

# NanoMeter

The newsletter of the Cornell NanoScale Science & Technology Facility

Winter 2006 • Volume 16, Number 2

## Directors' Column

It is with pleasure that we present to you the Winter 2006 issue of NanoMeter; the first issue since the two of us joined the CNF crew in mid-August. We would like to take this opportunity to thank John Silcox, the David E. Burr Professor of Engineering, for his outstanding leadership as interim Director of the CNF. We are also grateful to Dr. Jurriaan Gerretsen, who served as the interim Associate Director of the CNF.

Nanotechnology is a field which originated in the disciplines of engineering and physical sciences and has since expanded into the realm of life sciences. The application of nanotechnology to biological sciences is a relatively new venture. However, it seems that there are a multitude of ways in which the latter is benefiting from the ultimate control over matter proffered by nanotechnology. Several of the research projects at the CNF reflect this blossoming relationship between nanotechnology and biological sciences, as you may read in our newly published 2005-2006 CNF Research Accomplishments (available in PDF at [www.cnf.cornell.edu](http://www.cnf.cornell.edu)).

The next step along this path will be to extend nanotechnology to the area of medicine. Some of the benefits of this endeavor are obvious, such as improved materials for *in vivo* imaging and better tools for surgery. However, this is truly uncharted territory, with countless opportunities and possibilities to make a real impact on the future directions of medicine. CNF is poised to play a leading role in this emerging field, and we are pleased to announce that the CNF is launching an initiative in nanomedicine. At CNF we aspire to develop the appropriate capabilities and also to nucleate projects that will propagate the benefits of nanotechnology in the field of medicine. Look for future updates from us on this new enterprise over the coming months.

On a related note, the 30<sup>th</sup> anniversary of CNF will be celebrated next summer, on June 14<sup>th</sup>, 2007, with a major symposium along with our annual meeting. The overarching theme of the symposium will be the future of nanotechnology, which will be explored along three tracks. One of these tracks will be on nanomedicine, which will set the stage in defining important research directions in this emerging field. The second track will be on post-Moore's law and other future trends in nanotechnology, and the third track will be on social & ethical issues of nanotechnology. Each track will be introduced by a keynote presentation, while a major poster session will give our user community the opportunity to present their work. We hope this program will have broad appeal and will bring together many of you who have played a role in the rich life of the CNF. Please mark this date on your calendar and plan on joining the celebration!

Warm regards,  
George Malliaras, Lester B. Knight Director  
Donald Tennant, Director of Operations

## In This Issue...

DIRECTORS' COLUMN .....	1
INTRODUCING GEORGE MALLIARAS & DONALD TENNANT .....	2
SHIMON PERES VISITS CORNELL .....	3
RECENT RESEARCH AT CNF .....	4
SANDIP TIWARI RECEIVES BRUNETTI AWARD .....	5
IMAGES OF 2006 CNF ANNUAL MEETING .....	6
CNF 30 <sup>TH</sup> ANNIVERSARY CELEBRATION .....	8
2006 NNIN REU PROGRAM .....	9
NEW TOOLS & CAPABILITIES AT CNF.....	10
2006 CNF WHETTEN AWARD WINNER .....	12
JAMIE COHEN	
RECENT CNF-RELATED PATENTS, PRESENTATIONS & PUBLICATIONS .....	14
NEW STAFF AT CNF.....	15
CNF SHORT COURSE: TECHNOLOGY & CHARACTERIZATION OF THE NANOSCALE .....	15



Congressman Maurice Hinchey visits with George Malliaras and Donald Tennant at the CNF

Header SEM: Synthetic poly(dimethylsiloxane) fibrillar surface with terminal film. CNF Project # I225-04, "Mimicry of Biological Adhesion Through Fabrication of Fibrillar Surfaces." Principal Investigator: Anand Jagota, Users: Nicholas J. Glassmaker, Shilpi Vajpayee, Affiliation: Dept. of Chemical Engineering, Lehigh University.

# George Malliaras & Donald Tennant named directors of Cornell NanoScale Facility

*Adapted from article by Bill Steele*

George Malliaras, associate professor of materials science and engineering at Cornell, has been named the L.B. Knight Director of the Cornell NanoScale Facility (CNF), starting August 15. Donald Tennant, a 1973 Cornell graduate in engineering physics, and an alumnus of Bell Lab Lucent Technologies, began as CNF's Director of Operations on the same date.

The appointments are the result of more than a year's search in collaboration with researchers who use the national user facility, which is largely supported by the National Science Foundation.

"George and Don will bring new energies and new ideas to CNF, a facility that is already thriving," said Joseph Burns, the I.P. Church Professor of Theoretical and Applied Mechanics and Astronomy, and vice provost for physical sciences and engineering at Cornell, in announcing the appointments.

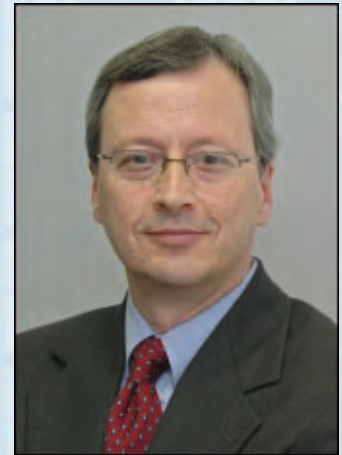
Malliaras succeeds Sandip Tiwari, professor of electrical and computer engineering, who served as director of CNF from 1999 until 2005, when he left to become Director of the National Nanotechnology Infrastructure Network, a consortium of 13 nanoscale manufacturing facilities, including CNF. John Silcox, the David E. Burr Professor of Engineering, has served as interim Director since then, with senior research associate Jurriaan Gerretsen as Associate Director.

"I'm honored and delighted," Malliaras said. "CNF has established a dominance in nanoscience and nanotechnology, and the challenge is going to be to perpetuate that excellence. And I look forward in particular to working with Don Tennant. We have a lot to learn from each other."



*George Malliaras*

Malliaras said he plans to expand CNF's efforts to work with biologists and hopes to bring in the medical community. "There are calls from the medical community, especially from surgeons, for better tools, and I think we can help with that." As part of the celebration of CNF's 30th anniversary in 2007, Malliaras plans



*Donald Tennant*

a major symposium, one track of which will deal with nanotechnology in medicine.

Malliaras' research focuses on organic electronics, the use of organic materials in place of such traditional semiconductors as silicon to create electronic devices, including organic light emitting diodes, organic thin film transistors and organic photovoltaics. He received a B.S. in physics from Aristotle University, Greece, in 1991, and a Ph.D. in mathematics and physical sciences from the University of Groningen, the Netherlands, in 1995.

Before joining the Cornell faculty in 1998, he spent two years at the IBM Almaden Research Center. He is the recipient of the National Science Foundation (NSF) Young Investigator Award, the DuPont Young Professor Grant and a Cornell College of Engineering Teaching Award. He is the chairman of the editorial board of the Journal of Materials Chemistry and serves on the editorial board of Sensors.

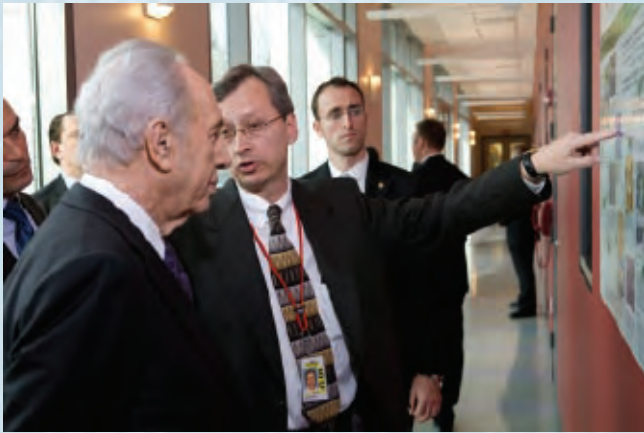
Don Tennant was a Distinguished Member of Technology Staff at Lucent Technologies, N.J.. He is one of the nation's most highly respected experts in nanofabrication and electron-beam lithography, and has been active in professional advisory roles.

**The Cornell NanoScale Science & Technology Facility  
is a member of the  
National Nanotechnology Infrastructure Network  
and is supported by:**

**The National Science Foundation,  
the New York State Office of Science,  
Technology and Academic Research,  
Cornell University, Industry, & our Users.**



# Israeli elder statesman Peres visits Cornell



Robert Barker/University Photography

Donald Tennant, director of operations at the Cornell NanoScale Facility, leads Peres on a tour of Duffield Hall.

## On visit to Cornell, Israeli elder statesman Peres sees technology at work and points to it as a key to peace

Excerpts of article by Daniel Aloi

Israeli elder statesman and former prime minister Shimon Peres stressed the role of science, technology and innovation in a global economy as a key to peace in the Middle East in a public lecture in Bailey Hall on Nov. 28. “Science doesn’t know nationalities,” he commented at a press conference before his speech.

While at Cornell, Peres met with President David Skorton and student leaders. He also toured Duffield Hall’s nanotechnology facilities, and during his talk he praised Cornell for its vision of the future. “You belong to the future, and you are going to participate in it.”

Skorton introduced Peres, who is currently Israel’s vice prime minister and who served as prime minister from 1984 to 1986 and 1995-96, as a key figure throughout Israel’s conflict-ridden history. Peres’ role in the Oslo Accords earned him the 1994 Nobel Peace Prize, which he shared with Prime Minister Yitzhak Rabin and Palestinian leader Yasser Arafat.

“He’s the last of Israel’s founders still in public service, and he has held every position of note in Israel’s government,” Skorton said.

During the lecture, Peres said, “Since the second World War, the driving force in history is more economy than strategy. You can build empires without force—take a look at Bill Gates, at the Google example. They really did it by negotiating with the potential of the future, successfully.”

Peres also related Cornell to this vision of change in world affairs. “The United Nations belongs more to the past than the future, and Cornell belongs more to the future than the past,” he said. “Today, I’m not sure the players are nations—they have lost their nationship. Today the greatest organizations are firms, serving an international economy. ... Your university is really a multi-language/multicultural university, and your outlook is really very good.”

As minister for the development of the Negev and Galilee regions of Israel, Peres has a keen interest in technology, water conservation and energy issues. During his tour of Duffield Hall, Peres learned firsthand of recent research at Cornell from Donald Tennant, director of operations at the Cornell NanoScale Facility, W. Kent Fuchs, dean of the College of Engineering, and from applied and engineering physics (AEP) professors.

Professor Harold Craighead told Peres of new techniques for DNA sequencing and applications for electrospun polymer microfibers and mentioned ongoing collaborations between Cornell and Tel Aviv University. Tennant talked about an exercise in making the world’s smallest tennis racket and about applications for sensing devices, including disease control and use “on the battlefield—seeing dust particles down to a single molecule.”

Peres questioned his guides throughout the tour—about medical applications, powering nanodevices and the scanning electron microscope, on which he was shown images of single atoms of strontium and titanium on a slice of semiconductor material magnified up to 29 million times.

“If this wafer is the United States, one chip on it is a car parked somewhere ... and one atom is a pin somewhere in a car,” said David Muller, AEP associate professor.

Peres, obviously impressed, called the demonstrations “fascinating.”



Robert Barker/University Photography

Tennant presents Peres with a portfolio on nanotechnology.

# Researchers create a broadband light amplifier on a chip

By Bill Steele

Cornell researchers have created a broadband light amplifier on a silicon chip, a major breakthrough in the quest to create photonic microchips. In such microchips, beams of light traveling through microscopic waveguides will replace electric currents traveling through microscopic wires.

A team of researchers working with Alexander Gaeta, Cornell professor of applied and engineering physics, and Michal Lipson, assistant professor of electrical and computer engineering, used the Cornell NanoScale Facility (CNF) to make the devices. They reported their results in the June 22 issue of the journal *Nature*.

In four-wave mixing, two photons at a pump wavelength are converted into two new photons, one at the signal wavelength and one at a wavelength equal to twice the pump wavelength minus the signal wavelength. The new signal photons combine with the originals to create an amplified signal. The idler photons are a copy of the signal at a new wavelength, so the system can be used to convert a signal from one communications channel to another. The amplifier uses a phenomenon known as four-wave mixing, in which a signal to be amplified is “pumped” by another light source inside a very narrow waveguide. The waveguide is a channel only 300 x 550 nm wide, smaller than the wavelength of the infrared light traveling through it. The photons of light in the pump and signal beams are tightly confined, allowing for transfer of energy between the two beams.

The advantage this scheme offers over previous methods of light amplification is that it works over a fairly broad range of wavelengths. Photonic circuits are expected to find their first applications as repeaters and routers for fiber-optic communications, where several different wavelengths are sent over a single fiber at the same time. The new broadband device makes it possible to amplify the multiplexed traffic all at once.

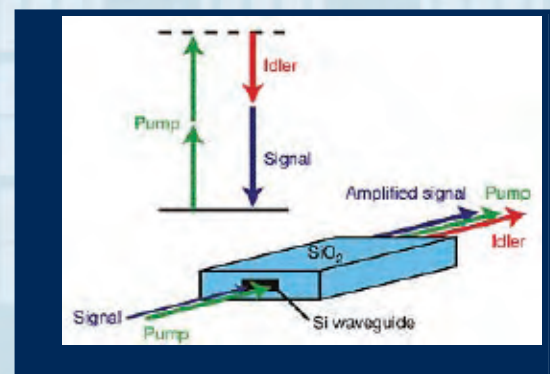
The process also creates a duplicate signal at a different wavelength, so the devices could be used to convert a signal from one wavelength to another.

Although four-wave mixing amplifiers have been made with optical fibers, such devices are tens of meters long. Researchers are working to create photonic circuits on silicon because silicon devices can be manufactured cheaply, and photonics on silicon can easily be combined with electronics on the same chip.

“A number of groups are trying to develop optical amplifiers that are silicon compatible,” Gaeta said. “One of the reasons we were successful is that Michal Lipson’s group has a lot of experience in making photonic devices on silicon.” That experience, plus the manufacturing tools available at the Cornell NanoScale Facility, made it possible to create waveguides with the precise dimensions needed. The waveguides are silicon channels surrounded by silicon dioxide.

Computer simulations by the Cornell team predicted that a waveguide with a cross section of 300 x 600 nm would support four-wave mixing, while neither a slightly smaller one—200 x 400 nm—nor a larger one—1  $\mu\text{m}$  x 1.5  $\mu\text{m}$ —would. When Lipson’s Cornell Nanophotonics Group built the devices, those numbers checked out, with best results obtained with a channel measuring 300 x 550 nm. The devices were tested with infrared light at wavelengths near 1,555 nm, the light used in most fiber-optic communications. Amplification took place over a range of wavelengths 28 nm wide, from 1,512 to 1,535 nm. Longer waveguides gave greater amplification in a range from 1,525 to 1,540 nm. The researchers predict that even better performance can be obtained by refining the process. They also predict that other applications of four-wave mixing already demonstrated in optical fibers will now be possible in silicon, including all-optical switching, optical signal regeneration and optical sources for quantum computing.

The work was supported by the Cornell Center for Nanoscale Systems. The Center for Nanoscale Systems and the CNF are funded by the National Science Foundation and the New York State Office for Science, Technology and Academic Research.



In four-wave mixing, two photons at a pump wavelength are converted into two new photons, one at the signal wavelength and one at a wavelength equal to twice the pump wavelength minus the signal wavelength. The new signal photons combine with the originals to create an amplified signal. The idler photons are a copy of the signal at a new wavelength, so the system can be used to convert a signal from one communications channel to another.



# Sandip Tiwari receives Brunetti Award

By Bill Steele

Sandip Tiwari, the Charles N. Mellowes Professor in Engineering and director of the National Nanotechnology Infrastructure Network, has been named the recipient of the 2007 Cleo Brunetti Award from the IEEE.

The Institute of Electrical and Electronics Engineers (IEEE) presents the award for “outstanding contributions to miniaturization in the electronics arts.” Tiwari was cited “for pioneering contributions to nanocrystal memories and to quantum effect devices.”

The award consists of a certificate and honorarium and will be presented at an IEEE conference during 2007.

“This award brings well-deserved honor to Sandip. This is great news for all of us,” said Cliff Pollock, director of the School of Electrical and Computer Engineering.

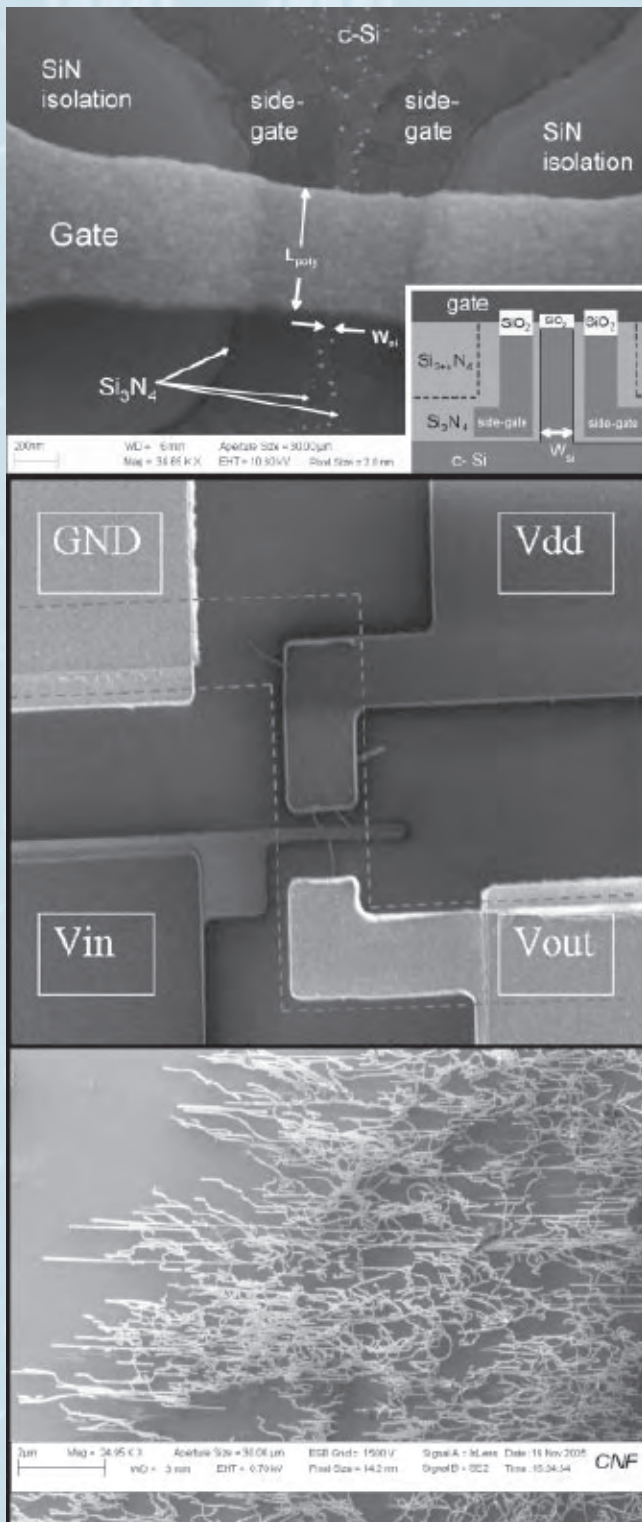
Tiwari joined the Cornell faculty in 1999 as professor of electrical and computer engineering and the Lester B. Knight Director of the Cornell NanoScale Facility. In 2004 he was named director of the National Nanotechnology Infrastructure Network, a consortium of 13 institutions, including Cornell, that provides nanoscale research and development capabilities, supported by the National Science Foundation.

Tiwari's current research looks into the challenging questions that arise when connecting large scales, such as those of massively integrated electronic systems, to small scales—small devices and structures that come about from the use of nanoscale technology. His work has spanned science and engineering of the solid state. His highly cited publications include the subjects of nanocrystal memories, quantum wire lasers, transistors in silicon and compound semiconductors, and his Cornell group's work on power-adaptive devices and circuits and three-dimensional integration.

The IEEE Cleo Brunetti Award was established in 1975 through a bequest made by the late Brunetti, who was an executive of the FMC Corp.



Sandip Tiwari

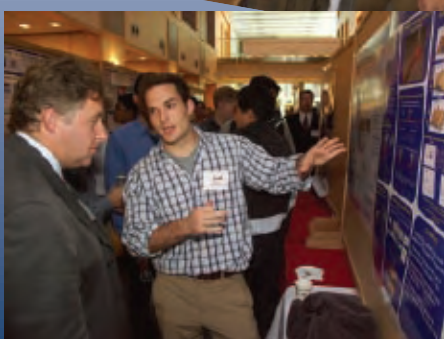
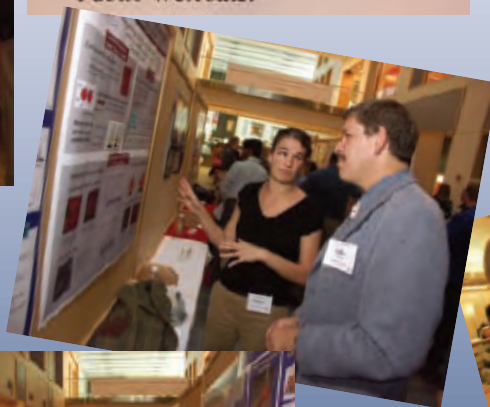


Top: SEM of a side-gated FET and cross-section schematics (inset).  $t_{ox} = 4$  nm. Prof. Sandip Tiwari; User: Ali Gokirmak.

Middle: Top view SEM of inverter (dashed lines indicate underneath nMOSFET active area). Prof. Sandip Tiwari; User: Hao Lin.

Bottom: SEM of carbon nanotubes on obliquely-deposited oxide layer. Prof. Sandip Tiwari; Users: Jay VanDelden & Hao Lin.

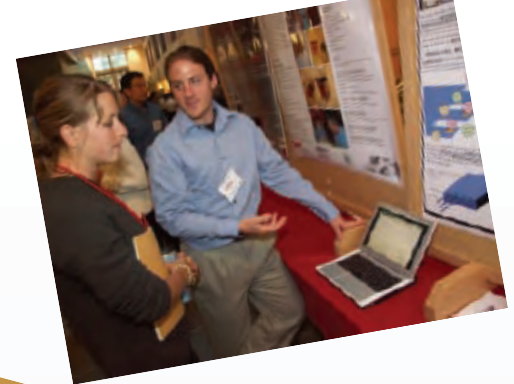
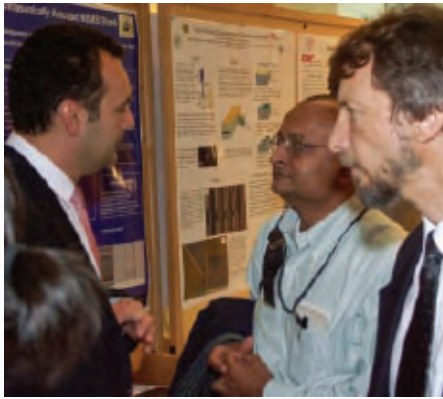
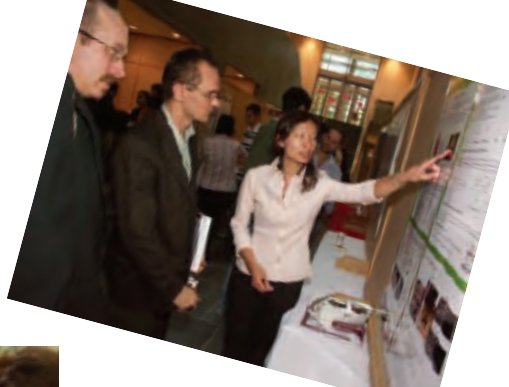




# The 2006 CNF Annual Meeting

All images: Charles Harrington Photography







# CNF's 30th Anniversary & Annual Meeting

Future of Nanotechnology • Nanomedicine • Societal and Ethical Issues

Please save the date,  
Thursday, June 14th, 2007,  
for the  
CNF Annual Meeting and  
30th Anniversary Celebration.

We will have plenary talks on the above three topics in the morning and split into three tracks regarding the same, in the afternoon. And we'll wrap up the day with a Poster Session & Reception. All events will take place in Phillips Hall and Duffield Hall, Cornell University campus.

Please find our mission statement and tentative schedule on our web site below.

We will add speakers to the schedule as they are confirmed and registration information will be available soon, so check this site often!

Please plan to join us on this  
momentous occasion!  
[http://www.cnf.cornell.edu/  
cnf\\_nanofutures.html](http://www.cnf.cornell.edu/cnf_nanofutures.html)

## Confirmed Speakers:

### Future of Nanotechnology Track

- Dr. Phaedon Avouris**, Manager, Nanometer Scale Science & Technology, IBM Research Division
- Prof. Stephen Chou**, Joseph C. Elgin Professor of Engineering, Princeton University
- Prof. Robert Corn**, Professor, Chemistry; School of Physical Sciences, University of California, Irvine
- Prof. Chris Jacobsen**, Physics & Astronomy, Stony Brook University
- Prof. John Rogers**, Founder Professor of Engineering, Professor of Materials Science & Engineering, University of Illinois at Urbana-Champaign
- Dr. R. Stanley Williams**, HP Senior Fellow, Hewlett-Packard Laboratories; founding Director of the Quantum Science Research (QSR) Group

### Nanomedicine Track

- Prof. Tejal Desai**, Director, UC San Francisco's Laboratory of Therapeutic Micro & Nanotechnology, UC San Francisco
- Prof. Dorian Liepmann**, Chair, Department of Bioengineering, University of California, Berkeley
- Prof. Michael Sheetz**, William R Kenan Jr. Professor, Department Chair, Biological Sciences, Columbia University

### Societal and Ethical Issues Track

- Prof. Juergen Altmann**, Professor, Experimentelle Physik, Universität Dortmund
- Prof. Rosalyn W. Berne**, Associate Professor, Department of Science, Technology & Society; School of Engineering & Applied Sciences, University of Virginia
- Prof. David Guston**, Director, Center for Nanotechnology in Society, Arizona State University
- Prof. Sheila Jasanoff**, Pforzheimer Professor of Science & Technology Studies, Harvard University
- Dr. Priscilla Regan**, Program Director, Science & Society Program, National Science Foundation





## 2006 NNIN REU Program



**Completing a comprehensive experimental research task in 10 weeks can be a very formative experience.**

NNIN attempts to this by the strong collaborations and challenging tasks brought together. This report demonstrates that enthusiastic participating students coupled to the sustained support from staff, faculty, and graduate students leads to significant accomplishments. The students participating in this effort have just started on the path of technical education and are getting their first experience with advanced hands-on research as part of our REU program. The focus on advanced research and knowledge, the strong mentoring and support, the strong exposure to a professional research environment, the strong expectations built into the research and presentations at convocations, the exposure to a wider variety of research conducted by peers and other users in diverse disciplines of science and engineering within the unifying facilities, and the strong scientific and social interactions across the network, have been critical to the program's success. Equally critical is the continuing dedication and effort from our staff, faculty, and graduate students. This year's participants also saw increased cross-site interactions through video-conferences and presentations, and hands-on experimentation.

I wish the participants the best wishes for future technical careers; NNIN hopes to see them build on this summer's experience. My thanks to the staff, the graduate student mentors, and the faculty for their participation and involvement. Particular thanks are due to Melanie-Claire Mallison and Lynn Rathbun at Cornell, Michael Deal at Stanford, and Nancy Healy at Georgia Institute of Technology for their contributions in organizing the logistics of the program and the convocation.

*Sandip Tiwari*  
**Director, NNIN**

*Photos this page: Dede Hatch, Photographer*

## 2006 CNF REU



*Left: The NNIN REU interns at the network-wide convocation held at Cornell University in August. Above: The 2006 CNF REU Interns with Melanie-Claire.*

In support of our REU program, CNF received funds from the Intel Foundation to support five additional talented students, allowing us to expand the CNF REU program from 5 to 10 interns. We thank the Intel Foundation and Intel Academic Relations for their continued support of this and other CNF programs.



*Intel Undergraduate Research Interns at CNF*



# New Tools and Capabilities at the CNF

## Plasmatherm 720/740 Reactive Ion Etch System

CNF recently retired the Plasmatherm 720 RIE system, which accommodated both aluminum and silicon etching, and replaced it with a newer dual chamber load-locked system. The left side (740) chamber is dedicated to Al, Al-Si, and Al-Si-Cu etching, while the right chamber (720) is dedicated to single crystal silicon and polysilicon etching. This is an important distinction, especially to those who fabricate CMOS and other advanced silicon based electronic devices.

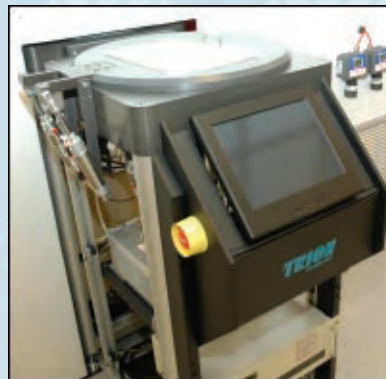
The system is plumbed for both chlorine ( $\text{BCl}_3$ ,  $\text{Cl}_2$ ) and fluorine ( $\text{SF}_6$ ,  $\text{CF}_4$ ) chemistries and has a variety of additive gases to meet overall process objectives.

This tool offers many enhancements over the previous generation, which enable more effective and repeatable process results. Both chambers have quartz platens covering the bottom aluminum electrodes, leading to much more consistent chamber conditions. The Al etch chamber is configured with a modified upper electrode design, allowing the plasma to be generated in a plasma-etch configuration, where the wafer resides on a grounded electrode, in addition to the traditional RIE powered electrode mode. This has allowed us to implement an *in-situ* post Al etch passivation, using  $\text{SF}_6/\text{O}_2$  in an isotropic low bias environment. Hence, post Al etch corrosion concerns are alleviated since any residual aluminum chlorides are converted to harmless aluminum oxyfluorides. A considerable amount of aluminum etch characterization has taken place with etch rates as high as 300 nm/min along with very favorable selectivities to both resist and silicon oxide.

Specific recipes are being developed for pure Al, sputtered Al-Si and Al-Si-Cu as the aluminum alloys offer additional challenges with respect to etch termination and selectivity to the underlying oxide. Likewise, silicon etch characterization has demonstrated etch rates for both single crystal and polysilicon as high as 135 nm/min again with favorable selectivity to  $\text{SiO}_2$ .

The PT720/740 is now available to the general user community. Contact CNF staff members Meredith Metzler or Vince Genova.

## Trion Minilock III



The CNF has recently installed a Trion Technology Minilock III etch system. It is a load-locked inductively coupled (ICP) high density plasma reactive ion etch system and is capable of handling 3", 4", 6" and 8"

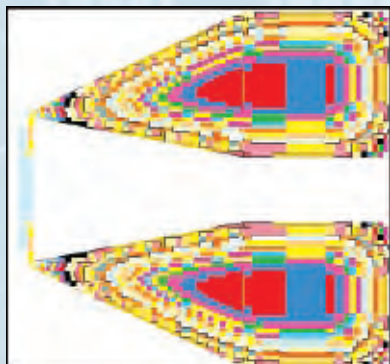
wafers with mechanical clamping, He backside cooling, and substrate heating to approximately 200°C. In addition, the tool can also accommodate 5", 6" and 7" square substrates.

The primary purpose of the tool is to allow us to fabricate both conventional and advanced photomasks, and assist us in our efforts to establish a nanoimprint capability here at CNF. Hence, the majority of the effort will be to successfully plasma-etch chrome and any underlying layers in addition to quartz (glass). Furthermore, all types of advanced photomasks (binary, embedded attenuated phase shift, alternating aperture phase shift masks, etc..) which typically are composed of Mo-Si, TaSi, and TiSiN layers, can also be etched. The tool will have both chlorine ( $\text{BCl}_3$ ,  $\text{Cl}_2$ ) and fluorine ( $\text{CHF}_3$ ,  $\text{CF}_4$ ) based chemistries, along with additive gases such as Ar,  $\text{N}_2$ ,  $\text{O}_2$ , and  $\text{H}_2$  in order to achieve the process objectives. Nevertheless, there are a number of process challenges associated with advanced photomask etching which include critical dimension (CD) etch uniformity, minimized CD etch bias both for isolated and dense features, and zero defect generation. The Minilock III has a very large ICP coil and independent biasing of the electrode, which will allow us to attain these critical specifications.

CNF etch personnel, Vince Genova and Meredith Metzler, are currently formulating a process development and characterization strategy, along with equipment and software enhancements. We hope to have the tool available to the general user community by mid 2007.



# New Tools and Capabilities at the CNF



Courtesy of Kyle  
Preston, Michal  
Lipson's Cornell  
Nanophotonics Group

## PROXECCO™ E-Beam Proximity-Correction Software

During the last year, CNF continued to upgrade its equipment resource base in Duffield Hall. To enhance our e-beam lithography capability, we acquired the PROXECCO and Sceleton™ proximity correction software by aiss, GmbH.

This acquisition was funded by a generous semiconductor equipment grant from Intel.

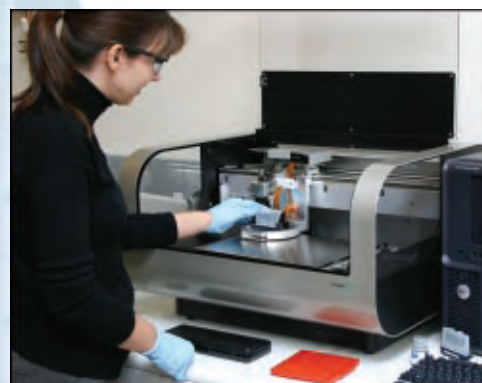
PROXECCO, integrated within the CATS pattern conversion suite from Synopsys, Inc., calculates adjusted e-beam exposure doses to compensate for electron scattering. PROXECCO can be used after a run with the aiss sceleton Monte Carlo simulator, which calculates a point spread function (PSF) for scattered electrons. Alternatively, a sum of Gaussians can be used to model the PSF. A typical Sceleton simulation of 10,000,000 electron histories runs overnight on our dual-processor Xeon Linux server for a material stack with specified layer thicknesses and compositions. The result is stored for later use with any pattern exposed using the same material stack.

Michael Rooks, a former CNF staff member now at IBM, has found that good results can be obtained without doing a Sceleton run for each combination of resist and substrate [1]. Instead, he fit the long range part of a sceleton-generated PSF with a Gaussian function. Then he determined the amplitude and width of a smaller Gaussian representing forward scatter experimentally. For chemically amplified resists, he found that a larger value of the forward scatter component's width can compensate for the diffusion of acid in the resist. CNF is now using his streamlined correction method.

Examples of devices that may benefit from use of proximity correction include photonic crystals, gratings, tapered couplers, and gaps between large features.

For more information and updates, see the CATS Pattern Conversion and Proximity Correction Suite web page, in the Computing section of the online CNF Lab and Equipment Information.

[1] M. Rooks et al., "Experimental optimization of the electron-beam proximity effect forward scattering parameter," *J. of VS and T B: Microelectronics and Nanometer Structures* 23 (6), 2769-2774 (2005).



## Dimatix Materials Jet Printer

The FUJIFILM Dimatix Materials jet printer prints a broad range of fluids and inks in support of applications in electronics, materials science and life science, as well as other areas. It uses a MEMS piezo drop-on-demand print head in combination with an interchangeable cartridge system requiring only small amounts of fluid. The print head can be adjusted for printing solvent based solutions as well as aqueous solutions.

To enable optimum tuning of the printing process, the printer features drop visualization, and tunable jetting electronics for each individual of the available 16 nozzles. We plan to print conductive fluids, aqueous solutions containing DNA, proteins, and enzymes, fluids that contain nanometer-sized particles as well as other suitable fluids. The minimum dispensable drop size is 10 pL with a placement accuracy of 10  $\mu\text{m}$ .

The non-contact printing process allows for printing on both, rigid and flexible materials. These include but are not limited to silicon, glass, ITO-coated glass, polyimide, and substrates with existing topography.

With this printer in our tool set, we plan to support a wide variety of applications. We envision its primary use in the areas of organic electronics, photovoltaic applications, nanoparticle based applications, and life science applications.

## CNF's 2006 Nellie Yeh-Poh Lin Whetten Memorial Award Winner; Jamie Cohen

*Jamie Cohen is originally from Ohio and earned her BS in Chemistry in 2002 at Miami University of Ohio. Jamie is now a fifth year graduate student in Chemistry and Chemical Biology at Cornell University and her advisor is Prof. Héctor Abruña. She has been focusing on using electrochemistry to characterize new fuel cell catalysts for the anode of polyelectrolyte membrane fuel cells, carrying out kinetics studies of methanol oxidation at platinum, and intermetallic, catalyst surfaces, and the fabrication and development of a planar membraneless microchannel fuel cell platform.*

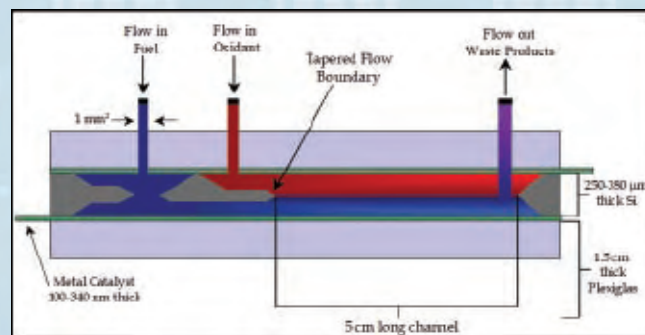
The push for research into alternative energy sources has become mainstream news in the past couple of years. One of those alternative power sources which has garnered much interest, especially in the electrochemistry community, is fuel cells. Fuel cells convert chemical energy directly into electrical energy. A fuel cell has an anode electrode that catalyzes the oxidation of fuel to produce electrons that travel around a circuit and power your device. On the opposite side, there is a cathode electrode that reduces an oxidant using those same electrons and produces waste products that are removed from the system.

In addition to fuel cells for cars and stationary power supplies, there is a push to scale down the size of fuel cells to be used as portable high energy density power sources for cell phones, laptop computers, and military applications. My research has focused on the development of a microchannel fuel cell to meet the power needs of these smaller devices. The fuel cell system I focus on is the polyelectrolyte membrane fuel cell (PEMFC) that operates between 25°C and 70°C. In addition to the anode and cathode, this fuel cell has a polyelectrolyte membrane (PEM). A PEM facilitates selective ion transport from the anode to the cathode to maintain charge balance within the fuel cell and serves to prevent fuel and oxidant crossover. The PEM is very

expensive and has numerous problems associated with it. For example, it can dehydrate if the fuel cell is run at too high a temperature, causing loss of ionic conductivity, and it can also degrade over time from the fuel, oxidant, acidic or alkaline electrolytes, and reaction by-products all present inside the fuel cell during operation.

My main research project focuses on the fabrication a planar microchannel fuel cell that eliminates the PEM (Figure 1). In order to retain the functions of the PEM, I employ laminar flow of the fuel and oxidant, one on top of the other, in a silicon microchannel fabricated at the CNF using basic photolithography and KOH etching. When both the fuel and oxidant flow laminarly, they do not mix, preventing fuel crossover. At the same time, at the interface of the two solutions, which are typically dissolved in electrolyte, there is ionic transport. By employing laminar flow, one can retain the useful functions of a PEM, but not have to worry about the PEM limitations in terms of degradation. This leads to flexibility in the choice of fuel and oxidant to improve the power output of this device. The planar design allows for maximizing anode and cathode electrode areas, which also aids in power enhancement.

Figure 2 presents data obtained using the device shown in Figure 1. To maximize the fuel cell potential, a dual electrolyte fuel cell system has been developed and employed. This type of system cannot be used in conventional fuel cells. Because there is no PEM, our fuel can be dissolved in alkaline electrolyte and oxidant



*Figure 1: The planar membraneless microchannel fuel cell platform used to test a variety of microchannel and electrode parameters, in addition to fuel and oxidant combinations.*



can be dissolved in acidic electrolyte. Electrochemically, this means that the theoretical potential of our fuel cell is nearly 2.0 volts, while other conventional macro-scale fuel cells can only achieve theoretically 1.2 volts when running the H<sub>2</sub>/O<sub>2</sub> fuel cell system because they can only run using a single electrolyte. Figure 2 demonstrates that we can obtain fuel cell potentials that are over 500 mV greater in the dual electrolyte case, translating into twice as much power output, when compared to a single electrolyte system.

Currently, we are looking to increase the power output of our device using fuels and oxidants other than dissolved gases to increase the current density, and power output, of our fuel cell. Increasing the fuel efficiency is also important in a flow fuel cell and efforts to address this issue are currently underway. While we are still a long way from our goal of 1-3 watts, we have been steadily increasing the power output of our device by orders of magnitude. Hopefully, by stacking our microchannels, we will be able to develop a viable portable high energy density power source!



Charles Harrington Photography

Jaime gave a talk, and here presents a poster, on her research, at the Annual Meeting.

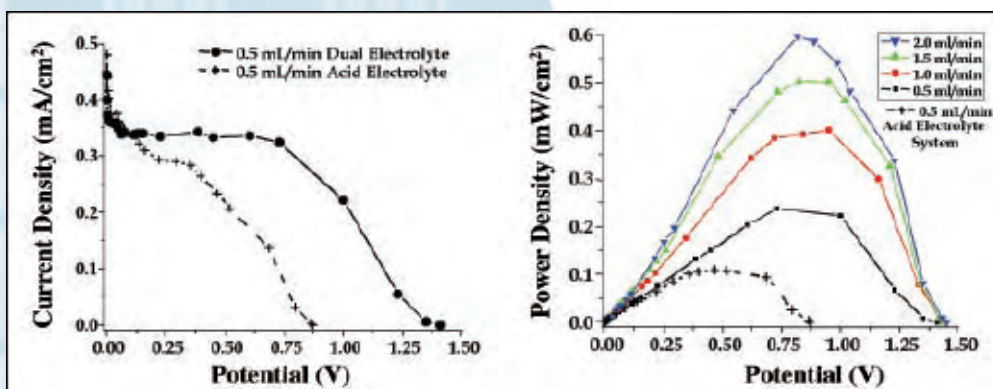


Figure 2: Data obtained using the device in Figure 1. The unique membraneless design of this fuel cell allows for the fuel and oxidant to be dissolved in solutions of differing pH. This affords large increases in fuel cell potential and device power output.

## Nellie Yeh-Poh Lin Whetten Memorial Award

Each year at our CNF Annual Meeting, we recognize—with the Nellie Yeh-Poh Lin Whetten Memorial Award—an outstanding, collaborative female graduate student whose work is currently, or has been recently, carried out at CNF.

As stated on the award plaque, “This award is given in fond memory of Nellie Whetten, 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.”

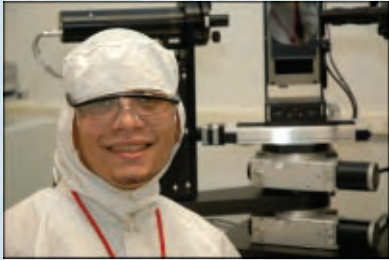
The successful candidate for this award is a female researcher who freely interacts with others and interacts often—willing to help other researchers solve problems, sharing ideas and results. Therefore, we look not only for excellent personal research, but also a community-minded spirit. The award consists of a certificate, a monetary prize, and the recipient's name added to the Nellie Yeh-Poh Lin Whetten Memorial Award plaque, quoted above.

# Recent CNF-Related Patents, Presentations & Publications

- “Accumulated Body MOSFET”; A. Gokirmak and S. Tiwari, Tech. Dig. of IEEE Device Research Conference, June, 77-78 (2006).
- “Anisotropic magnetoresistance and anisotropic tunneling magnetoresistance in ferromagnetic metal break junctions”; K. I. Bolotin, F. Kuemmeth, and D. C. Ralph, Phys. Rev. Lett. 97, 127202 (2006).
- “Apparatus Comprising a Thermal Bimorph with Enhanced Sensitivity”; G. Simelgor and S.R. Hunter, U.S. Patent applied for, 2006.
- “Arraying of Intact Liposomes Into Chemically Functionalized Microwell Surfaces”; N.D. Kalyankar, M.K. Sharma, C. Maldarelli, D. Calhoun, A.r Couzis and M. Lane Gilchrist, Langmuir, 22, 5403-5411, 2006.
- “Chemical and biological sensors based on organic thin-film transistors”; J.T. Mabeck, and G.G. Malliaras, Anal. Bioanal. Chem. 384, 343 (2006).
- “Comparing the kinetics of bias stress in organic field-effect transistors with different dielectric interfaces”; T. Nga Ng, J.A. Marohn, and M.L. Chabiny, J.A.P., V100, N8, page 084505 (2006).
- “Comparison of screened hybrid density functional theory to diffusion Monte Carlo in calculations of total energies of silicon phases and defects”; E.R. Batista, J. Heyd, R.G. Hennig, B.P. Uberuaga, R.L. Martin, G.E. Scuseria, C.J. Umrigar, and J.W. Wilkins, Phys. Rev. B 74, 121102 (2006).
- “Contact and adhesion mechanics of biomimetic fibrillar interfaces”; Glassmaker, N.J., Jagota, A., Chaudhury, M. K., Hui, C.-Y. 29th Annual Meeting of the Adhesion Society, 93-95 (2006).
- “Correlation-induced inhomogeneity in circular quantum dots”; A.Ghosal, A.Guclu, C.Umrigar, D. Ullmo, H.Baranger, Nature Physics 2, 336 2006.
- “Critical particle size for fractionation by deterministic lateral displacement”; D.Inglis, J.Davis, R.Austin and J.Sturm, Lab Chip, 6:655-658 2006.
- “Design of an active pixel electrochemical detector array to monitor quantal release events”; S.Bandla, B.A.Minch and M. Lindau. 13th Intl Symposium of Chromaffin Cell Biology, Pucón, Chile (2006).
- “Development of a biologically-inspired directional microphone for hearing aids, The”; R. Miles & R. Hoy, Audiology & Neur., V11, N2, 86-93 (2006).
- “Directed Fluidic Self-Assembly of Microscale Tiles”; M. Tolley, V. Zykov, H. Lipson, and D. Erickson,  $\mu$ TAS, Tokyo, Japan, Oct. 2006.
- “Electrochemical microfluidic biosensor for nucleic acid detection with integrated minipotentostat”; S. Kwakye, V.N. Goral and A.J. Baeumner, Biosensors and Bioelectronics, vol. 21, pp. 2217-223 (2006).
- “Electronic structure of intrinsic defects in crystalline germanium telluride”; A.Edwards, A.Pineda, P.Schultz, M.Martin, A.Thompson, H.Hjalmarson, and C.Umrigar, Phys. Rev. B 73, 045210 2006.
- “Fabrication and characterization of microfluidic probes for convection enhanced drug delivery”; K. Neeves, C.Lo, C.Foley, W.Saltzman, & W.Olbright, J. Controlled Release, 111, 252-262 (2006).
- “Formation and Properties of Nylon-6 and Nylong-6/Montmorillonite Composite Nanofibers”; L.Lei, L.Bellan, H.Craighead, Polymer 17, 6208-17 2006.
- “From ballistic transport to tunneling in electromigrated ferromagnetic breakjunctions”; K.I. Bolotin, F. Kuemmeth, A N. Pasupathy, and D.C. Ralph, Nano Lett. 6, 123 (2006).
- “High Sensitivity Uncooled Microcantilever Infrared Imaging Arrays”; S.Hunter, G.Maurer, L.Jiang, G.Simelgor, Infrared Tech. and Applications XXXII, Proc. SPIE 6206, pg. 62061J-1,12 (2006).
- “Interfacial oxide and barrier engineering at the CoFeB/MgO interface”; J.C. Read, P.G. Mather and R.A. Buhman, submitted for publication, 2006.
- “MEMS filter with voltage-tunable center frequency and bandwidth”; L.F. Cheow, H. Chandralahim and S.A. Bhawe, 2006 Solid State Sensor, Actuator and Microsystems Workshop (Hilton Head 2006), Hilton Head Island, SC, pp. 304-307, June 2006.
- “Method for Sequencing Nucleic Acid Molecules”; H. Craighead, #7,033,764 issued April 25, 2006.
- “Methods and Systems for an Integrated Micro-Bioreactor Device”; P. Zhou, L. Young, J. Diao, M.L. Shuler, joint Kionix/Cornell patent, 2006.
- “Microfluidic high gradient magnetic cell microfluidic high gradient magnetic cell separation”; D.W. Inglis, R. Riehn, J.C. Sturm and R. H. Austin, Applied Physics 99: 08K1011-08K1013 (2006).
- “Micromachined Sparse Cell Isolation Device: Application in Prenatal Diagnostics, A”; H. Mohamed, J. Turner, and M. Caggana, 2006 NSTI Bio Nano Conference, vol2, pp. 641-644, 2006.
- “Mobility in Back-Gate/Double-Gate Undoped Thin Silicon Channel Transistors”; A. Kumar, S. Mohta, U. E. Avci, A. Kumar and S. Tiwari, Tech. IEEE Device Research Conf., June, 35-36 (2006).
- “Multireference Correlation in Long Molecules with the Quadratic Scaling Density Matrix Renormalization Group”; J. Hachmann, W. Cardoen and G. Kin-Lic Chan, cond-mat/0606115 (2006).
- “Non-Ideal Behavior in a Model System: Contact Degradation in a Molecularly Doped Polymer Revealed by Variable-Temperature Electric Force Microscopy”; T. Nga Ng, W.R. Silveira, and J.A. Marohn, SPIE, vol. 6336, paper 63360A (2006).
- “Non-PFOS photoacid generating compounds for chemically amplified resists”; R. Ayothi, Y. Yi, N. Felix, C.K. Ober, H. Cao and W. Yueh, Polymer Preprints, 47 (1), 528-529 (2006).
- “Optofluidic Particle Manipulation and Characterization in Individually Addressed Nanowell Sensors”; B. Cordovez, S. Tung, D. Erickson, IEEE/LEOS Summer Topical on Optofluidics, Quebec City, July 2006.
- “Patterning of organic electronic materials using photolithography”; J.DeFranco, B.Schmid, M.Lipson and G.Malliaras, Org.Electr.7, 22 2006.
- “Pierce’s disease of grapevine: new insights into Xylella fastidiosa cell motility and colonization”; H.C. Hoch, Department of Plant Pathology, Cornell University, Ithaca. April 5, 2006.
- “Polarization Controlled Transport in PANI-BaTiO<sub>3</sub> Nanofibers”; M. Nikiforov, H. Liu, H. Craighead, and D. Bonnell, Nano Letters, 6, 896-900 (2006).
- “Probing Electrostatic Potentials in Solution with Carbon Nanotube Transistors”; L. Larrimore, S. Nad, X. Zhou, H. Abruna, and P. McEuen, Nano Letters, Vol. 6 (7), 1329-1333, 2006.
- “Prototype cantilevers for SI-traceable nanoNewton force calibration”; R.S. Gates and J.R. Pratt, Meas. Sci. Technol. 17 2852-2860 (2006).
- “Recirculating Microfluidic Mixer”; K.P. Nichols, J.R. Ferullo, and A.J. Baeumner, Lab-on-Chip, vol. 6 (2) pp. 242-246 (2006).
- “Scalable Nano-Transistor and Memory Using Back-Side Trapping”; S. Tiwari (7,057,234; Issued 6/6/2006).
- “Sensing Arrays Constructed from Nanoparticle Thin Films and Interdigitated Microelectrodes”; L. Wang, N. N. Kariuki, M. Schadt, D. Mott, J. Luo, C. J. Zhong, X. Shi, C. Zhang, W. Hao, S. Lu, N. Kim, J.-Q. Wang, Sensors, 6, 667-679 (2006).
- “Separation Characteristics of On-chip Biopolymer Membranes”; H. Mohamed, A. P. Russo, D. H. Szarowski, L. A. Lepak, M. G. Spencer, D. L. Martin, M. Caggana, and J. N. Turner, Separation Science and Technology, Accepted 2006.
- “Strength and toughness of a fibrillar interface and effect of lateral collapse”; Tang, T., Hui, C.-Y., Glassmaker, N.J. Proceedings of the 29th Annual Meeting of the Adhesion Society, 90-92 (2006).
- “Supercritical CO<sub>2</sub> for High Resolution Photoresist Development”; N. Felix, K. Tsuchiya, C. Man Yin Luk and C.K. Ober, SPIE-The International Society for Optical Engineering, 6153 61534B (2006).
- “Symmetrically supported torsion levers remove probe dependent AFM drift”; Beyder, A., Spagnoli, C., Sachs, F. Review of Scientific Instruments, 77:056105 (2006).
- “Time-Resolved Spin Torque Switching and Enhanced Damping in Py/Cu/Py Spin-Valve Nanopillars, “ N.C. Emley, I.N. Krivorotov, A.G.F. Garcia, O. Ozatay, J.C. Sankey, D. C. Ralph, R. A. Buhman, Physical Review Letters, 96, Art. No. 247204, Jun 23, 2006.
- “Two-dimensional model of a directional microphone: Calculation of the normal force and moment on the diaphragm, A”; Homentcovschi, D., Aubrey, M., Miles, R.N., Journal of the Acoustical Society of America, 119 (2) (2006) pp 756-768.
- “Viscous scattering of a pressure wave: Calculation of the fluid tractions on a biomimetic acoustic velocity sensor”; Homentcovschi, D., Miles, R.N., Journal of the Acoustical Society of America, 119 (2), pp 777-787, 2006.
- “Waveguides for Performing Spectroscopy with Confined Effective Observation Volumes”; H. Craighead, U.S. Patent #7,013,054 issued March 14, 2006.



# New CNF Staff



*Edward Camacho* is CNF's newest Research Support Specialist in lithography. Born in the Dominican Republic, Edward grew up in New York City. He received a B.S. in Micro-Electronic

Engineering from the Rochester Institute of Technology in NY. Edward worked as a student technician for RIT's Semiconductor & Microsystems Fabrication Laboratory, and as a process engineer for the same organization. He also worked at the General Electric Global Research Center in Niskayuna, NY, on state-of-the-art medical sensors for x-ray imaging technology.

*David Botsch* joined the CNF staff in October as our Programmer/Analyst. Dave was born in Normal, Illinois, and grew up in the heart of Thoroughbred Country; Aiken, SC. He received a Bachelor of Arts in Computer Science from Cornell University in 2002. Dave has worked as an Information



Technology specialist at Hubbell Power Systems, a security programmer for the Project Salsa team at Cornell Information Technologies, and a computer guy doing a little of everything for the Cornell Center for Materials Research.

## • Upcoming CNF Events •

**JANUARY 16-19, 2007** . . . . . CNF TCN (SEE BELOW)

**JUNE 4, 2007**.. . . . . 2007 CNF REU PROGRAM STARTS

**JUNE 5-8, 2007** . . . . . CNF TCN

**JUNE 14, 2007** . . . . . CNF ANNUAL MEETING & 30TH

**JULY 30-AUGUST 2, 2007** . . . . . WOOLLAM SHORT COURSE

**AUGUST 3, 2007** . . . . . CNF REU CONVOCATION

## CNF TCN Summary:

- Next offering: January 2007
- Lectures: 12 hours
- Lab demos & hands-on: 6 hours
- Textbook: Provided
- Cost: \$400 (academic), \$850 (industrial)
- Register: [www.cnf.cornell.edu](http://www.cnf.cornell.edu)

## CNF Short Course: Technology & Characterization at the Nanoscale



*CNF's Technology & Characterization at the Nanoscale (TCN) short course* is taught during the summer and winter break, and aims to be an alternative to a full semester / in depth class for students, faculty and professionals who seek to develop a good understanding of the technology without committing to a semester-long course. CNF especially invites those researchers to the TCN who plan on performing nanotechnology research in areas not traditionally associated with the technology. The content of the course is designed to provide a comprehensive introduction to nanotechnology as well as to the techniques used to characterize nanoscale devices. Lectures focus on topics such as nanoscale device design, photolithography, e-beam lithography, etching, characterization, and process integration. The morning lectures are complemented by laboratory demonstrations in the afternoon. One afternoon includes hands-on lab work.





**Cornell NanoScale Science & Technology Facility has been serving the science and engineering community since 1977, and is supported by the National Science Foundation, the NYS Office of Science, Technology & Academic Research, Cornell University, Industry, and our Users.**

*The NanoMeter is published by the Cornell NanoScale Science & Technology Facility.*

*To be added to our mailing list, send your request via email to: [information@cnf.cornell.edu](mailto:information@cnf.cornell.edu). Your comments are welcome!*

*You will also find the NanoMeter in pdf on our web site at: <http://www.cnf.cornell.edu>*



250 Duffield Hall  
Cornell University  
Ithaca NY 14853-2700  
[www.cnf.cornell.edu](http://www.cnf.cornell.edu)  
607-255-2329

CNF NanoMeter, VI6#2