

# NanoMeter

The Newsletter for Cornell Nanofabrication Facility

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## Director's Corner

The last few months have been quite intense at CNF and in activities around it.

Foremost is the start of Duffield Hall construction, sited adjacent to CNF. Many of the staff moved into Phillips Hall, a section of Knight Lab is now missing, and we have gone through a period of blasting for rock removal. The coordination between the construction team and CNF has been very fruitful in managing this period without much noticeable disturbance in our research work. My thanks to Mr. Brian Brown, Ms. Susan Drew, Dr. Lynn Rathbun, Mr. Jerry Comeau and others, whose efforts are critical to a successful Duffield Hall and CNF. We will try our best to maintain these standards through the whole process.

The recent award from NSF of the Cornell Center for Nanoscale Systems in Information Technologies (CNS) is an example of the importance of interdisciplinary work across sciences and engineering at the nanoscale, and its intellectual promise. Congratulations to Prof. Bob Buhrman and participating faculty for bringing this achievement about. Cornell is now home to a number of such coordinated efforts across a broad range of disciplines, and CNF is proud to be an important catalyst.

These successes also mean the growth in CNF users is likely to continue unabated, and we will need to keep working hard at maintaining our accessibility and quality. Safety will continue to be an underlying important focus and an effort is now afoot to add temporary space to help us through the period leading up to the move into Duffield Hall.

A number of staff has joined over this year, bringing new knowledge and excitement, and we will continue to maintain this momentum. I welcome Dr. Alex Pechenik as the Associate Director. His joining us will lead to better coordination and administrative strength in these exciting times.

Sandip Tiwari, Lester B. Knight Director, CNF

## NSF awards CU \$11.6 million for Center for Nanoscale Systems in IT

The National Science Foundation (NSF) announced Sept. 19 that Cornell will be the home of a Center for Nanoscale Systems in Information Technologies. The grant is \$11.6 million over five years.

The director of the center, Robert Buhrman, the John Edson Sweet Professor of Engineering in the Cornell School of Applied and Engineering Physics, will oversee a broad program of research in nanoscale electronics, photonics and magnetics, with direct impact on future high-performance electronics, information storage, communications and sensor technologies.

The NSF announced a total of six new Nanoscale Science and Engineering Centers (NSEC), with three to be located in New York state. Besides Cornell, centers involved in nanoscale research will be located at Columbia University, Rensselaer Polytechnic Institute, Harvard University, Northwestern University and Rice University. The total NSF support of the six centers over five years is \$65 million.

Cornell's grant — the largest of the six — is the university's biggest single federal grant in information technology. Additional matching support is being provided by the New York State Office of Science, Technology and Academic Research (NYSTAR).

"This latest NSF grant emphasizes once again that Cornell is the national leader in nanotechnology research," said Cornell President Hunter Rawlings. "Building upon the decade-long leadership of the Cornell Nanofabrication Facility, the NSF in 1999 demonstrated its confidence in our leadership with a founding grant for the Nanobiotechnology Center at Cornell and the state of New York provided matching support through NYSTAR."

Cornell's NSEC initially will involve 17 faculty research groups working in four major nanoscale science and engineering research areas: silicon and carbon nanoelectronics, an effort led by Sandip Tiwari, director of the Cornell Nanofabrication Facility (CNF), and Paul McEuen, professor of physics; nanophotonics, led by Alexander Gaeta, associate professor of applied and engineering physics, and Yuri Suzuki, assistant professor of materials science and engineering; nanomagnetism, led by Buhrman and Daniel Ralph, associate professor of physics; and an enabling nanoscale science and technologies effort, led by John Silcox, professor of applied and engineering physics.

Buhrman emphasized that the research will be highly interdisciplinary, involving electrical engineers, materials scientists, chemists, physicists and applied physicists. Also participating will be researchers at Brigham Young University, Colgate University, the University of New Mexico and Pomona College.

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Buhrman



Tiwari



McEuen



Gaeta



Suzuki



Ralph

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# 2001 CNF Annual Meeting

National users of CNF continue to provide "a balanced representation" of research across the major disciplines, from biology to physics, reported director Sandip Tiwari at the facility's annual meeting at the Statler Hotel.

Users doing research in electronics and MEMS now account for 36 percent of research carried out at the facility, and 25 percent of users are doing research in biology and chemistry. Materials research accounts for 17 percent of research. "We are proud of the diversity and balance of strength that these numbers indicate," Tiwari said.

In sessions throughout the day, graduate students working with faculty associated with CNF presented their findings on several new discoveries and technology developed at CNF over the past year. The subjects presented included "separating biomolecules in microfluidic devices," "elastic properties of defects in nanometer-scale thin films," "three-dimensional electronic integration in silicon" and "single-molecule, single-electron transistors." The students also presented their work at a poster session.

The meeting's keynote speaker was Mildred Dresselhaus, institute professor at the Massachusetts Institute of Technology, who during the 1950s spent two years at Cornell as an NSF postdoctoral fellow. "Soon, all U.S. microchips will be nanoscale devices," she predicted.

*Edited from an article by David Brand  
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Cornell Chronicle*



*Gina Weibel, right, 4th-year grad student in materials science and engineering, discusses her poster on "Cleaner Microelectric Patterning" with 5th-year grad student Andrea M.P. Turner, applied physics and engineering, during a poster session at the CNF annual meeting Sept. 20th in the Statler Ballroom. Richard Killen/University Photography*

*To attend the 2002 CNF Annual Meeting & Career Fair, please contact Melanie-Claire Mallison, CNF Corporate & Public Relations. 607-255-2329, x 106 or mallison@cnf.cornell.edu*

# The 2001 NNUN REU Program



This year was the busiest so far! 202 applications for only 42 internships. It was a challenge. As the NNUN REU program becomes more and more popular, the award process becomes harder and harder. Not to mention having to enter all that information into a database!

But somehow we survived, and hired our 2001 NNUN REU interns. They came from Bard College to Washington University, majoring in Biological Chemistry through to Physics. We hired 24 women and 18 men - the first time we've hired more women than men! And University of California Santa Barbara had so many great projects to research, they decided to hire 4 extra interns with their own funds but include them in the NNUN REU Program.

Those reports are included in the 2001 NNUN REU Research Accomplishments on the [www.nnun.org](http://www.nnun.org) web site because the students did excellent work worth reporting, even though they were not covered under the NSF REU contract.

As I say, the more popular the program becomes, the harder it is to turn down motivated researchers.

As always, we are indebted to the NSF. Drs. Mary Poats and Rajinder Khosla were patient and encouraging. In addition, we would like to thank the following companies for their financial support:

*Agilent Technologies, Advanced Micro Devices, Analog Devices, Inc., Applied Materilas, Ericsson, Hewlett-Packard Co., Hitachi, Ltd., Infineon, IBM, Intel, Motorola, National Semiconductor, Panasonic, Philips, Robert Bosch Corporation, Taiwan Semiconductor Mfg. Corp., Texas Instruments, Toshiba, Varian Semi-conductor Equipment Associates, and Xerox Corporation.*

Each year, it is only because of the kind attentions of our NNUN REU site coordinators and staff that anything gets done at all. So a warm and well-deserved 'thank you' to Denise, Marsha, Mike, Yvette, James, Crawford, Lisa, Mark, Jane, Mike, Liu-Yen, Holly and Kirsten.

Information on the 2002 NNUN REU Program is on the web — here we go again!

*Melanie-Claire Mallison  
NNUN REU Program Coordinator*



**The 2001 NNUN REU Interns at the NNUN REU Convocation held at Howard University, Washington, DC.**

## User Profile: *Cindy Harnett*



Cindy Harnett worked at CNF as a graduate student and postdoc in Applied and Engineering Physics from 1995 to 2000. This year, Cindy received the CNF's Nellie Yeh-Poh Lin Whetten Award not only

for excellence in research, but equally important, for collaboration and outreach to colleagues, and enthusiasm for her work.

Her graduate work in Harold Craighead's group initially involved scanning tunneling microscopy (STM) of III-V semiconductor structures, such as quantum well lasers and self-assembled quantum dots. During this time, other students in the group were working with self-assembled monolayer coatings, so she investigated using the STM system to write patterns in the monolayers. However, the electron beam lithography system at the CNF produced more reliable patterns in the adhesive monolayers Cindy was studying, so she began using the Nanofabrication Facility often.

Staff and equipment at the CNF were essential for patterning the monolayers and characterizing what was happening to them during exposure. Applications of the monolayer patterns included templates for biochemical patterning [1] and surface treatments for the alignment of liquid crystal molecules [2]. An image of fluorescent particles attached to an adhesive template appears in Figure 1.

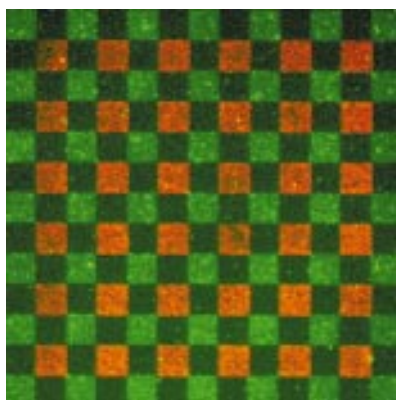


Figure 1: Red and green fluorescent particles adhering to a chemical template.

Cindy graduated with a Ph.D. in 2000, with the thesis topic "Self-Assembled Nanostructures for Integration with Microfabricated Devices." From then until August 2001, she worked in the Craighead

group as a PostDoc, studying materials and techniques for fabricating microfluidic structures by electron beam lithography.

This work was complementary to other projects in the Craighead group involving microfluidic structures for sorting biomolecules.

Using polymers produced at Cornell by Professor Geoff Coates in the Department of Chemistry and Chemical Biology, Cindy made microfluidic structures by electron beam lithography of the polymer, deposition of an oxide layer, and removal of the remaining polymer by heating [3]. A tube filled with fluorescent dye can be seen in Figure 2.

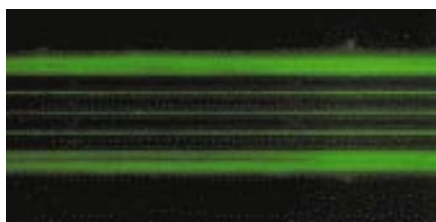


Figure 2: Dye flowing through microfluidic tubes fabricated using a polycarbonate sacrificial layer. Width of each of the three tubes in the center is 1  $\mu\text{m}$ .

In September 2001, Cindy joined the Microfluidics Group at Sandia National Laboratories. Her current interests are surface treatments and sensor fabrication for microfluidic systems, and low-cost polymer microfabrication methods.

Previously, Cindy graduated from Harvey Mudd College in 1993 with a B.S. degree in physics and an art minor. Cindy would like to thank her teachers there, the Craighead Group and the staff and users of the CNF for their years of help and friendship.

### References:

1. "Bioactive templates fabricated by low-energy electron beam lithography of self-assembled monolayers", C.K. Harnett, K.M. Satyalakshmi, and H.G. Craighead, *Langmuir* 17, 178 (2001).
2. "Liquid crystal micropolarizer array for polarization-difference imaging", C.K. Harnett and H.G. Craighead, *App Optics* (accepted 9/2001).
3. "Heat-depolymerizable polycarbonates as electron beam patternable sacrificial layers for nanofluidics", CK Harnett, GW Coates, and HG Craighead, *J.Vac.Sci.Tech.B* (in press, Nov/Dec 2001).

## CNF Associate Director:

### *Dr. Alexander Pechenik*

Dr. Alexander Pechenik has joined the CNF staff as Associate Director. Dr. Pechenik graduated from Northwestern University, Evanston, Illinois in 1984 with a Ph.D. in Materials Science and Engineering. He has worked as a senior engineer at the Dow Chemical Company, associate professor at UCLA, research scientist at NIST, and program manager with the Air Force Office of Scientific Research.

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Strong collaborations with industrial and governmental laboratory scientists also are a key aspect of the center's research strategy. Buhrman said that research collaborations already have been formed with IBM, Corning and Xerox. Prospective research partners include Motorola, NVE and the National Institute of Standards and Technology.

Important contributors to the program will be the research support capabilities provided by two other NSF-funded centers on campus, CNF and the Cornell Center for Materials Research. Buhrman noted that the thrust of the research will be on understanding and controlling the nanoscale properties of materials "and looking at devices based on those properties that can be put together to make successful new systems for the ultrahigh-performance processing, storage and transmission of information."

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*The CNF is a member of the National Nanofabrication Users Network, and supported by the National Science Foundation. Serving the Science and Engineering Community since 1978.*

# *Workshop on Electron Beam Lithography for Nanostructure Fabrication*

The Network Access Committee of the National Nanofabrication Users Network will hold a workshop on Electron Beam Lithography for Nanostructure Fabrication, at Cornell University on January 14, 2002. Emphasis will be on the latest advances in nanostructure fabrication in university laboratories.

This is an informal workshop for the exchange of ideas, results, and technologies among researchers. The emphasis will be on technology that might not be shared at a formal conference yet is critical to successful fabrication. The primary audience will be the academic research staff and senior graduate students at university fabrication facilities who work in e-beam lithography, although all others are invited to participate as well. Mask fabrication by e-beam lithography is not included but most other applications are.



Topics for discussion will include instrument operation and characteristics, resist evaluation, pattern specification, exposure and fabrication schemes, and novel applications. Both SEM-based and commercial system lithography are included. Discussions of non-micro-electronic applications of e-beam lithography are particularly encouraged.

Technical contributions are solicited from all, on the above listed topics.

This workshop follows prior NNUN workshops on Reactive Ion Etching, Photolithography, and BioMEMS held in recent years at UCSB, Penn State, and Stanford, respectively. They are an outreach effort of NNUN to promote the exchange of microfabrication techniques within the academic community. Considerable information exchange on the primary topic, as well as general laboratory operation, is expected.

Full information including the registration form and agenda can be found at: <http://www.nnun.org>

We welcome the participants to the CNF and look forward to an exciting and productive meeting.

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Photo: E-Beam Fabrication of Electrodes for Transport Measurements Across Single Molecules. Michael Naughton, Physics, Boston College.



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