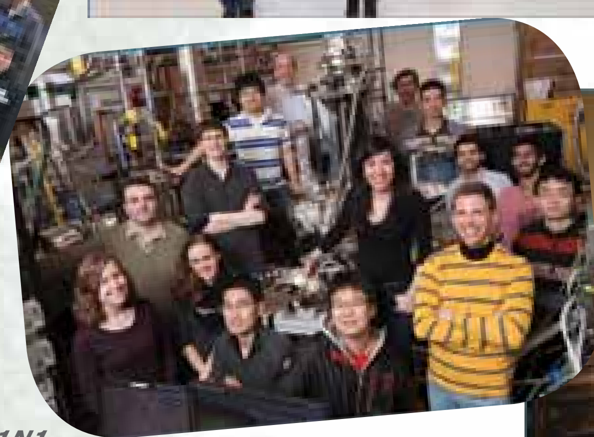




"It is noteworthy that CNF continues to provide uniquely enabling technology for a wide spectrum of science and engineering research at a university, founded by Ezra Cornell, under the motto, 'I would found an institution where any person can find instruction in any study.'"







Quotes on pages 6-9, Edward D. Wolf, Director of CNF (1978-1988), Professor Emeritus, School of Electrical Engineering, Cornell University; unless otherwise noted

I joined the CNF about 30 years ago —

Knight Lab had just been completed, the lab environment was new, and the research program was a blank slate. It was an exciting time, with much of the work in the category of facility development — searching for a purpose for these powerful techniques.

We had a small research community. There were so few people that everyone was on a first-name basis, and so few equipment charges that they could be tabulated manually.

There were some local users and very few outside users — so few in fact, that the start of an outside project called for a kick-off meeting in which all would gather and discuss ways to optimize the work. Folks were engaged and anxious to help.

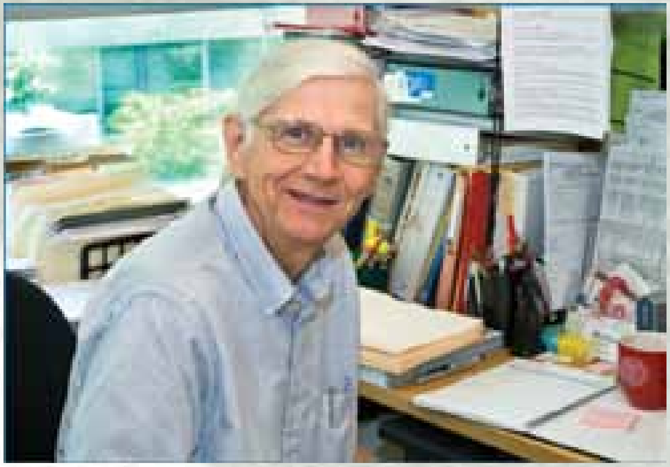
That same concept has continued through the refinements of the last few decades. The welcome process now happens much more frequently (several new users per week) and often with a bit more intensity. But the attention-to-the-work and the dedicated, competent and enthusiastic staff have continued to define the interaction process.

The natural evolution of this original and very successful concept has resulted in distributed networks (NNIN), new instrumentation, and new research opportunities, serving as a model for other entities and the accepted standard for addressing the research opportunities of the future.

Michael Skvarla

The NRRFSS Staff in 1986*

Mike crosses the finish line at the Skunk Cabbage Run, May 2012. Photo Sander Hunter



Michael recently received Cornell's George Peter Award for Dedicated Service, given by the Staff Recognition & Award Committee of the Employee Assembly and the Office of Human Resources to recognize outstanding staff contributions "above and beyond normal job expectations."

** National Research and Resource Facility for Submicron Structures (NRRFSS)*

The first-ever NanoMeter; January/February 1989, Volume 1 Number 1

Volume 1, Number 1
January/February 1989

NNF National Nanofabrication Facility at Cornell

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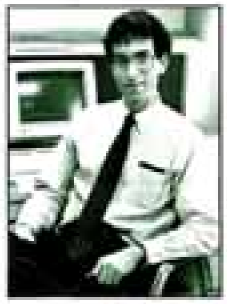
NEWS & REFERENCE

Craighead becomes director of NNF



We can play a leadership role in applying the techniques of microfabrication to photonic devices and optoelectronic circuits, growth areas of global importance.

Harold G. Craighead

Not another newsletter!

by Greg Galvin, Deputy Director, NNF

THE BATON IS PASSED

Rapid pace and broad accomplishments seen for the future

by Edward D. Wolf, Professor, Electrical Engineering

Ed Wolf, retiring director of the NNF

The support of our affiliates and the NSF have enabled us to make a significant difference in nanofabrication research and education.

Ed Wolf

Present Day

Continuity Assured

Recent Appointments

Laser Pulsed Cathodes for Time-Resolved Microscopy

Introduction

Process Description

Progress to Date

Acknowledgements

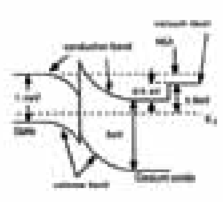


Figure 1. GaAs/Cs2O... energy band diagram

Recent Publications

NNF Offers Summer Short Course

nm

NNF National Nanofabrication Facility at Cornell

Knight Laboratory, Ithaca, NY 14853-5403

Undergrad Synthetic Biology Team Takes a Top Prize at World Championship

By Anne Ju, Cornell Chronicle, December 1, 2011

With today's most pressing problems ranging from the environment to health care, it's clear that life scientists and engineers need to work together. A Cornell undergraduate project team, only three years old but already winning international accolades, is getting in at the ground floor. Cornell University Genetically Engineered Machines (CU GEM), a mostly undergraduate, highly interdisciplinary project team started in 2008, achieved its highest honor yet at the iGEM 2011 World Championship Jamboree, Nov. 5-7.

Presenting their tested and working "Biofactory" — a series of microfluidic chips that use a biosynthetic pathway to produce a useful chemical — the students beat out 120 other teams to take the "Best Manufacturing Project" prize.

"At Cornell, our goal is to foster future leaders," said Xiling Shen, assistant professor of electrical and computer engineering and team adviser. "We are not trying to have research superhumans who can do it all, but to learn how to harness other people's expertise."

The nature of CU GEM's successful BioFactory project says it all. The goal of the project involved molecular biology, chemistry and chemical engineering — using a known biosynthetic pathway to convert tryptophan into prodeoxyviolacein, a useful precursor to some biopharmaceuticals. The device, an array of chips etched with microfluidic channels and lined with modified enzymes that act as a linear biochemical pathway, were made in the Cornell NanoScale Facility by electrical, mechanical engineering and materials science students.

"We're interested in developing biopharmaceuticals inside of cells," said team leader Jim Mathew '14, a chemical engineering major. "But sometimes you have a lack of reactor control when working with cells, and it's hard to get a final chemical output."

CU GEM's microfluidic reactors are a scalable, cell-free method for producing complex biomolecules, which could reduce unwanted side reactions and ultimately lead to a lower-cost method of production, Mathew said. Virtually every area of engineering, chemistry and biology were tapped in order to make the project successful — including mass spectrometry data to confirm their results.

"The judges said they were especially impressed with how we tied everything together," said Malinka Walaliyadde '12, senior undergraduate adviser. The projects were scrutinized on technical details as well as ethical considerations. Teams were also judged by their commitment to outreach and helping public school students, for example, gain access to science. In its short duration, CU GEM has hosted outreach events at both the Ithaca Sciencenter and at Cornell's CURIE Academy, and has already sprouted an alumni network.

Shen also pointed out that Cornell's relatively young team beat out more established teams from other top institutions. They were one of the few who came with an entire working system, rather than staying on a conceptual level.

The team's interdisciplinary nature is evidenced through its growing list of sponsors: The College of Engineering, Department of Electrical and Computer Engineering, Weill Institute for Cell and Molecular Biology, Cornell Institute for Biotechnology and Life Sciences, and Cornell NanoScale Facility. They have also garnered corporate sponsorship from Corning Inc., New England Biolabs, Integrated DNA Technologies, and Modo.

Figure 1: CU GEM's BioFactory, which consists of an array of chips etched with microfluidic channels that act as a linear biochemical pathway. Photo Provided.

Figure 2: The 2011 CU GEM team with their world championship award. Photo Provided.

Biosensor May Improve Disease Detection, Water Monitoring

By Anne Ju, Cornell Chronicle, December 8, 2011

A quick, inexpensive and highly sensitive test that identifies disease markers or other molecules in low-concentration solutions could be the result of a Cornell-developed nanomechanical biosensor, which could potentially help with early stage disease detection.

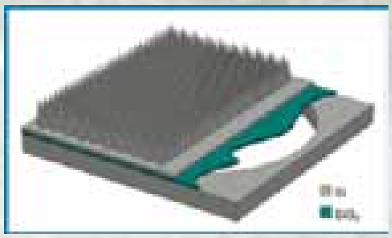


Figure 1: A schematic drawing of the biosensor, which consists of ordered nanowires on top of a silicon-silicon dioxide membrane. Yuerui Lu

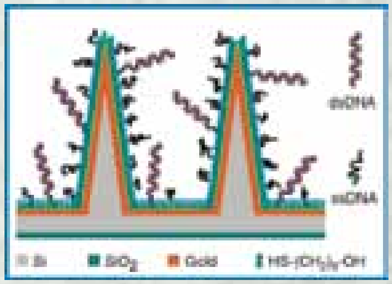


Figure 2: A drawing of how single-stranded DNA is immobilized and hybridized on the sensor. Yuerui Lu

The biosensor, based on a photonic crystal nanowire array, was developed by Yuerui Lu, a graduate student in the lab of Amit Lal, professor of electrical and computer engineering. Their research was published online December 6 in the journal Nature Communications. The sensor's operation was confirmed in collaboration with Dan Luo, professor of biological and environmental engineering, and his graduate student Songming Peng.

The experimental device is a mechanical resonator 50 µm in diameter made of a thin silicon-silicon dioxide membrane with ordered, tightly packed vertical nanowires on top. The design achieves a high surface-to-volume ratio for biomolecule detection, which means it can detect molecules at very low — down to femtomolar — concentrations. The sensor could be useful, for example, for finding just a few molecules in a glass of water.

The sensor works by attaching single-stranded probe DNA molecules onto the nanowires. When those molecules come into contact with a target single-stranded DNA, the relevant molecules bind together, changing the mass detected by the device. The mass change causes a change in the resonance frequency of the device. A laser beam is shone on the device, and the nanowires' innovative design allows for more than 90% absorption of the light, resulting in an efficient opto-thermo-mechanical excitation of the resonator. An optical readout of the resonance frequency change can be accomplished remotely, quickly and free of electrical wires, making the device convenient and inexpensive to make, the researchers said.

Lal said he imagines doctors could use such a device in clinical analysis, for example, in DNA testing. Typically today, DNA in drawn blood is compared against a standard sequence. The new device could instead be coded with particular DNA sequences of relevance, and those specific molecules could be detected in early stages when concentrations are low.

"You could have a cartridge with an array of the membrane sensors, and you could quickly scan to see what DNA imperfection you might have," he said. "Today's tests take time and are expensive."

Such sensors could also be useful for environmental applications, such as water quality monitoring. The researchers hope to improve their device by making it sensitive to certain protein molecules, which are trickier because they do not bind as specifically as DNA molecules do.

The research was funded by the Defense Advanced Research Projects Agency Microsystems Technology Office. Fabrication was performed in part at the Cornell NanoScale Science and Technology Facility.

Scientists Predict An Out-Of-This-World Kind Of Ice

By Anne Ju, Cornell Chronicle, January 16, 2012

Cornell scientists are boldly going where no water molecule has gone before — that is, when it comes to pressures found nowhere on Earth.

Exploring what Cornell's Neil Ashcroft calls the "utterly fundamental" transition from insulating to conducting, or metallic, matter, the researchers have combined high-powered computing and "chemical intuition" to discover new phases of water — specifically, ice at extremely high pressures nonexistent on Earth but probably abundant elsewhere in the solar system.

The research, published online December 29 in Proceedings of the National Academy of Sciences, was conducted by Ashcroft, the Horace White Professor of Physics Emeritus; Roald Hoffmann, the 1981 chemistry Nobel laureate and Frank H.T. Rhodes Professor in Humane Letters Emeritus; and Andreas Hermann, a postdoctoral associate in chemistry and physics.

Combining their interests in condensed matter physics, the discovery of new chemistries and high-pressure studies of water, the researchers predict a sequence of never-before-seen, stable structures of ice in the 1-5 terapascal pressure range. In terrestrial terms, pressure is expressed in atmospheres (we live under one atmosphere of pressure). A terapascal (TPa) is ten million atmospheres.

"This pressure is way above anything that can be done in the laboratory," Hoffmann said. "It certainly can't be found in Ithaca, not even at Lynah Rink during the Harvard game."

It is, however, in the range of the pressure regimes on Uranus and Neptune — planets whose major components include, well, ice. This means that these far-fetched phases of ice might not just be theories — they are probably what you would find if you could descend toward the core of the outer planets of our solar system, or in the center of extra-solar planets being discovered today.

So what does ice do at these pressure scales? Discrete water molecules disappear; the H_2O in the new ices has an extended network of oxygens and hydrogens. Like sardines in a can, the oxygen-hydrogenoxygen bonds get squeezed together, forming new shapes. The new ices eventually become metals, but not as quickly as others had previously thought.

Researchers at other universities (who inspired the Cornell researchers) have described ice phases that became metallic at pressures higher than 1,550 gigapascals (one gigapascal is 10,000 atmospheres). The Cornell researchers' calculations predict new phases stable at pressures above 1 TPa, but the most stable new ices will be insulating — not metallic — pushing the theoretical transition pressure for metallization of ice beyond 4.8 TPa. Their calculations also point to evidence that, in fact, in those extreme pressure regimes, ice might become squeezed to the point of transforming into a quantum liquid — a most unusual intimation, they said.

"It's hard to imagine — pressure-induced melting of bulk ice," Ashcroft said.

The research was supported by the Department of Energy and the National Science Foundation, and the computational work was done on the TeraGrid network provided by the National Center for Supercomputer Applications and the Cornell NanoScale Facility.

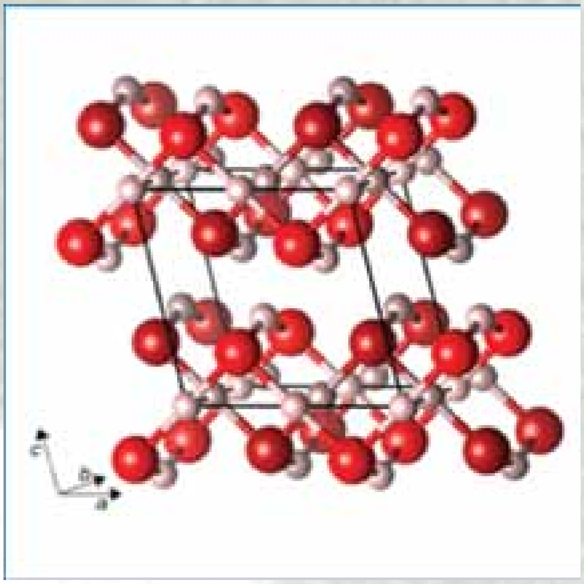


Figure1: Static crystal structure of a phase of ice at a pressure of 2 terapascals. Photograph Provided.

Food Safety Inspires Children to Build LEGO Machines

By Susan Lang, Ithaca Journal, January 30, 2012

After working for months on their LEGO creations for the 2011 Snack Attack Challenge, scores of 6- to 9-year-olds showed off their teams' LEGO creations depicting solutions to food safety concerns at the sixth annual Junior FIRST (For Inspiration and Recognition of Science and Technology) LEGO League Expo at Cornell's Duffield Hall atrium, January 28.

This is the sixth year that the Cornell NanoScale Facility has organized and hosted the Expo, for which elementary school student teams conducted research and developed LEGO models with a motorized moving part and posters. At the expo, the children from Ithaca, Binghamton, Rochester and beyond presented their work and explained to reviewers — Cornell NanoScale Facility researchers and staff — how they worked as teams.

More than 12,000 youngsters from four other countries also participated in this year's Junior FIRST LEGO League challenge. Teams were asked to take a "hands-on" approach to food safety by exploring how proper preparation and storage can help keep us healthy.

The junior league is a spinoff of the FIRST LEGO League, which is for older children. Each year, the FIRST organization releases a science-themed challenge for the teams. Teams are formed by teachers, coaches, parents or other mentors who want to encourage children in science and technology, with the fun of building with LEGOs. FIRST, a nonprofit founded by Dean Kamen, inventor of the Segway Human Transporter, has developed the challenges for organizations like Cornell to run.

The event at Cornell was in funded in part by the Shell Corp.

Figure 1: Yajaira Sierra, a reviewer for the 6th annual Junior FIRST LEGO League in Duffield Hall Atrium, works with team members from Northside Lego club, 9-year-old Dymond Pyne, center, and 6-year-old Tashawn Pyne, right.
Robert Barker/University Photography.

Figure 2: Geoffrey Clark, 10, a member of the Mini Fingers team from Ithaca, works with the team's LEGO display.
Robert Barker/University Photography.

To Make Better Fuel Cells, Study The Defects

By Bill Steele, Cornell Chronicle, February 20, 2012

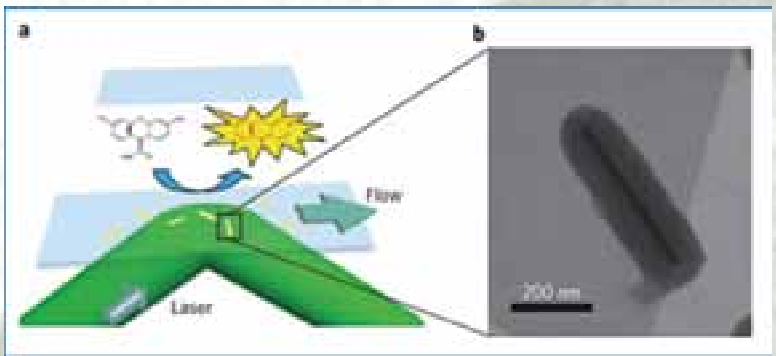


Figure 1: When Amplex Red connects with a gold catalyst the structure is changed to make a fluorescent molecule that immediately emits a flash of light, showing where the catalytic event took place. Right, electron microphoto of a single gold nanorod, encased in a poirus silica shell. The shell keeps rods from clumping together and allows experimenters to use heat to clean away a coating that forms when the rods are created. Provided/Chen Lab.

Engineers trying to improve fuel-cell catalysts may be looking in the wrong place, according to new research at Cornell.

There is growing interest in forming the catalysts that break down fuel to generate electricity into nanoparticles. Nanoparticles provide a larger surface area to speed reactions, and in some cases, materials that are not catalytic in bulk become so at the nanoscale. These nanoparticles, typically just a few tens of nanometers (nm) wide, are not neat little spheres, but rather jagged chunks, like microscale gravel, and researchers have found that they can correlate catalytic activity with information about the number and type of their surface facets. But they may be looking at the forest and ignoring the trees.

"People measure the activity of a sample and then try to understand by using facet information," said Peng Chen, associate professor of chemistry and chemical biology. "The message we want to deliver is that surface defects [on the facets] dominate the catalysis."

Chen's research is reported February 19 in the online edition of the journal Nature Nanotechnology. Instead of particles, Chen's research group studied catalytic events on gold "nanorods" up to 700 nm long, effectively letting them see how activity varies over a single facet. Gold acts as a catalyst to convert a chemical called Amplex Red into resorufin, which is fluorescent. Each time a catalytic event occurs, the newly created molecule of resorufin emits a flash of light that is detected by a digital camera looking through a microscope. A flash typically appears as several pixels, and additional computer processing averages their brightness to pinpoint the actual event to within a few nanometers. The researchers call the technique "super-resolution microscopy."

After flooding a field of nanorods with a solution of Amplex Red, they made a "movie" with one frame every 25 milliseconds. The researchers found more catalytic events near the middle of a rod, tapering off toward the ends and a jump back up at the ends. They also found variation in the amount of activity from one rod to another, even though all the rods have the same types of facets. To explain the results, they proposed that activity is higher in areas where there are more surface defects.

The nanorods are made by growing gold crystals from a small "seed" crystal, growing outward from the center to the ends, Chen explained, and more defects form at the beginning of the process. "Knowledge of the surface facets ... is insufficient to predict reactivity," the researchers said in their paper. "Surface defects ... can also play a dominant role."

The findings with a gold catalyst and fluorescent molecules should be equally applicable to other catalysts, including those used in fuel cells and for pollution remediation, Chen said.

The research was supported in part by the Army Research Office, the National Science Foundation (NSF), the Department of Energy and the Alfred P. Sloan Foundation. Part of the work was carried out at the Cornell Center for Materials Research and the Cornell NanoScale Science and Technology Facility, both supported by NSF.

Obama Praises New York State Tech Growth

By Jon Campbell, Ithaca Journal, May 9, 2012

ALBANY — During a visit to the Capital Region on Tuesday, President Barack Obama said he wanted "what's happening in Albany to happen all across the country." The comment, on its surface, turned a few heads. In a city known foremost for its political battles, Obama touted it as a model for a nation still recovering from a recession. He made his comments after taking a tour of the Albany NanoTech Complex at the College of Nanoscale Science and Engineering, a state-owned facility that has fostered lucrative partnerships that have injected billions of private investment in the state.

"Right now, some of the most advanced manufacturing work in America is being done right here in upstate New York," Obama said Tuesday. "Cutting-edge businesses from all over the world are deciding to build here and hire here. And you've got schools like this one that are training workers with the exact skills that those businesses are looking for."

It's a model that's been eighteen years in the making, and one that officials are hoping can be replicated across upstate and beyond. In introducing the president on Tuesday, Gov. Andrew Cuomo compared the work being done in Albany to that of the Erie Canal, which transformed the state's economy when it opened in the early 1800s.

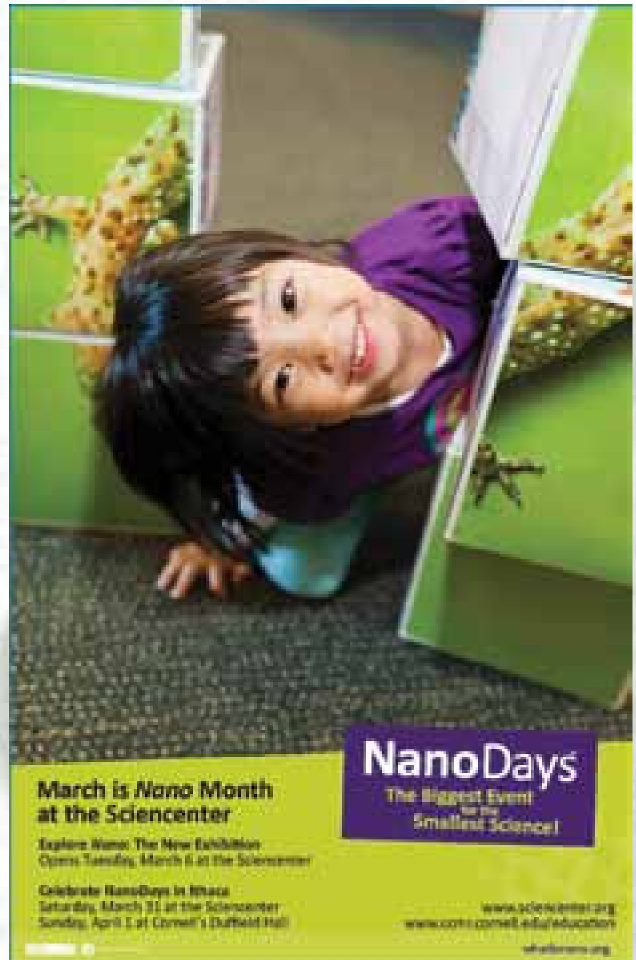
"With this new publicly managed and driven economic model, the governor is kind of repeating history," said Alain Kaloyeros, senior vice president and chief executive officer of the College of Nanoscale Science and Engineering. "But as opposed to using the Erie Canal as the physical, we're using now the innovation — nanotechnology — as a new Erie Canal to drive economic development."

Officials say that approach has been successful in the Capital Region, where the state has made an enormous investment of taxpayer funds in the Albany facility and a GlobalFoundries computer chip manufacturing center being built in Saratoga County. The company's plant, which is still under construction, is expected to have a total cost of more than $4 billion. GlobalFoundries was also part of the consortium that entered into the separate deal with the state in September.

NYS has become a hub for research and development of nanotechnology, which deals with looking at systems at a molecular level.

The Cornell NanoScale Science & Technology Facility in Ithaca traces its roots back more than 30 years, when it then began researching "submicron" technology, according to Robert Buhrman, senior vice provost for research. Now, the CNF focuses on partnering with startup companies with nanotech research and development, and pulls in about $20 million each year in federal funding. It partners with well-known companies as well, including Eastman Kodak and Xerox, according to Buhrman.

Kaloyeros said it's not a stretch to say the state's approach to nanotech will be replicated not just across the state, but across the country and world.



Sciencenter

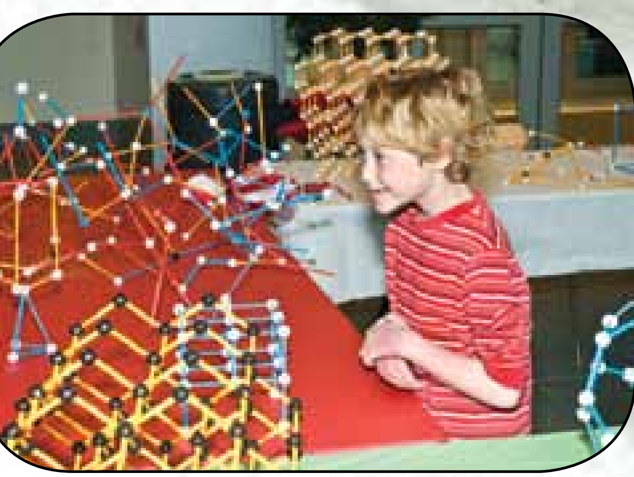
Going Small: Cornell Shows Off Nano-Sized Science

Simon Wheeler, Ithaca Journal, April 1, 2012

The beauty of a cathedral's stained glass and the diversion of a game of Angry Birds might not seem to have much in common, but each owes its function to one essential thing: nanotechnology.

Features at the mind-boggling scale of small were on display Sunday as part of NanoDays at Cornell University during the second day of a nationwide, weekend-long education and outreach initiative focused around nanoscale science, technology and engineering.

A nanometer, about the width of three atoms, measures one-billionth of a meter. Pluck out a single strand of hair, and you're holding something that's 100,000 nanometers wide. Some of the earliest experimenters with nanotechnology were stained glass artisans from the Middle Ages, said Jamie Benitez, a postdoctoral scholar at Cornell. "Only thing they were probably not aware they were using nanomaterials at the time."



Benitez, along with other Cornell students, scholars and professors, set up booths at Duffield Hall, showing off some of the interesting science being done at the nanoscale in an effort to educate, enlighten and entertain. For Benitez, that meant using nanoparticles of gold to demonstrate how stained glass is made. "When you go to tinier sizes at nanometer scale," he said, particles "have different behaviors, especially to light." In the glass, gold particles of 10 nanometers create ruby-red colors, while silver makes yellow hues. Put into the hands of an experienced artisan, those colors could awe from Canterbury to La Sainte-Chapelle.

While those artisans of centuries ago never knew the micro realms they exploited, researchers nowadays in business and academia in multimillion-dollar laboratories all over the world are exploring realms of space a million times smaller than a grain of sand. Such work has led to advances in computer technology used in hand-held devices, including those for playing time-killing games.

Activities like NanoDays aim to spur interest in science, said Garry Bordonaro, a microlithographic process engineer at the Cornell NanoScale Facility. "There seems to be a real lack of interest in math and science in this country," he said. "It's a cultural problem." Inviting members of the community — especially the youngest ones — to see the cutting edge work being done every day at Cornell, allows the science of the laboratories to spill out to an awaiting, engaged audience. It's important, he said, that "people see (science) as something other than a lot of boring numbers and class work — that it really is hands on, and exciting and stimulating."

Nanofluidics Sorts DNA One Molecule at a Time to Study Cancer-Causing Changes

By Bill Steele, Cornell Chronicle, May 23, 2012

Cornell nanotech researchers have devised a new tool to study epigenetic changes in deoxyribonucleic acid (DNA) that can cause cancer and other diseases: a nanoscale fluidic device that sorts and collects DNA, one molecule at a time.

Epigenetics refers to chemical changes in DNA that do not alter the actual genetic code, but can influence the expression of genes and can be passed on when cells reproduce. One of the most important is DNA methylation, where methyl groups — small structures of carbon and hydrogen — are appended to DNA. Biologists study this by chemically precipitating out the methylated molecules, but these methods require large samples and often damage or throw away molecules they are supposed to find. Nanofluidics offers a way to select individual molecules out of tiny samples and collect them for further study.

The new device, developed in the lab of Harold Craighead, the Charles W. Lake Jr. Professor of Engineering, is described in the May 21 early online edition of the Proceedings of the National Academy of Sciences. The process begins with a biochemical reaction that attaches a fluorescent tag to methylated DNA molecules. Then the sample is driven through a nanofluidic channel about 250 nm across — so small that DNA molecules go through one at a time. Lasers illuminate the stream and cause fluorescence. When a fluorescing molecule goes by, a detector triggers a pulsed electric field that pushes the molecule to one side just before the channel splits into a Y. Methylated molecules go down one branch, everything else down the other.

“The color identity becomes a barcode for how the molecules are treated,” explained Ben Cipriany, Ph.D., lead researcher on the project, drawing an analogy to the methods used by the post office to sort packages on a conveyor belt. “Eventually we could use multiple colors, each representing a different epigenetic characteristic,” he added.

The device reacts so swiftly that it can sort more than 500 molecules per minute, the researchers said. Fluorescent sorting is not new, they noted, but previously it has been done only with larger materials, such as nanoparticles or cells.

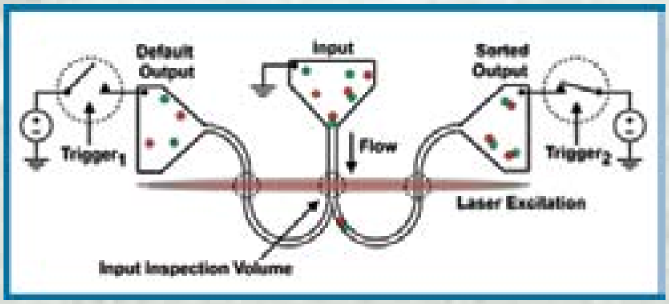


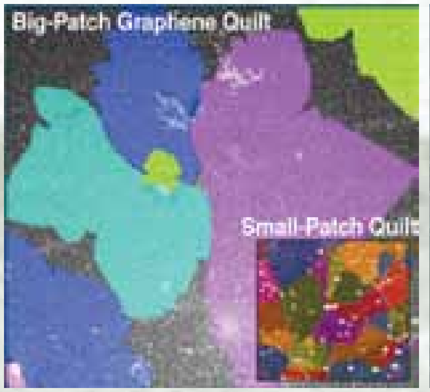
Figure 1: A mix of DNA molecules is pushed through a nanofluidic channel. Molecules tagged with a fluorescent tag trigger an electric field that diverts them to one side. Provided/Craighead Lab.

“We’ve made a miniaturized version that sorts individual molecules and works with a very tiny amount of input material,” Cipriany said.

To test their method, the researchers observed fluorescence in each arm of the Y. They also collected the tiny sample of molecules that had been sorted out as methylated, amplified it using the PCR (polymerized chain reaction) method familiar to organic chemists and analyzed the resulting sample. False positives were limited to about 1-2%, which compares favorably with other sorting methods, they said. The sorted output could be directed to a further microfluidic system for automated gene sequencing, the researchers suggested. The method also could be adapted to other molecule-separation tasks, they added.

The research was supported by the National Institutes of Health, Cornell Center for Invertebrate Genetics and the National Cancer Institute. Nanofabrication was performed at the Cornell NanoScale Science and Technology Facility, funded by the National Science Foundation.

Cipriany ‘12, who began this research as part of his Ph.D. studies at Cornell, is now at the IBM Semiconductor Research and Development Center in Hopewell Junction, N.Y.



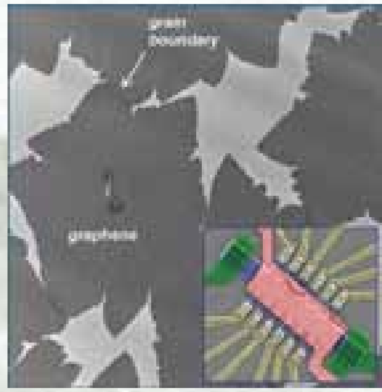


Figure 1, left: False-color microscopy images show examples of graphene grown slowly, resulting in large patches with poor stitching, and graphene grown more quickly, resulting in smaller patches with tighter stitching and better performance. Figure 1 Courtesy of Muller Lab.

Figure 2, right: An SEM image of graphene crystals growing on copper. The inset is a false-color SEM image of an electrical device consisting of a single grain boundary in graphene. Figure 2 Wei Tsen/Park Lab.

Tighter 'Stitching' Means Better Graphene, Scientists Say

By Anne Ju, Cornell Chronicle, May 31, 2012

Similar to how tighter stitches make for a better quality quilt, the "stitching" between individual crystals of graphene affects how well these carbon monolayers conduct electricity and retain their strength, Cornell researchers report. The quality of this "stitching" — the boundaries at which graphene crystals grow together and form sheets — is just as important as the size of the crystals themselves, which scientists had previously thought held the key to making better graphene.

The researchers, led by Jiwoong Park, assistant professor of chemistry and chemical biology and a member of the Kavli Institute at Cornell for Nanoscale Science, used advanced measurement and imaging techniques to make these claims, detailed online in the journal Science on June 1st.

Graphene is a single layer of carbon atoms, and materials scientists are engaged in a sort of arms race to manipulate and enhance its amazing properties — tensile strength, high electrical conductance, and potential applications in photonics, photovoltaics and electronics. Cartoons depict graphene like a perfect atomic chicken wire stretching ad infinitum. In reality, graphene is polycrystalline; it is grown via a process called chemical vapor deposition, in which small crystals, or grains, at random orientations grow by themselves and eventually join together in carbon-carbon bonds.

In work published in Nature last January, the group had used electron microscopy to liken these graphene sheets to patchwork quilts — each "patch" represented by the orientation of the graphene grains (and false colored to make them pretty). The researchers, along with other scientists, wondered how graphene's electrical properties would hold up based on its polycrystalline nature. Conventional wisdom and some prior indirect measurements had led scientists to surmise that growing graphene with larger crystals — fewer patches — might improve its properties.

The new work questions that dogma. The group compared how graphene performed based on different rates of growth via chemical vapor deposition; some they grew more slowly, and others, very quickly. They found that the more reactive, quick-growth graphene, with more patches, in certain ways performed better electronically than the slower growth graphene with larger patches. As it turned out, faster growth led to tighter stitching between grains, which improved the graphene's performance, as opposed to larger grains that were more loosely held together.

"What's important here is that we need to promote the growth environment so that the grains stitch together well," Park said. "What we are showing is that grain boundaries were a main concern, but it could be that it doesn't matter. We are finding that it's probably ok."

Equal in importance to these observations were the complex techniques they used to make the measurements — no easy task. A four-step electron beam lithography process, developed by Adam Tsen, an applied physics graduate student and the paper's first author, allowed the researchers to place electrodes on graphene, directly on top of a 10 nanometer-thick membrane substrate to measure electrical properties of single grain boundaries.

"Our technique sets a tone for how we can measure atomically thin materials in the future," Park added.

Collaborators led by David A. Muller, professor of applied and engineering physics and co-director of the Kavli Institute at Cornell for Nanoscale Science, used advanced transmission electron microscopy techniques to help Park's group image their graphene to show the differences in the grain sizes.

The work was supported by the Air Force Office of Scientific Research, and the National Science Foundation through the Cornell Center for Materials Research. Fabrication was performed in part at the Cornell NanoScale Science and Technology Facility.

Antje Baeumner has received the SUNY Chancellor Award in Excellence in Teaching, 2012, and the College of Engineering Sonny Yau '72 Teaching Award in Excellence in Teaching, 2011.

Also, a recent review article in Lab-on-a-Chip belonged for weeks to the 'top most downloaded' articles: Asiello, P. and Baeumner, A.J. "Miniaturized isothermal nucleic acid amplification, a review"; Lab Chip, vol. 11 (8), 1420 - 1430 (2011).

Diego Rey came to the CNF in 2002 as an intern in the National Nanotechnology Infrastructure Network Research Experience for Undergraduates (NNIN REU) Program. Diego returned to Cornell as a graduate student in BioMedical Engineering, and now, having recently graduated, he is the founder and CTO of GeneWeave Biosciences (geneweavebio.com). Congratulations on your many successes, Diego!

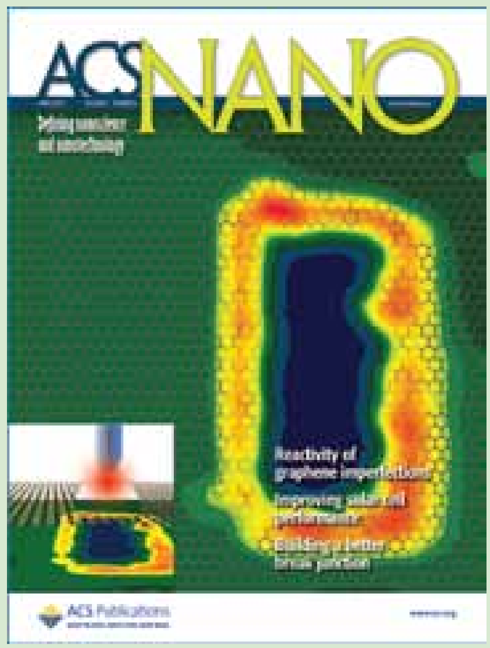
To Everyone at the CNF -

Thank you all so very much for hosting the Lansing seventh graders today - they had an a wonderful time! Here is a quick note from one of the teachers:

> "Lora the entire field trip was awesome! EVERYONE had a great time. The kids couldn't stop talking about it and the teachers already want to do it again next year. The grade levels other than 7th were so jealous when we got back and the kids started talking about it. Thank you so much for all of your hard work organizing it. We loved every minute!"

You guys rock!!
Thanks again, Lora

Lora K. Hine
Director of Educational Programs
Cornell Laboratory for Accelerator-Based Sciences and Education



ACS Nano Journal Cover

Users: Cen Tan, Joaquin Rodriguez-Lopez

Image Description: SEM of graphene and graphene imperfections. An SEM probe scans over the surface of single-layer graphene. The electron transfer kinetics is higher at regions with greater defect density compared to those with lower density.

Peter J. Lindner (right) recently graduated with a Ph.D. in chemical engineering from Stevens Institute of Technology, where he studied under Dr. Ronald S. Besser (left). His doctoral research entitled "Microplasma Reforming of Hydrocarbons" was based on MEMS microfluidic-plasma reactors used to breakdown hydrocarbons to produce a readily available stream of hydrogen for portable fuel cells. Two generations of these microplasma devices were fabricated at CNF with various geometries.

Recently, Dr. Lindner accepted an Assistant Professor position at Manhattan College teaching chemical engineering. There, he plans to implement nanotechnology focused research similar to the work previously done at CNF.

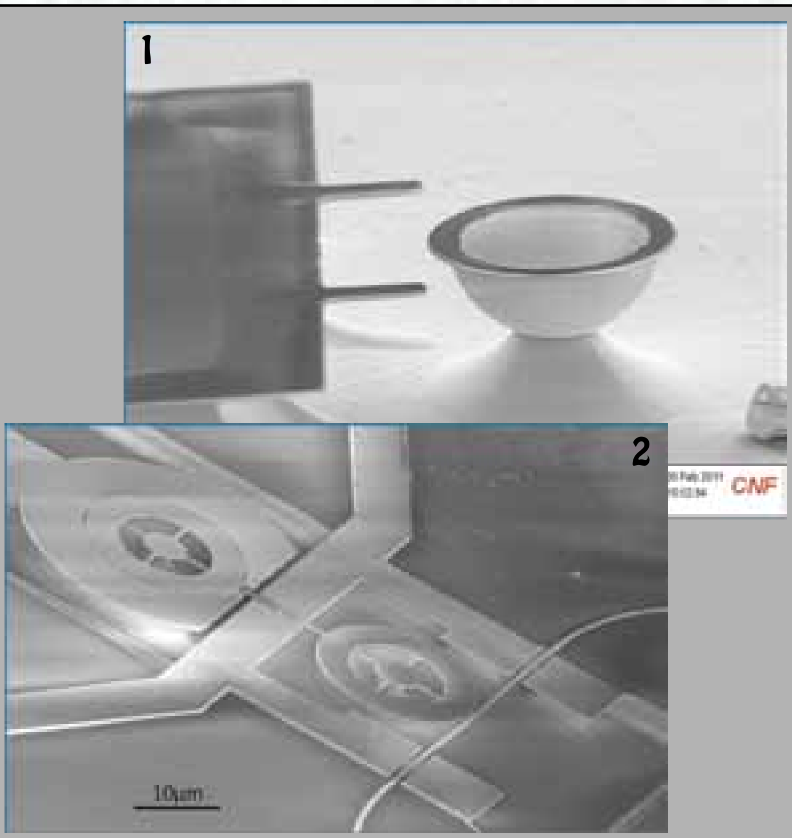
IBM recognizes Syracuse University Physicist for Excellence in Research: Britton L.T. Plourde receives 2011 IBM Faculty Award

Oct 31, 2011 | Article by: Judy Holmes

Britton L.T. Plourde, associate professor of physics in Syracuse University's College of Arts and Sciences, received a 2011 IBM Faculty Award. The highly competitive and prestigious award is presented annually to recognize high-quality research programs and researchers' contributions to their respective fields and comes with a cash grant of $34,000. The Faculty Award program fosters collaboration between researchers at leading universities worldwide and IBM, and promotes curriculum innovation to stimulate growth in disciplines and geographies that are strategic to IBM.

Plourde is a collaborator with IBM's TJ Watson Research Center, Yorktown Heights, N.Y., on a project to expand research in the area of quantum computing. Plourde's role in the project is to explore the fabrication of nanoscale superconducting circuits. Led by IBM, the collaboration includes Raytheon BBN Technologies in Cambridge, Mass., Princeton University, and the University of Wisconsin-Madison. The federal Intelligence Advanced Research Projects Agency (IARPA) is providing major funding for the research.

Over the past three years, Plourde has received more than $2.2 million from federal agencies to further his research into building nanoscale superconducting circuits that may someday form the basis of quantum computers. The funding includes grants from IARPA, DARPA, and NSF. The IARPA and DARPA grants were part of larger awards to Plourde's research associates at the University of Wisconsin-Madison; Saarland University, Germany; the University of California, Irvine; and IBM.



OMG: An Opto-Mechanical Gyroscope, Laura Fegely and Sunil Bhave, 2012

This issue's background image is the device pictured above, top — an 85 micron diameter silicon nitride GOBLiT: a goblet that vibrates due to light beams coupling into it. The goblet is fabricated on a silicon wafer at the Cornell NanoScale Science & Technology Facility (CNF). The interplay of laser beams and mechanical vibrations at the rim opens up fascinating avenues in ultra sensitive gyroscopy. The cover image, Figure 2 above, is from this same research group.

North versus South America PASI Soccer Match
(See PASI article on page 28)

NNIN Winter School: An Inspiring Boy from a Flood-Stricken Town

by Kevin Luke

It was a clear day in the large public square of the small Brazilian town we were in. All around us, young children, students, and parents were inquisitively exploring the many science booths we had set up. As participants of the NNIN Winter School Program, my fellow students and I had organized a science fair in the small town of Sao Luiz do Paraitinga in Sao Paolo, Brazil. We set up several booths in which we performed scientific demonstrations or simply had fun science toys for the Sao Luiz citizens to tinker with. One booth showcased the classic baking soda and vinegar reaction, using the violent reaction to inflate a balloon attached to the beaker. Another booth had magnets and metallic toys for kids to play with. All of the attendees, from toddlers to parents, were having a good time while learning a lot.

Most of the attendees ranged from excited little children with their parents, to interested but coolly aloof young teenagers. However, one young teenage boy, around 14 years of age, seemed more interested in us Americans than in our science experiments. As I began chatting with him in my broken kindergarten-level Portuguese (with the aid of another Brazilian student that had come with our NNIN group), I soon became captivated by his inspiring story — it gave insight into the darker side of Brazilian life.

Usually, we Americans think of Brazilians as a very happy and carefree people. Tales of the insane partying of the Brazilian Carnival season reinforce this stereotype. Although we are vaguely aware of the stark poverty portrayed in movies such as Cidade de Deus, we tend to think of these as isolated pockets of people that are not representative of the majority of Brazilians. Although the town of Sao Luiz do Paraitinga is not necessarily poor, it does have a history of tragedy. This small town has suffered several floods in the past, but none so bad as the recent flood on January 1, 2010. This flood was among the worst to hit the town, completely submerging most of the town itself. Indeed, as we traversed the very hilly town, we reached a high point where we could see the flood waterline on building walls. From the elevation of this waterline, we were amazed to look down and see most of the town beneath us. As a particularly crushing blow, during the 2010 flood the church in the central square — which had been built in the early nineteenth century and served as the symbol of Sao Luiz do Paraitinga — had collapsed completely.

As I began talking with the young boy at the science far, he started to open up and share his amazing firsthand experience with the disastrous flood. He happened to be in the church when the flood began. However, the flood waters soon rose to his chest level, and he realized it would be too dangerous to try to leave the church for higher ground. So naturally, he ascended to the higher levels of the church. However, the flood waters continued to rise. Eventually, he was standing on the roof of the church (which was several stories high). Perhaps he was a bit comforted by the fact that this church, the pillar of his town, had withstood many floods in the past. This comfort would not have lasted very long, though.

As the waters continued to rise, he began to see parts of the church beginning to crumble around him. With the flood waters continuing to rise, and the decreasing stability of the church he was standing on, he made a

bold decision to take the plunge. He jumped off of the roof of the church into the flood waters below and somehow managed to swim to higher ground. Ever since that traumatic moment, he has had a fear of heights.

As our conversation continued, he began to open up to me even more, revealing a dark side of his personal life. The conversation began very innocently — we were discussing what kind of instruments we played. I talked about playing the drums, and my fellow Brazilian student mentioned that he knew a few tunes on the guitar. The young boy responded that he used to play guitar, but he recently broke his guitar — on his brother's back. It turns out that his older brother was yelling at their mother, and the young boy attacked his older brother in order to protect his mother. This was rather surprising, given that fact that the young boy had mentioned previously that he was studying Brazilian Ju-Jitsu. However, he said that he could not use his martial arts training on his brother because he was only allowed to use his training for self-defense.

Despite the young boy's traumatic past and his grim family situation, he seemed highly motivated and had a bright outlook. He was diligently training in Brazilian Ju-Jitsu, and he dreamed of one day becoming a professional Mixed Martial Arts fighter — hopefully even in the American Ultimate Fighting Championship (UFC). His high hopes for the future, despite his past and present struggles, are truly inspiring.

He is still in my thoughts, and he will remain in my thoughts for the rest of my life.

Although I have taken back many memorable experiences and valuable lessons from my NNIN trip to Brazil, my relatively short conversation with this young boy has been among the most rewarding.

Kevin Luke is a Cornell University graduate student in the School of Electrical & Computer Engineering. He is also a CNF researcher working with Professor Michal Lipson on Optical Microcavities.

A damaged home, above, and the remains of the church, at right. Photos provded by Romy Fain, another Winter School participant from Cornell.

Live from CNF

By: Yajaira Sierra Sastre

Figure 1: Daron Westly giving a cleanroom tour with his iPhone at Natividad Rodríguez González High School.

More than 200 students from different school districts in the south coast of Puerto Rico had the opportunity to 'visit' the cleanroom facilities at '*El Centro de Fabricación a la Nanoescala de la Universidad de Cornell*' (or CFN in Spanish). Lab use manager Daron Westly and I have been collaborating on various projects on the island including nanotechnology workshops for K-12 students and virtual lab tours using Skype with a smart phone.

In the last few months, the CNF cleanroom became a virtual classroom in which the students learned about the lab environment and tools, and the processes used in the nanofabrication of tiny devices. Needless to say, top-down nanotechnology became something students could see as they 'wandered' around the different areas of the cleanroom and observed users dressing up, spinning resist on silicon wafers, operating equipment, and using the chemical hoods. The students were thrilled.

For many of them it was the first time they were seeing a science and technology lab and having real-time interactions with researchers. Curiosity kicked in and questions abounded — How is the air in the lab kept clean? How does resist spinning process work? Why are the lights in the cleanroom yellow? How expensive are those machines? What does it take to study a career in nanotechnology?

Ramón Rivera Ocasio (PREM outreach coordinator at University of Puerto Rico-Humacao) also joined us at Genaro Cautiño Vázquez, a public middle school specializing in science and math in the town of Guayama. We provided a historical overview about nanotechnology, described the process used to 'write' the smallest national anthem 'La Borinqueña,' and participated in hands-on activities to explore the properties of nanoscale materials — such as graphene, gold nanoparticles, ferrofluids, and butterfly wing structures.

I was impressed at the level of competence and enthusiasm of the students. One of them even described to us all he knew about the computing capabilities, size, and complexity of the first general-purpose computer (the ENIAC).

The nano-excitement on the island is so high that the nano himno (the nano anthem fabricated at CNF) even made it in the most widely read newspaper (El Nuevo Día) and a local TV show. Additionally, several students have joined our team of translators for the Spanish version of the website Nanooze (www.nanooze.org). We have been recruiting high school students to be

Figure 2: Outside the classroom at Jose Horacio Cora Middle School.

part of this effort and the following schools and municipalities are represented: Natividad Rodríguez González (Arroyo), Dra. María Socorro Lacot (Guayama), and Escuela Especializada en Ciencias y Matemáticas Thomas Armstrong Toro (Ponce).

Through this translation project we will provide an opportunity for students to responsibly engage in the dissemination of scientific literacy for a Hispanic audience with a huge need of Internet resources in our mother tongue ¡El Español! We look forward to having more opportunities to share the work at CNF and inspire a new generation of scientists and engineers from la Isla del Encanto (the Enchanted Island).

Media links:

http://www.elnuevodia.com/laborinquenamaspequena-1222612.html

http://www.wapa.tv/programas/entrenosotras/en-el-centro-del-universo---_20120417110126.html

Figure 4: Members of the team of student translators of Nanooze! Several of these students received scholarships and computers as part of an award ceremony of a non-profit organization where I currently serve as scientific advisor (Adelaida Bazán PS Inc.). From left to right: Edwin, Giancarlo, Paola, Yajaira, Lorenzo (back), Darinelys, Jan, Mrs. Peña (biology teacher).

Figure 3: Student Shania Rivera from Genaro Cautiño Vázquez Middle School. Shania contacted my mom asking for my contact information and helped coordinating our visit. Thank you, Shania, for serving as the point of contact!

CIENCIA 65

En el centro del universo

La Dra. Yajaira Sierra Sastre se destaca como científica, sin olvidar sus raíces

CIENTÍFICA MENTE

CNF Helps Organize International School on Simulation Approaches for Energy Research

Group Picture of PASI Participants

By Derek Stewart

Energy research requires a strong knowledge of material properties and in recent years, it has also demanded a greater understanding of how these properties can be manipulated on the nanoscale.

Simulations can provide important insight in this area and they can also help identify candidate materials or devices for further experimental testing. However, many of these approaches come with steep learning curves that can prevent young scientists from adopting them for their research. To address this issue, Dr. Derek Stewart and Prof. Richard Hennig hosted a Pan-American Advanced Studies Institute (PASI) on *Computational Materials Science for Energy Generation and Conversion* in Santiago, Chile in January. The school was made possible through a grant from the Pan American Advanced Studies Institute, which is jointly supported by the National Science Foundation and the Department of Energy.

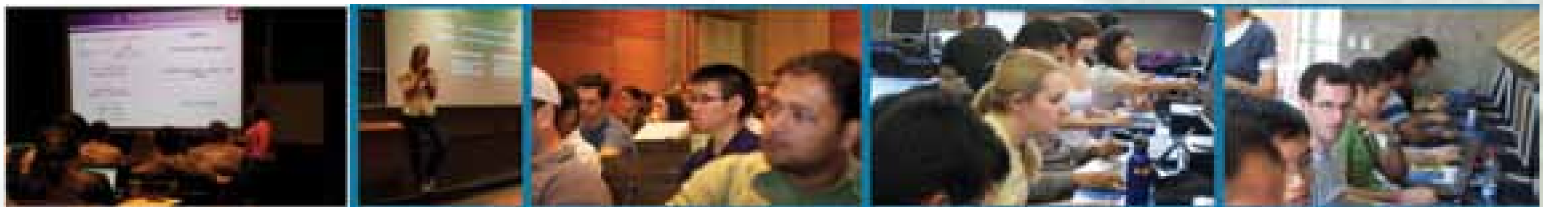
The PASI program focuses on both educating young researchers in critical areas of scientific research and also encouraging interaction and collaboration between North and South American participants. Additional support was also obtained from the Office of Global Naval Research, NNIN, the International Center for Materials Research, Cornell Center for Materials Research, and EMC^2. The workshop took place at Pontificia Universidad Catolica de Chile where the local host, Prof. Miguel Kiwi, greatly assisted with preparations. Additional organizers included Dr. Michelle Johannes of the Naval Research Laboratory, Dr. Valeria Ferrari (CNEA-Argentina) and Dr. Bruce Harmon (Ames National Laboratory).

This two week school brought together over forty graduate students and post-doctoral researchers from the United States (with participants from twelve states), Chile, Argentina, Mexico, Colombia, and Brazil. The workshop provided lectures in first principles density functional approaches, molecular dynamics, optical simulation techniques, and finite element calculations. Advanced topics included piezoelectrics for energy harvesting, lithium battery design, and engineering thermal properties of materials for next generation thermoelectrics. Students also participated in daily hands-on sessions to gain experience in various simulation approaches.

Although the workshop was held in Santiago, through an NSF Extreme Science and Engineering Discovery Environment (XSEDE) educational grant, students were able to access computational resources on the University of Texas supercomputer, Ranger, for their tutorial sessions. In keeping with the spirit of the PASI program, the workshop also organized a North versus South America soccer game in which North America had a respectable showing: *Final Score: South America 2: North America 1* (see team photo on page 23).

Many of the lectures and tutorials are available on the PASI website listed below. They will also be incorporating into existing tutorial material available to researchers at the CNF and through the NNIN.

Pan-American Advanced Studies Institute "Computational Material Science for Energy Generation and Conversion", Pontifica Universidad de Chile, Jan. 9th -20th, 2012, Santiago, Chile; http://www.cnf.cornell.edu/cnf_pasi2012.html



Lecturers during the PASI Workshop

Congratulations to Code Red Robotics!

By Karlis Musa

In May 2012, Code Red Robotics, the Ithaca High School's FIRST (For the Inspiration and Recognition of Science and Technology, www.usfirst.org) robotics team, attended the FIRST World Championships in St. Louis, Missouri. This is the first time in seven years that the team has been able to take part in the world competition and the opportunity would not have been possible without the generous support from the community.

Code Red was able to raise $28,000 in less than two weeks, which is certainly a remarkable feat that would not have been achieved if it weren't for the team's sponsors, one of which was the CNF.

Figure 1: One of the semi-final matches - in the six matches that we played during the elimination rounds, our alliance triple-balanced three times.

The team made a stunning comeback, after seeding 88th out of 100 teams in their division, by being selected by the third-ranked team to compete in the elimination tournament. The alliance consisted of Code Red Robotics from Ithaca, NY, Truck Town Thunder from Ortonville, MI, and the Beach Bots from Hermosa Beach, CA. This alliance, stretching through the continental United States, blazed through the competition, making it all the way to the divisional finals where there were 400 teams competing in four divisions.

In the quarterfinals, Code Red defeated the defending world champion, as well as a FIRST Hall of Fame member. In the semifinals, the alliance upset the second ranked alliance, a powerhouse alliance with a combined record of six regional wins during the season. Unfortunately, Code Red was defeated in the divisional finals by the first ranked alliance.

Nevertheless, all the hard work from the team certainly paid off, because Code Red finished in the top one percent of all teams worldwide, and made it farther than all other New York state teams.

IPEI

Ithaca Public Education Initiative

April 10, 2012

Cornell NanoScale Science & Technology Facility (CNF)
Attn: Mr. Don Tennant
250 Duffield Hall
Ithaca, NY 14853

Dear Don:

Thank you for your gift to support Code Red Robotics of Ithaca High School. I am pleased to be writing to acknowledge your gift of $800 on 04/05/2012 that will help the team participate in the international invitational competition in St. Louis this April. Your gift has been doubled by a generous donation from Kionix.

Code Red Robotics is affiliated with the Ithaca Public Education Initiative (IPEI) which provides necessary organizational support for the high school club. Financial support like your gift with contributions from relatives and friends as well as local, regional and national organizations is critical for the club operations.

Your generosity enables IPEI to carry out its mission is to enhance the education of every student through community connections and support. Our Grants Program, the Fine Arts Booster Group, and the *Kids Discover the Trail* collaboration are other exciting examples of our efforts to make a difference for our schools.

In addition, IPEI welcomes interested persons to join the committees and groups that are actively working to enhance local public education for all district students. Please contact me if you would like to get involved or if you have questions. You may also visit our web site for more information.

Thank you again for your support of Code Red Robotics and for your commitment to local public education!

Sincerely,

Mary

Mary M. Grainger
Development Committee

Tax ID # 16-1508703

As you have received no goods or services in return for your contribution, the full amount of your contribution is tax deductible to the extent permitted by the Internal Revenue Code.

New Staff Member: Christopher Alpha

Christopher Alpha is the newest addition to the CNF technical staff. His primary responsibilities are with the MVD100, VCA Optima, CMP, EV620/photolithography, KOH, and electroplate hoods as well as general wet chemistry work. Chris has a broad background and is a fab generalist — able to assist with process flow integration with an eye towards creating production device process flows for ease of manufacture.

Prior to joining the Cornell NanoScale Facility this past spring, Chris was Senior Product Development Engineer at Advion, Inc. — responsible for creating new microfluidic platforms for the mass spectrometry market, and supporting the ESIchip® fabrication and consumables production at Advion.

Many years ago, in 2000, Chris started working at the CNF as an industrial user to develop the ESIchip — which was the core technology at Advion — and bring it into commercial production. The ESIchip consists of an array of nanoelectrospray ionization (nESI) emitters and is a consumable item for use in the Triversa Nanomate, which is an automated platform for performing nESI as a means of sample introduction into atmospheric pressure ionization mass spectrometers. Core markets for these technologies spanned the life sciences (proteomics, lipidomics, etc.) and pharmaceutical research applications. Other recent work included development of liquid surface sampling strategies and a new smaller dedicated nESI/nano liquid chromatography (nLC) robotic ion source for Advion. Chris also worked with another CNF startup — NABsys — in their efforts to create a genomic DNA sequencing chip.

Chris has a diverse background in biology, mass spectrometry (MS) and nanofabrication with other prior experiences helping run a core MS facility here at Cornell, and work at Corning, Inc., in fundamental research and development at Sullivan Park.

Chris is native to the area and did undergraduate work at St. Lawrence University and graduate work at the University of Hawai'i. Outside of work Chris enjoys riding and working on his collection of old motorcycles and cars, working in his home orchard and is a rabid road-racing fan.

CNF TCN

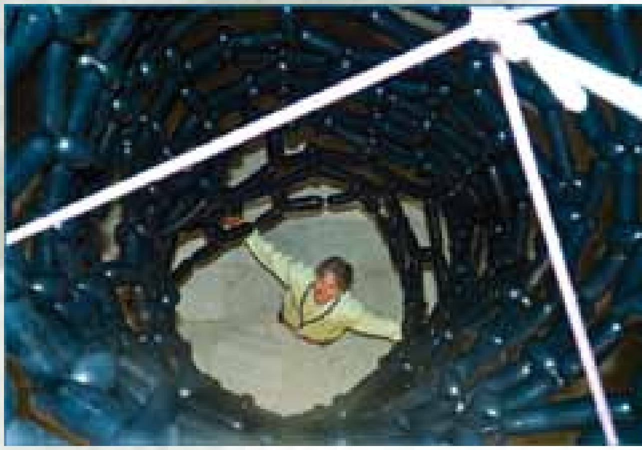
"*Technology & Characterization at the Nanoscale*" (TCN) is CNF's introductory course to nanotechnology. The course is open to the public and aims to educate students, industrial personnel, technology managers and entrepreneurs. CNF offers the TCN semiannually during the summer and winter recess, so that students from Cornell and other universities can easily participate.

The content of the TCN is designed to encompass all nanotechnology techniques relevant to current research in the field. While traditional topics — thin films, lithography, pattern transfer (etching), and characterization — provide the basic structure of the course, we include emerging technologies and new approaches. The printed notes for the TCN course have been developed over 16 years and are a highly valued resource. The lectures on fabrication and the laboratory demonstrations are organized so that they center around three topics: microfluidics, microelectromechanical systems and nanostructures. Hands-on sessions are available for teaching photolithography as well as microfluidic device fabrication and operation.

For more on the TCN, visit www.cnf.cornell.edu/cnf5_courses.html or contact Dr. Mandy B. Esch at mandy.esch@cornell.edu.

CNF & ASML

CNF is pleased to be participating in a technology partnership with ASML, the world's leading manufacturer of wafer exposure systems. Through this agreement, CNF provides a fully-equipped demonstration facility for one of ASML's world-class optical exposure tools, with the capability of completing multiple manufacturing process steps. In this way ASML can show customers how the tools can function in real-world situations. ASML provides CNF favorable rates for maintenance and parts, as well as leading-edge upgrades to both hardware and software. This allows CNF to provide capabilities that would otherwise be unattainable without large funding commitments.



For information and training on the ASML, contact Garry Bordonaro, bordonaro@cnf.cornell.edu

From ASML's brochure:

> ***ASML has shared demo capabilities with two premiere universities, Cornell's CNF and Stanford's SNF. In cooperation with these universities, ASML is able to demo and utilize the ASML steppers and other non-litho equipment on site to showcase the benefit of the equipment and options through short loop experiments, in some cases, right through die yields.***
>
> ***The process capabilities at CNF include Photolithography, Furnace Processing, Computer Facilities, Electron-Beam Lithography, Electrical Testing, Metrology, SEMS / Microscopes, Etching, Thin Film Deposition, Packaging and Miscellaneous Processing, and In-house Reticle Design and Manufacturing. CNF also hosts The Societal and Ethical Issues (SEI) Program and other Educational programs.***
>
> ***The options available on the ASML stepper at CNF include Compound Image, 3DAlign (backside alignment), Annular Illumination, Scribe Line Marks, Multi-Step Imaging, Shifted Measurement Scan, Extended NA Range, and Single Reticle SMIF. The stepper can also accommodate 3″ – 200 mm wafers in thicknesses up to 1 mm.***

Toho FLX-2320-S

CNF is now using a new Toho FLX-2320-S, which was purchased to replace the old Flexus thin film stress measurement system. The new system uses a laser scanning technique to measure substrate curvature before and after coating and will then calculate the stress in the coating. The new system runs on Windows 7, and allows finer mapping of both 4″ and 6″ wafer surfaces, as well as film stress vs. temperature. The biggest advantage is that all data can be downloaded through USB 2.0, and can now be processed with FLX software also downloaded on CNF users computers for analysis and presentation.

For more information and tool training contact Jerry Drumheller, drumheller@cnf.cornell.edu.

Significant Upgrade to the Oxford PlasmaLab 100 for Nanoscale Dielectric Etching

Earlier this year, a substantial upgrade to the Oxford 100 ICP etch system was completed. This upgrade included the installation of a large 12 gas pod, a gas ring manifold, and the latest version of the PLC.

The installation of a larger gas pod allows us to expand our gas chemistry to include more advanced fluorocarbon based gases. The installation of the gas ring manifold will supplement the existing gas showerhead. The gas ring is placed in close proximity to the electrode on which substrates are placed. The gas ring will alter the dissociation and ionization percentages in the plasma and allow us to effectively tune the plasma gas chemistry. The new PLC will allow us to direct the flow of gases to either the showerhead or the gas ring, depending on the device etch requirements by a simple programming of the etch recipe.

This upgrade was proposed as part of CNF's ongoing cooperative development agreement with Oxford Instruments. The role of the Oxford 100 system is dielectric etching of primarily silicon oxide, fused silica, and silicon nitride. Dielectrics, such as these, rely on the use of fluorocarbon based chemistry with a fluorine to carbon ratio of 3 or less due to its intrinsic polymer forming nature. Polymer forming precursor gases — especially those with large monomer structure such as C_4F_8 and C_2F_6 — are increasing used for dielectric etching in the microelectronics industry.

Our upgrade includes the investigation of up to three advanced fluorocarbon chemistries, specifically C_4F_6, CH_2F_2, and C_5F_8. The lower F/C ratio will enhance polymerization allowing us to achieve greater etch selectivity to silicon and to advanced lithographic resists such as those used in deep UV (DUV), electron beam, and nanoimprint lithography.

As the need for nanoscale lithographic resolution at increasingly small dimensions continues to drive down the resist thickness, selectivity of the etch becomes paramount. The use of additive gases such as O_2, H_2, CO, CO_2, etc., can further modify the plasma gas chemistry to either increase or decrease the degree of polymerization thereby influencing selectivity. The additional selectivity attained with respect to these advanced resist systems will enable users to achieve high aspect ratio etching of nanoscale features in excess of 15:1. Further process development with these new advanced chemistries will expand upon our recent work of nanoscale etching of fused silica, silicon nitride, and silicon oxide as illustrated in the following SEM images, depicting pattern transfer of nanoscale features defined by electron beam and DUV lithography.

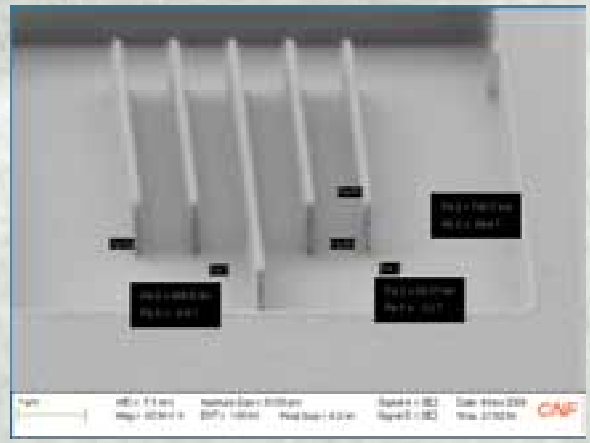


Figure 1: ASML DUV defined silicon nitride etched with CHF_3/O_2 in the Oxford 100.

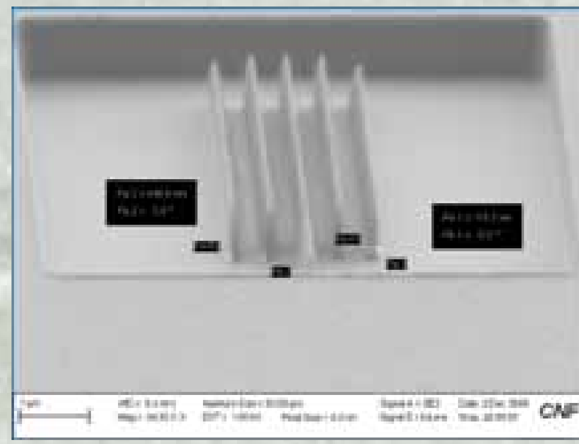


Figure 2: ASML DUV defined silicon oxide etched with CHF_3/CO_2 in the Oxford 100.

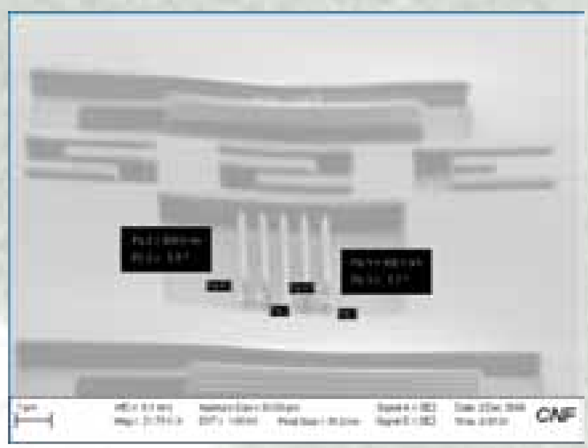


Figure 3: ASML DUV defined silicon oxide etched with CHF_3/O_2 in the Oxford 100.

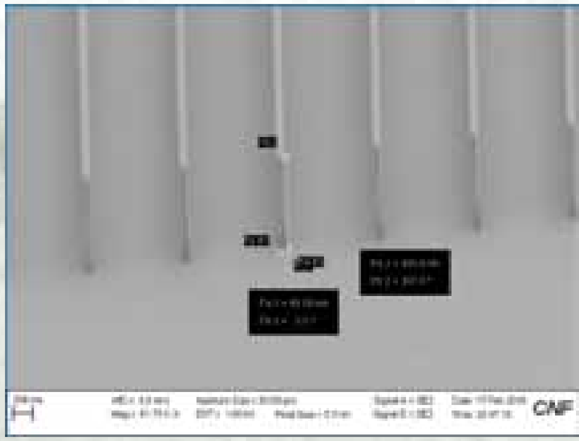


Figure 4: EBL Chrome masked fused silica etched with C_4F_8/CO_2 in the Oxford 100.

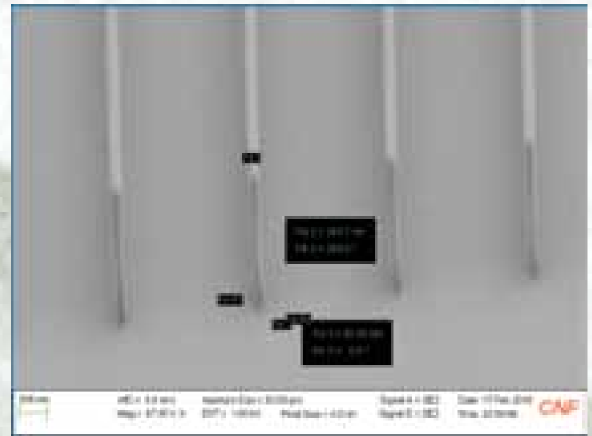


Figure 5: EBL Chrome masked fused silica etched with C_4F_8/CO_2 in the Oxford 100.

These enhanced capabilities of the Oxford 100 will benefit users who are fabricating a wide variety of devices including those in nanophotonics, advanced CMOS, and NEMS where precise high aspect ratio structures need to be defined by pattern transfer. For further information on these processes, please contact CNF research staff member Vince Genova, genova@cnf.cornell.edu.

The VersaLaser

The CNF's VersaLaser is a versatile tool that is very useful for fabricating micron-scale or larger devices in polymers and glass. It's always interesting to see what the user community makes using the laser. Previously, we reported on toroids of silicon oxide, and staff member Beth Rhoades has demonstrated a variety of microfluidic devices at the annual meetings in materials such as acrylic, silicone, and paper and shadow masks in fused silica or quartz.

Just recently, Dave Moore from the Hanrath group has used the laser to create a collection of excellent shadow masks for creating electrodes in working photovoltaic cells.

The Hanrath Energy Laboratory focuses on the study of optoelectronic properties of semiconductor nanocrystals, both fundamentally and in applied devices. For fabricating these masks, the VersaLaser was especially useful in prototyping mask designs and creating a spectrum of final mask patterns. The laser provided several key advantages compared to masks made using a traditional machine shop process including: (1) the laser is fast reducing the design-to-implementation cycle to a matter of hours, (2) the laser gives much sharper corners, leading to more precise device areas, and (3) the laser can cut thinner materials minimizing the shadow effect during sputtering or evaporation processes.

Dave created a library of patterned shadow masks that could be mounted in metal holders that were made elsewhere. (Unfortunately, the VersaLaser does not cut metals.) Take a look at a couple of masks. And contact Beth Rhoades for laser training (rhoades@cnf.cornell.edu).

Polymer shadow masks made using the VersaLaser:

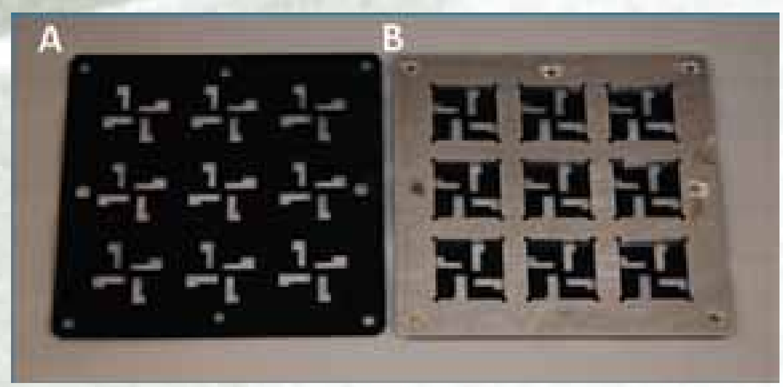


Figure 1: Thin polymer (254 µm thickness) was cut on the VersaLaser to yield sharp corners and ultrathin shadow profiles for use as a shadow masks. Laser jobs were run in a matter of minutes per mask with excellent reproducibility of features. Alignment and mounting holes were cut for aligning to other mask designs. (A) Kapton© mask for use in ITO sputter deposition tool. (B) Kapton© mask (black underside) mounted in a metal holder (made in the Clark Hall machine shop) for use in thermal evaporation for placing metal contacts.

Figure 2: Pre-purchased glass with a layer of fluorine tin oxide (FTO). The electrode pattern was etched directly into the FTO using the VersaLaser.

Versaline Deep Reactive Ion Etcher Achieving High Aspect Ratios

The Oerlikon (now PlasmaTherm) Versaline Deep Reactive Ion Etcher (DRIE) has an extensive list of process capabilities and is capable of producing dramatic high aspect ratio structures, such as those seen in the accompanying figures.

The high throughput, close-coupled turbo pump and fast throttle valve in combination with the fast switching gas configuration enable the process to achieve up to 7 µm per minute etch rate with minimal sidewall scalloping. The control software has the ability to continuously adjust the process conditions over the duration of the etch process. This is referred to as morphing, which enables the user to tune the polymer passivation and etch conditions on a per cycle basis. With this technique, the appropriate balance between the amount of polymer deposited in the passivation step and the extent of the etch step can be maintained for every cycle or loop of the etch process. This may be as simple as adjusting the time duration of the step(s) in each cycle or it may require that the gas flows, pressure, ICP power or DC bias voltage all be modified.

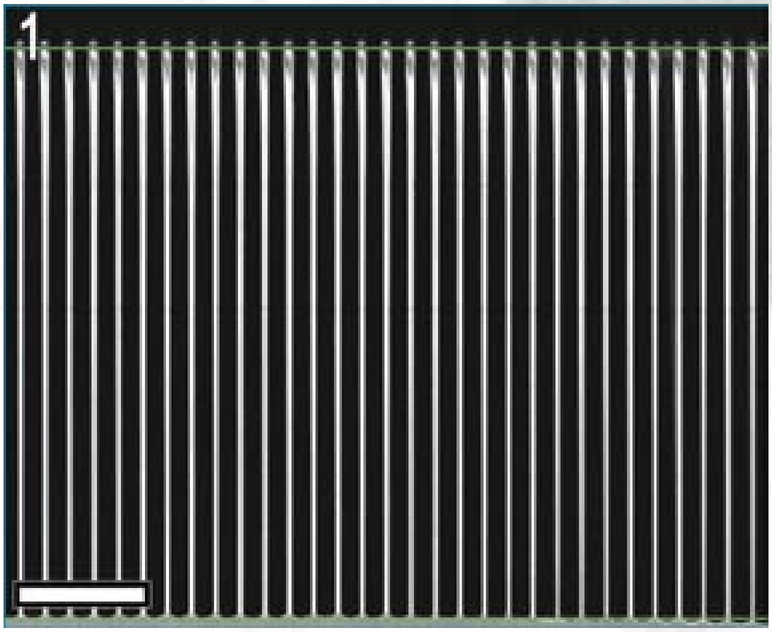
Parameter values may increase or decrease using linear or non-linear interpolation algorithms. The images illustrate the result of recent development work conducted with a 1 cm^2 two-dimensional array of two micron diameter pillars with a four micron center-to-center spacing. This pattern area is important to note, as both micro- and macro-loading effects play significant role in the process.

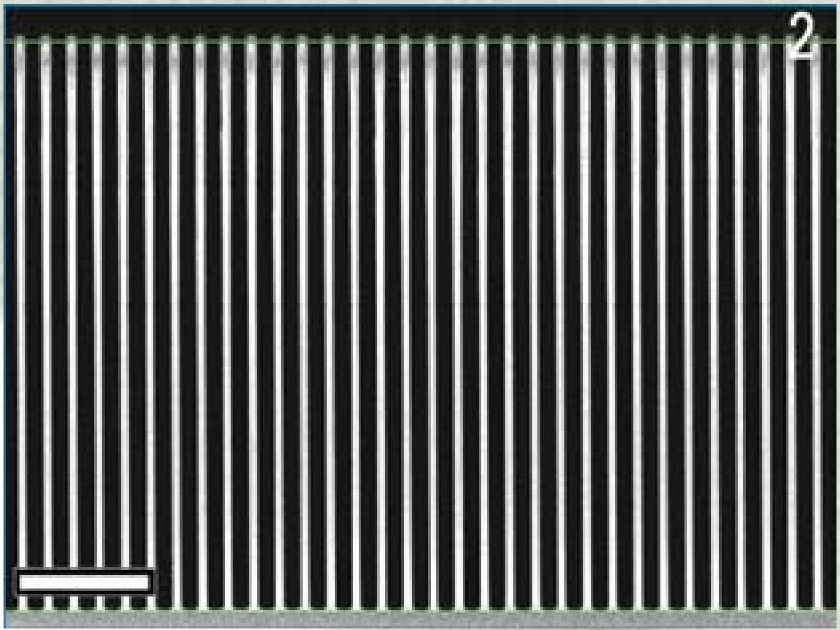
Figure 1 shows an etch profile that is 94 µm deep with a resulting aspect ratio of 47:1. The pillars show some taper as they are narrower at the bottom than at the top.

Figure 2 shows further improvement made by tuning the morph conditions. The etch depth e is 90 µm with a resulting aspect ratio of 45:1, and the degree of tapering is substantially reduced. The scale bar in both figures is 20 µm.

Results to date indicate that it is possible to push the aspect ratio limits even further!

For more information and tool training contact Vince Genova (genova@cnf.cornell.edu) and or Meredith Metzler (metzler@cnf.cornell.edu).





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CNF Hosted Vendor Events

The CNF has hosted several very successful vendor workshops over the past year; a SÜSS MicroTec Wafer Bonding and Lithography Workshop in September, and the GenISys BEAMeeting Technical Workshop & Discussion in November and Beamer Workshop in February.

We are currently working with Plasma-Therm on their workshop in August, as announced on the back page.

If your company is interesting in arranging such an event, please contact Don Tennant to begin the planning, tennant@cnf.cornell.edu.

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Your Comments Are Welcome!

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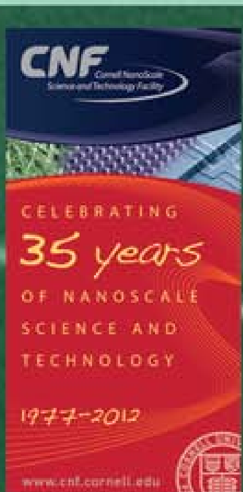

CNF 35th Anniversary Celebration & Annual Meeting

Thursday, July 19, 2012

Please Join Us! Register Now!

http://www.cnf.cornell.edu/cnf_35th2012am.html

PLASMA-THERM WORKSHOP:

Fundamentals of Plasma Processing (Etching and Deposition)

21 August 2012

http://www.cnf.cornell.edu/cnf_2012plasmatherm.html

The Cornell NanoScale Science & Technology Facility (CNF) has been serving the science and engineering community since 1977. The CNF is supported by the National Science Foundation, the New York State Office of Science, Technology & Academic Research (NYSTAR), Cornell University, Industry, and our Users.

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