NanoMeter

Newsletter for Cornell Nanofabrication Facility

Volume 10 **July 1999** **Number 2**

The Director's Corner

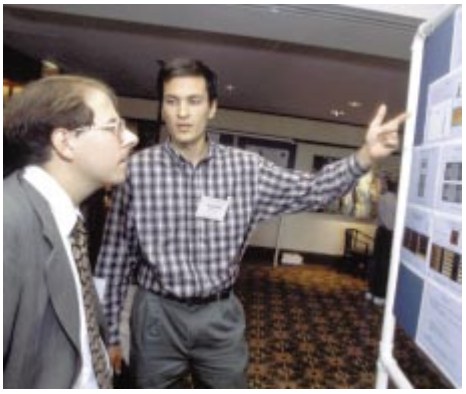
The number of new projects starting at Cornell Nanofabrication Facility has been increasing at a fairly fast rate. The breadth and scope of this new work is a constant source of surprise and pleasure. One particular area showing a large surge in interest is work related to biology. This issue highlights Andrea Perez, a graduate student in Applied and Engineering Physics; it is exciting to see her work and the interesting ideas that underlay it, as well as to watch the scope of work from other external and internal users reaching down to molecular dimensions.

We all take great pride in being helpers in such endeavors and are delighted to see it rapidly approaching a critical mass. The history of the facility has several examples of such periods of changes where the moment is just right; nearly all of this past work went on to influence many areas of modern technology in a significant way. CNF's openness, embrace, and this help in execution has been its traditional strength. CNF is a melting pot of science and engineering.

To biology, CNF brings its knowledge of microelectronics and micromechanical processing, as well as the ability to make structures in the 10-30 nm range through the work in nanostructure physics. These are biological molecular dimensions. Greg Baxter, who joined us last year after a number of years working with biological applications, helps build the bridges between the work and techniques of the electronic and biological communities. If you have interests or ideas you would like to pursue, but are not sure where to start, I encourage you to call him.

Sandip Tiwari

The 1999 CNF Annual Meeting and Career Fair



The CNF Annual Meeting and Career Fair will be held on **Thursday and Friday, September 16th and 17th** at the Statler Hotel on Cornell campus. This year's opening speaker will be Dr. Mark T. Bohr from Intel Corporation, and the after-dinner speaker will be Dr. Gregory Galvin from Kionix, Inc., Ithaca, NY.

If you would like to attend the annual meeting and / or the career fair, please contact Ms. Denise Budinger at: 607-255-2329 or budinger@cnf.cornell.edu.

The CNF Annual Meeting and Career Fair is:

- Oral and Poster Presentations which allow CNF's students and users to show you their recent research and discoveries.
- Informal lunches which offer additional one-on-one time with students and faculty members.
- Thursday night dinner: a more formal occasion to meet, and hear an invited speaker.
- An opportunity for CNF and Cornell University engineering students to learn about your career opportunities in engineering or related industries.
- A proactive event designed to help you illustrate the benefits of employment in your company, including internships or full-time experiences, to a focused group of engineering students.
- A chance to showcase your commitment to diversity by providing our students with access to recent hires, minority executives and substantive information about entry-level positions in your organization.
- An opportunity to complete on-campus interviews with experienced nano-fabricators.

In This Issue . . .

This issue was formatted by Melanie-Claire Mallison

New Equipment at the CNF

Leica VB6

The Cornell Nanofabrication Facility (CNF) houses a Leica VB-6HR, the newest in its series of electron beam lithography tools. The VB6 is one of the most advanced electron beam lithography tools in the world.

The VB6 has replaced the JEOL 5DIIU which served our nanofabrication needs for over 9 years. The JEOL joins the CNF Leica EBMF10.5 in providing complementary electron beam lithography capability extending from above 1 μm to below 0.03 μm.

The VB-6 has a thermal field emission electron source running at 100 kV providing the high brightness and small source size required for nanolithography. Minimum feature sizes < 0.03 μm are possible over field sizes up to 655 μm. For 0.1μm lithography, beam currents as high as 10 nA are possible. These features, combined with the precise addressability of the 16 bit field, make high resolution lithography of 0.1μm features routine.

The system has a large precision stage which will handle 8" wafers. CNF is equipped to routinely handle 3, 4, 6, and 8" wafers, as well as small pieces and 5 or 6" masks. Stage positioning is monitored by a laser interferometer with $\lambda/1024 = 0.6$ nm precision. The VB6 is also equipped with a height sensor for dynamic field size corrections, and dynamic focus / astigmatism corrections.

To support the VB6 and lithography on batches of larger wafers, CNF has also added an automated resist coat/develop system from Brewer Scientific; the Cee 6000. This provides reproducible resist coating and development of large batches of wafers.

The addition of the VB6 places CNF at the forefront in nanolithography capability. This new e-beam system is the result of many years of effort by the CNF staff and management. It was made possible, in part, by funds from the NSF Academic Research Infrastucture program, with significant additional support from Cornell University and the semiconductor industry. We are excited about this new capability and look forward to an exciting future.

Of note:

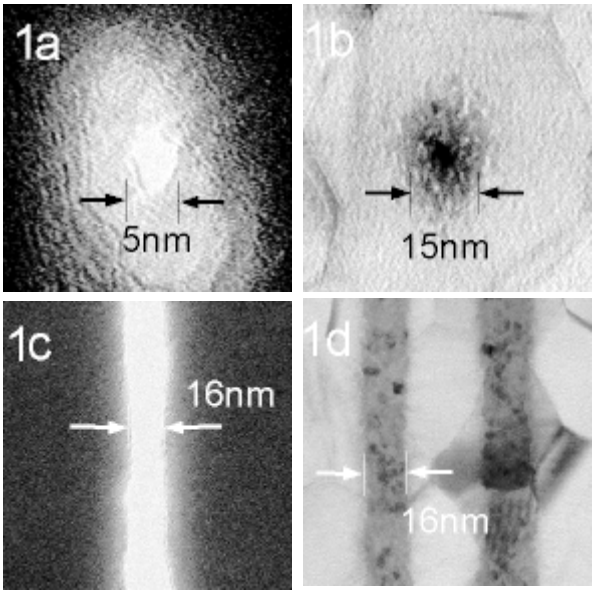
100 KeV Field Emission
25 MHz Advanced Pattern Generator
The stage handles 8" wafers
Minimum feature size is under 30 nm
The stage is precise to lambda/1024

At right:

"Nanofabrication using a Stencil Mask."
CNF Project # 598-96
User: Mandar M. Deshmukh
PI: Dan Ralph

We have developed nm-scale stencil masks to use for direct deposition of nanostructures without employing a resist layer.

Fig. 1a : STEM (Scanning Transmission Electron Microscope) image of a 5-nm-diameter hole in the silicon nitride membrane. Fig.1b: STEM image of a dot fabricated by evaporating metal through a hole similar to one shown in Fig. 1a. Fig. 1c: STEM image of a 15-20 nm wide line shaped orifice etched in a silicon nitride membrane. Fig. 1d: STEM image of two lines made by depositing material through a line shaped orifice.



New Faces at the CNF

From Left to Right:

Michael Deeb is a native of Ithaca and went to college here in the area. He is our research equipment and clean room technician.

Sandip Tiwari is the Lester B. Knight Director of CNF. Tiwari, who earned his doctorate in electrical engineering at Cornell in 1980, is also a Cornell professor of electrical engineering. The new director was born in India and received his undergraduate degree at the Indian Institute of Technology, Kanpur. He earned his master's degree in electrical and systems engineering at Rensselaer Polytechnic Institute, Troy, N.Y., before coming to Cornell for his Ph.D. He joined IBM's Watson Center as a research staff member in 1982 and became a manager for exploratory memory and device modeling in 1989.

Marsha Appleby previously worked for six years at Bethel Grove Bible Church. She went to Florida on a mission for youth, and returned to Ithaca to assist at the Ithaca Pregnancy Center, working in administration and also counseling young women in crisis pregnancies. Marsha joined the CNF staff this past January as receptionist and feels like she's fitting right in. (Especially the crisis part!)

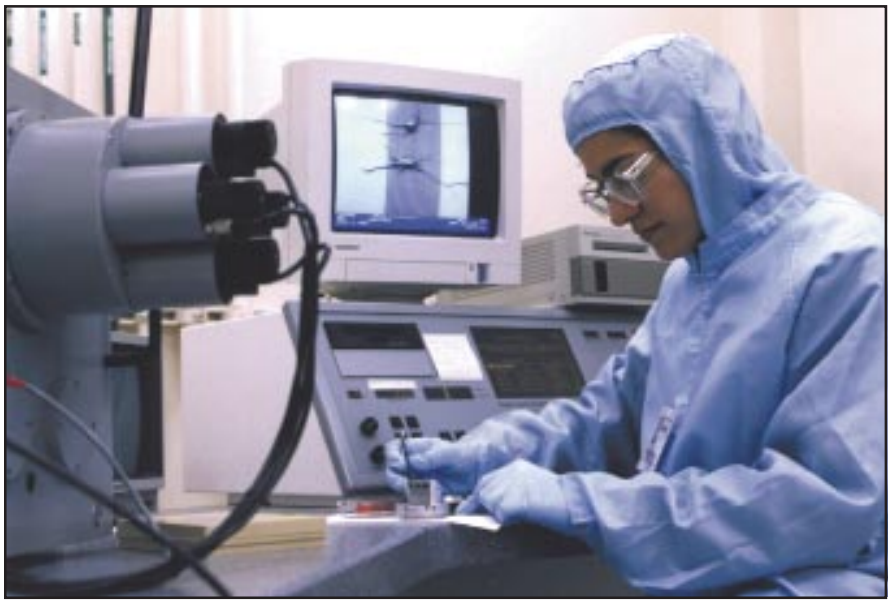
John Williams received his B.S. in Physics from Louisiana State University while working on Al Josephson junctions in 1996. He joined the MEMS field as a research associate at the Center for Advanced Microstructures and Devices at LSU in late 1996. Currently, John is working to complete his M.S. in Engineering Science from LSU while serving on the CNF technical staff. John's position is primarily dedicated to device fabrication and processing for the MEMS Exchange. This multi-site foundry provides low cost processing to a variety of researchers in an effort to expand the industrialization of MEMS.

After receiving his Ph.D. in biochemistry and molecular biology from UCSB, ***Gregory Baxter*** worked for Syntex Research in Palo Alto, CA in the department of Cancer and Developmental Biology. His research entailed elucidating the signal transduction mechanisms involved in growth factor stimulation of proliferation in small cell lung carcinoma cells. Greg then worked for Molecular Devices Corp., where he was involved with developing a cell-based high-throughput screening device for drug discovery applications. After leaving Molecular Devices, he worked for the National Cancer Institute's Chemoprevention Branch. Greg joined the staff at CNF in June, 1998. His primary function is to provide special attention to the needs of biology users and increase the visibility of CNF within the biology and biomedical communities.

Gabor Nagy did his undergraduate studies in physics at Cornell, and his graduate and Ph.D. work at Clarkson University (also in physics), where he researched the nonlinear optical response of interfacial reactions for his thesis. Gabor's postdoctoral research was carried out at Columbia University, where he was involved with the processing and diagnosis of semiconductor materials and optical devices. Since December, Gabor has been responsible for CNF processing involving electron beam lithography with the EBMF and LEO-NPGS systems, as well scanning electron microscopy.

Shijie Yang, below, received his B.S. in computer science in 1984, and his M.S. in computer science in 1987, both from the Northeast University, P. R. China. He has worked for the Wearnes Technology Co. both in P. R. China and San Jose, CA. He has also worked at Appalachian State University, Compucel Services, Laurel, MD, and UTStarcom, Inc. Iselin, NJ. Here at CNF, Shijie maintains and improves the local area network to campus-wide area network interface, keeps the CNF phone system ringing, maintains the DEC cluster system and our desktop computers, all the while supporting CNF staff on hardware/software-related issues and web development.

User Profile -- Andrea Perez



Pioneering in the Field of Nano-Biotechnology

Andrea Perez is currently a graduate student in Applied and Engineering Physics. She came to Cornell in 1997 and has been working in the lab of Harold Craighead since that time. Born in Flushing, Queens and raised in Montgomery, New York, Andrea received her B.S. in Physics from Michigan State University in 1996. Her interest in the field of neural prosthetics began in her freshman year in college, long before coming to Cornell.

While visiting Cornell as a prospective student, Andrea discovered that Professor Craighead was involved in pioneering the field of nano-biotechnology. The Craighead group's research involved the use of the Cornell Nanofabrication Facility to fabricate devices like neural probes for the potential restoration of neural function, patterned surfaces to study cell attachment and growth, and electrode arrays for the study of cellular electrophysiology. Andrea knew that this was the group for her and that the opportunities presented by the CNF for exploring biotechnological applications were innumerable.

One of the projects with which Andrea is currently involved is the study of astroglial and neuronal cell attachment and growth on micropatterned silicon surfaces. The body has a way of rejecting foreign objects and one task in the effort to overcome such rejection is to study cellular responses to materials that have been chemically modified and/or topographically patterned.

In studies involving the insertion of neural probes into the brain tissue of rats, it has been determined that astrocytes, a type of cell found in neural tissue, are responsible for forming a sheath around the shafts of probes preventing neurons from making electrical contact. Ideally, it would be desirable if neurons could make intimate contact with the surface of the probe while astrocytes remained nearby. Thus, it is crucial to study the response of both astrocytes and neurons to different substrates.

Since topography can have a tremendous effect on the attachment and growth of cells, arrays of silicon pillars were fabricated to serve as the substrates for the most recent studies. Results indicate that astrocytes prefer to grow on the tops of pillars rather than smooth silicon and that neurons can send their processes down between pillars if the separation between adjacent pillars is big enough.

These observations indicate that topographical modifications such as micron-sized pillars might be useful to regulate the growth of different cells on the surface of devices such as neural probes.

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More on Andrea's research can be found in the Cornell Nanofabrication Facility 20th Anniversary Edition of the Research Accomplishments, page 23. And Dr. Harold Craighead's many research projects are also covered in this publication.

The 1999 NNUN CNF REU Program

The next installment of the National Nanofabrication Users Network (NNUN) Research Experience for Undergraduates Program is underway! Our twelve interns are training on CNF's excellent nanofabrication equipment, and learning their way around a research project that will introduce them to a whole new, small world.

This summer marks my third year working with this program, and each year brings new challenges and great satisfaction. This year is no different -- even though it has barely begun! For the first time, we have interns from Puerto Rico and Hawaii, so my usual United States map will not work as a graphic representation of where our students hail from. Even so, our twelve interns represent ten universities from ten different states. Electrical Engineering dominates the majors, but Chemical and Mechanical Engineering are also represented, along with Physics.

This year's main challenge seems to be the fact that our usual dormitory and cafeteria are closed for renovations this summer, so the interns are in a building that is new to me, and I'm not really sure where they are eating! Each suite of dorm rooms has a kitchen, but it's too hot to cook and they're all in the cleanroom anyway. However, if this is the most complicated it gets, we are sure to have a great summer.

Having attended the three-week session of the CNF Nanocourses, the students are now free to get to know their mentors and dive into their research projects. The scope of expertise they'll gain covers CAD, to photolithography and electron-beam lithography, right through to using the microscopes to see what they have created. And in August, we'll fly them all to Stanford, CA, to meet with the rest of the NNUN REUers for the network-wide REU Convocation. There, they will all present their findings, hear from guest speakers and enjoy the beauty and warmth of California. It will be a fine ending to great introduction into nanotechnology.

Melanie-Claire Mallison,
NNUN REU Coordinator

The REU Program is funded by the NSF, the NNUN sites, and Industry Users.

1999 CNF REU Intern Project Title	School Affiliation	Field of Study	Principal Investigator
Ms. Amber Bullington Micro-Circuit Breakers	Cornell University, Ithaca, NY	EE	Norm Tien
Mr. Johnathan Carlson Dynamic Behavior of Large Arrays of Coupled Oscillators	Tennessee Tech University, Cookeville, TN	EE	Dustin Carr
Ms. Liang-Yu Chen Integration of Millimeter-Wave MEMS Phase Shifters for Phased-Array Antenna Applications	University of Hawaii/Manoa, Honolulu, HI	EE	Herc Neves
Mr. Keith Green Determining the Multi-Phase Processing Window for Amorphous Silicon	University of Arizona, Tucson, AZ	ChemEngr	Mike Thompson
Ms. Renee Munoz-Verdejo Imprinting of Periodic Nano-Structures on Glass and Measurement of Viscous Flow	University of Puerto Rico, Carolina, PR	EE	Jack Blakely
Ms. Vanessa Ortiz Pagan Chemical Control of Surface Morphology	University of Puerto Rico, Mayaguez, PR	MechEngr	Melissa Hines
Mr. S. Kumar Ravula Damascene Tungsten and Poly-Silicon Structures	Duke University, Durham, NC	EE	Sandip Tiwari & Lynn Rathbun
Mr. Adam Siegel Drug Delivery with Microfluidic Channels for Microelectrode Studies of Cells	University of Michigan, Ann Arbor, MI	EE	Harold Craighead
Ms. Ruth Stritsman Lithographically Defined "Smart" Surfaces	Cornell University, Ithaca, NY	ChemEngr	Chris Ober
Mr. Ethan Swint Characterization of Photolithographic Lift-Off Process	Baylor University, Waco, TX	Engr	Garry Bordonaro & Mike Skvarla
Mr. John Vrakas Transistor Gates and Short Gate Lengths	Illinois Wesleyan Univ, Bloomington, IL	Physics	Sandip Tiwari & Richard Tiberio
Mr. Daron Westly Auger Analysis	University of South Florida, Tampa, FL	EE	Lynn Rathbun & David Spencer

The background photo is part of the research from 1998's CNF REU intern Cadet John Jochum.

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Comments and future article ideas can be sent to: Nanometer, c/o Knight Laboratory, CNF - CU,
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Your comments are welcome!

CNF Publications

"Applications of Bicrystal Geometry," S.Y. Kim, R. DiSabella, L. Hartsuyker, and S.L. Sass, Senior Thesis, 1998

"Ballistic Electron Emission Microscopy and Metallic Band Structure Effects," M.K. Weilmeier, Ph.D. Thesis, 1998

"Ballistic Electron Emission Microscopy Studies of Lateral Variation in Schottky Barrier Heights," F.D. Pardo, Ph.D. Thesis, Cornell Univ., 1998

"Basal Plane Oxygen Vapor Pressure of Co-Doped $YBa_2Cu_3O_{7-delta}$," J.P. Sydow, B.H. Moeckly, and R.A. Buhrman, Appl Phys Let 72/26, p.3512, 1998

"Boron Diffusion in Silicon Oxides and Oxynitrides," K.A. Ellis and R.A. Buhrman, J Electrochem Soc. 145/6, p.2068, 1998

"Depth Profiling Block Copolymer Microdomains," C. Harrison, M. Park, R.A. Register, D.H. Adamson, N. Yao, and P. Chaikin, Macromolecules 31/7, p.2185, 1998

"Dielectric and Pyroelectric Response in Nb/semiconducting Y-Ba-Cu-O/Nb Structures," J.E. Gray, Z. Celik-Butler, D.P. Butler, and A.Jahanzeb, Ferroelectrics 209, p. 517, 1998

"Etched-Angled-Facet Superluninescent Diodes for Improved Mode Locking," S.F. Pesarcik, Ph.D. Thesis, Cornell Univ., 1998

"Extracting Site-Specific Reaction Rates from Steady State Surface Morphologies: Kinetic Monte Carlo Simulations of Aqueous Si_{111} Etching," J. Flidr, Y.-C. Huang, T. Newton, and M. Hines, J Chem Phys 108/13, p.5542, 1998

"Femtosecond Ultraviolet Autocorrelation Measurements Based on Two-Phonon Conductivity in Fused Silica," A.Streltsov, J. Ranka, and A.Gaeta, Optics Letters 23/10, 1998

"Growth and Properties of $YSr_2Cu_{2.75}Mo_{0.25}O_{7-delta}$," J.P. Sydow, D. Chamberlain, F. Ronnig, Y.Xu, and R.A. Buhrman, Unknown, 1998

"Lithography with a Mask of Block Copolymer Microstructures," C. Harrison, M. Park, R.A. Register, D.H. Adamson, and P.M. Chaikin, J Vac Sci B 16/2, p. 544, 1998

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"Low-Energy Excitations in Amorphous Films of Silicon and Germanium," Z. Liu and R.O. Pohl, unknown, 1998

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"Negative Domain Wall Contribution to the Resistivity of Microfabricated Fe Wires," U. Ruediger, J. Yu, S. Zhang, S. Parkin, and A. Kent, PRL, 1998

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"The Growth and Properties of Silicon Oxide and Oxynitride Gate Dielectrics," K. Ellis, Ph.D. Thesis, 1998

"The Radio-Frequency Single-Electron Transistor RF-SET: A Fast and Ultrasensitive Electrometer," R. Schoelkopf, P. Wahlgren, A. Kozhevnikov, P. Delsing, and D. Prober, Science Reprint Series 280, p.1238, 1998

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