NanoMeter

The Newsletter for Cornell Nanofabrication Facility

Volume 12 Spring 2001 Number 1

Director's Corner

The year 2000 was a very fruitful year for Cornell Nanofabrication Facility as well as for our network - National Nanofabrication Users Network. The technical accomplishments of CNF users were very significant over the range of disciplines and many garnered national attention. Two examples of these — the large changes in thermoelectric properties at nanometer dimension observed by nano-calorimetry of Allen et al., and the bio-motors described in the next column of Montemagno, et al. — are good examples of the diversity of the work made possible by such resources.

The year 2000 was also a year of substantial growth in the number of users in CNF — nearly 25%. This is not without a cost. Equipment access is harder, scheduling sequence of experiments is harder, the staff-user interaction is less, and the detailed attention to equipment and experimentation from the staff has stronger time constraints. There are multiple ways CNF is responding.

We are currently in the midst of several searches for a variety of technical positions, to be filled by personnel with significant expertise and multi-disciplinary interests. We hope that the early part of 2001 will see us beyond this stage. Additionally, we are instituting several steps, from retraining to stricter standards in the operation of the facility, to make sure that success of many doesn't suffer from the delinquency of a few. Making the work more productive and a pleasure, for the users and the staff, will require continuous attention in the coming years - increasing research in nanostructures is part of the national agenda and we also have to integrate our functioning together with the construction and deployment in Duffield Hall.

Among the new equipments that were inducted during the last quarter, one deserves special mention — the Unaxis 770. We now have capability to do deep reactive-ion etching from 3 to 6 inches in wafer size. One system is now devoted exclusively to 3 inches and the other to 4 and 6 inches.

Sandip Tiwari, Lester B. Knight Director of CNF
st222@cornell.edu

First Biomolecular Motors with Metal Propellers are Reported by Cornell Nanobiotechnologists

Artile by Roger Segelken
Cornell News Service

Ithaca, NY: Nanobiotechnologists at Cornell University have built and pilot-tested the first biomolecular motors with tiny metal propellers.

Success in fabricating and operating hybrid organic-inorganic nanodevices the size of virus particles is reported by the Cornell team of biophysicists and engineers in the Nov. 24 issue of the journal Science.

Fueled by adenosine triphosphate (ATP, the so-called energy of cellular life) and spinning nickel propellers at eight revolutions per second, molecular motors made of ATPase enzyme are said to herald a new generation of ultrasmall, robotic, medical devices: "nanonurses" that move about the body, ministering to its needs, for example, or "smart pharmacies" that detect chemical signals from body cells, calculate the dose and precisely dispense drugs.

"With this demonstration, we believe we are defining a whole new technology," said Carlo D. Montemagno, associate professor of biological engineering and leader of the molecular-motor mechanics. "This technology opens the door to hybrid nanodevices that can be assembled, maintained and repaired using the physiology of life."

Montemagno credited Cornell graduate student Ricky K. Soong with assembling the propeller-equipped nanodevices and noted that patent applications are in place for the relevant technologies.

Other Cornell authors of the Science report, titled "Powering an Inorganic Nanodevice with a Biomolecular Motor," are research associates George D. Banchand and Hercules P. Neves; graduate student Anatoli G. Olkhovets; and Harold G. Craighead, professor of applied and engineering physics and director of the Cornell Nanobiotechnology Center.

Nanobiotechnology is the relatively new enterprise to merge living systems, including products of genetic engineering, with fabricated nonliving materials, such as silicon, at the "nano" scale, where a nanometer (nm) equals one billionth of a meter. The Cornell molecular motors have propellers about 750 nm in length and 150 nm in diameter (whereas viruses range from about 17 nm to 1,000 nm wide).

The little metal propellers were made at the Cornell Nanofabrication Facility using a sequence of techniques, including electron gun evaporation, e-beam

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lithography and isotropic etching. Thin coatings of attachment chemicals, described in detail in the journal article, encouraged the propellers essentially to self-assemble with molecules of ATPase, which were produced from genetically altered Bacillus bacteria. Mounted on 200-nm-high pedestals and immersed in a solution of ATP and other chemicals, some of the biomolecular motors spun their propellers for two-and-a-half hours.

But before the nanodevices take flight, "We need to achieve a higher level of site occupancy," said Montemagno, noting that "only" five of the first 400 propeller-equipped motors worked. Some propellers came loose and flew off. Some motors apparently dropped off their test pedestals and others never took their places in the first place.

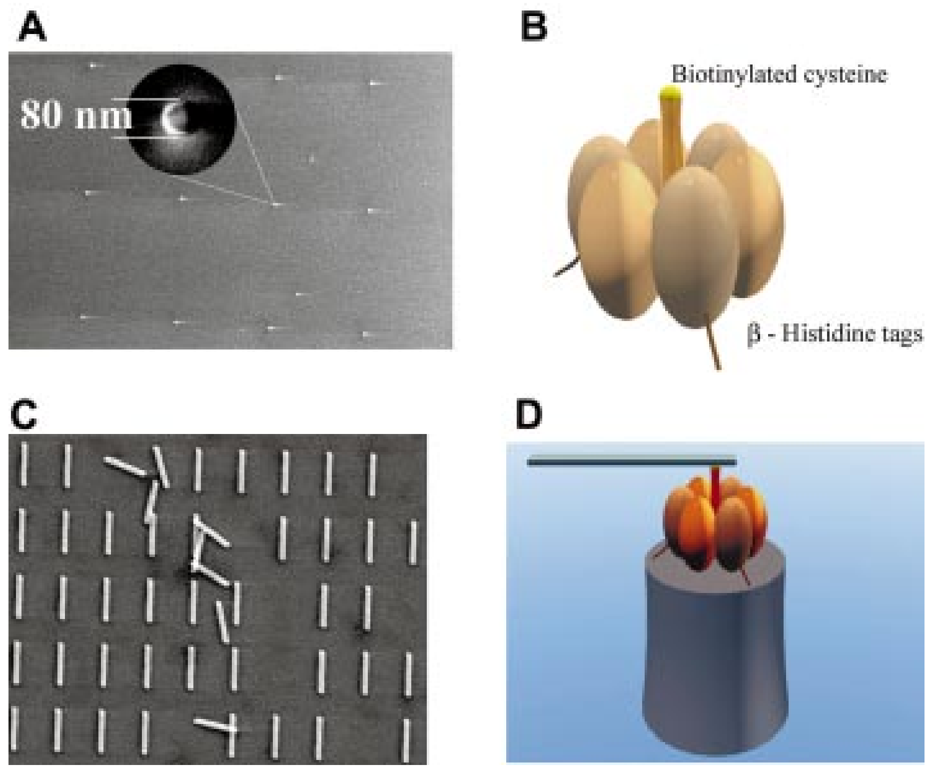
Eventually, the Cornell nanobio-technologists would like to engineer biomolecular motors to run on light energy, with photons instead of ATP. They also plan to add computational and sensing capabilities to the nanodevices, which ideally should be able to self-assemble inside human cells.

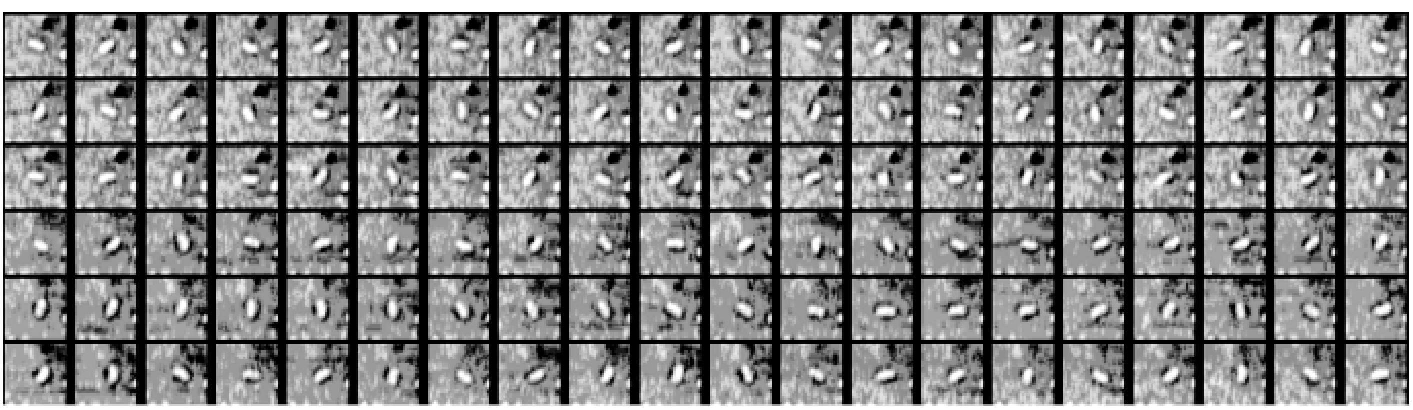
Cornell scientists are learning to clean away caustic chemicals left over from the nanofabrication processes with inorganic materials so that delicate living molecules are not hindered. Then there is the clumping problem: "These machines are as small as virus particles," Montemagno said. "It's hard to prevent them from clumping together. Remember, this is all new for us — and for everyone else in this line of work."

The experiments were funded by the National Science Foundation, Defense Advanced Research Projects Agency, Department of Energy, Office of Naval Research, National Aeronautics and Space Administration and the W.M. Keck Foundation of Los Angeles.

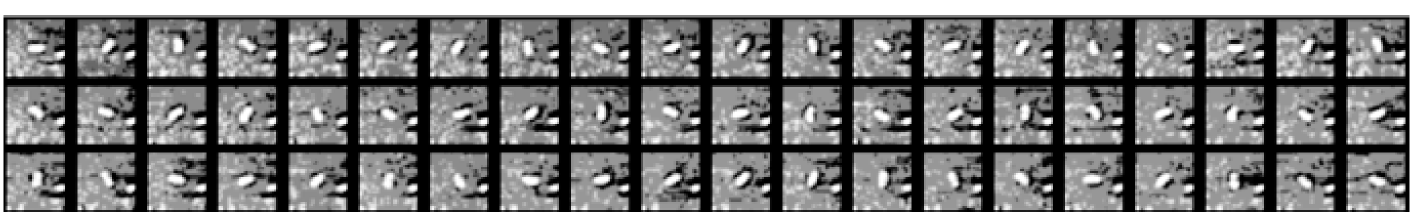
Figures below: Details of the first biomolecular motor with a nanofabricated propeller, as reported in the journal Science, 11/24/00. (A) Electron microscope photo of nanofabricated nickel post, 80 nanometers wide and 200 nanometers tall; (B) drawing of ATPase biomolecular motor; (C) electron microscope photo of nanofabricated nickel propellers, about 750 nm long and 150 nm in diameter; (D) drawing of assembled biomolecular motor (red) and nickel propeller (green) on nickel post (grey). Montemagno Research Group/ Copyright © 2000 Science.

http://falcon.aben.cornell.edu





CCD video image sequences (above and below) of nanopropellers being rotated at different velocities by the ATPase biomolecular motor. These sequences can be viewed as movies at http://falcon.aben.cornell.edu/News2.htm. Montemagno Research Group/Cornell University Copyright © Cornell University.



Researchers are Anticipating CU's 'National Resource'

By David Brand
Cornell Chronicle, September 14, 2000

Some time in 2003, one of the most intricate and carefully planned moves in the history of Cornell will begin. Piece by piece, over about four months, 40 major instruments, such as optical lithography steppers and ion beam etching systems, will be moved through a specially constructed clean corridor into a new facility. Amazingly, while this is going on, researchers from around the country will continue their work without interruption.

The move will be by Knight Laboratory, the home of the Cornell Nanofabrication Facility (CNF), into its new quarters in Duffield Hall, Cornell's $58.5 million, high-tech research center, whose three stories will begin rising on the Engineering Quad, adjacent to Phillips Hall, next spring.

In a project that will require fine-print planning, the new multidisciplinary research building will be constructed around the present Knight Lab, which adjoins Phillips Hall. Once CNF is safely ensconced in its new home, the old Knight Lab will be torn down to make way for a commanding atrium, one of three that will make Duffield the winter palace of the Cornell campus.

"I think Duffield is going to become a national resource," said Christopher Ober, director of the Department of Materials Science and Engineering and a member of the faculty since 1986. "What we are dreaming of right now is so advanced that it will take industry time to digest. Initially Duffield will focus on highly competitive academic research."

The "dream" of Duffield is to manipulate molecular structures to synthesize new materials for biology, for optics and for electronics and to advance this research by encouraging daily interaction among engineers, physicists, chemists and biologists. This mix will be commanded by Duffield's three main occupants: CNF, the newly formed Nanobiotechnology Center (NBTC) and components of the Cornell Center for Materials Research (CCMR). In addition, a first-floor characterization lab, directed by John Silcox, vice provost for physical sciences, will provide a wide array of analytical tools, such as scanning tunneling electron microscopes.

"It will be for people who really need to work at the nanotechnology scale," said Clifford Pollock, the Ilda and Charles Lee Professor of Electrical and Computer Engineering, who is the academic program leader on the Duffield management team ("nano" refers to a nanometer, a billionth of a meter, or the diameter of three silicon atoms). "It will be an interactive space and a project space."

Like all future occupants of Duffield — and aware that the research center will vault Cornell into new prominence in the field of nanotechnology — Pollock talks about the art of the possible in terms that sound like science fiction. One of the major research areas will be into tiny mechanical devices known as MEMS (for micro-electromechanical systems) that manipulate matter at nearly atomic dimensions and which one day might be laid down by the thousands on a single chip.

A model of Duffield Hall, the new interdisciplinary research building that will begin rising on the Engineering Quad next year, is described by project manager Bob Stundtner, right, to Clifford Pollock, left, the Ilda and Charles Lee Professor of Electrical and Computer Engineering, who is the academic program leader on the Duffield management team, and Al Clark, associate Director of the Cornell Nanofabrication Facility.

Robert Barker/University Photography

"The next big jump will be making thousands of MEMS devices work in concert as a system on a single chip," said Pollock. And after MEMS might come moletronics, or a new generation of electronic devices at the molecular level.

Increasingly, this research is using the tools of biology to create new materials, devices and systems, such as cell-sized devices with their own self-contained memory programmed to analyze, probe and synthesize. In Duffield, said Harold Craighead, director of NBTC, "we will have everything we need to do high-resolution analysis of biosystems." NBTC researchers, he said, will be culturing cells on devices in one room and doing optical and electrical measurements in another.

"My guess is that users are going to become more biological. Already I am seeing engineers moving more toward biosystems. So I suspect that with time there will be increasing demand for new types of fabrication processes," Craighead said.

For now, though, NBTC scientists will have to be satisfied with perhaps one-fourth of the 12,000 square feet of clean rooms that will occupy Duffield's first floor. CNF Associate Director Al Clark explains that it is essential to dedicate clean room space for NBTC, "so that biologists can do a lot of stuff with saline solutions and other things that could grossly contaminate normal CNF operations."

CNF, which is a national user facility, needs about 40 percent more clean room space than the facility has at present to alleviate crowding and to allow for growth. Over the past three years, in particular, growth at the facility has accelerated to about 14 percent a year.

The reason, said CNF laboratory manager Lynn Rathbun, is the huge growth of nanotechnology research. Most of the researchers who use the facility are physicists, biophysicists and bioengineers, and perhaps only 20 percent have some biology relation. But, said Rathbun, the number is growing.

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Gregory Baxter, a biological research associate at the Cornell Nanofabrication Facility who helps physicists and engineers with biological processes, assists applied physics graduate research assistant Andrea M. Perez Turner with pipetting central nervous system cells onto a silicon wafer.

Frank DiMeo/University Photography

The user committee, chaired by Pollock, is still considering how much space the three major occupants of Duffield finally will get. This involves many difficult decisions about who and what projects will occupy the 20,000 square feet of lab space on the second and third floors. But Pollock makes it clear that space will be allocated only for three to six years at a time, and once a project is concluded, the space will be allocated to others.

Already, said Ober, the promise of Duffield is attracting new researchers to Cornell, and prospective students want to know when it will be finished. "In two years we will see an explosion of students coming to Cornell just because of Duffield," he said.

More information may be found on the Duffield Hall Project web site, http://www.engineering.cornell.edu/duffield/

Science Coalition Presention includes a CNF Nanosaxophone for President Clinton

Adapted from an article by Bill Steele, Cornell Chronicle
Paperweight photographed by University Photography

Presenting the world's smallest saxophone to the White House and describing recent Cornell research for a radio audience were among the activities that filled a day in Washington, D.C., for Cornell President Hunter Rawlings on July 13, 2000. Rawlings and four other Cornellians joined delegations from 50 institutions in a series of Capitol Hill events sponsored by the Science Coalition, a nationwide organization that lobbies for continued federal support for basic scientific research.

At the White House, Rawlings presented a nanosaxophone paperweight, created by the Cornell Nanofabrication Facility (CNF), to John Podesta, President Clinton's chief of staff, for inclusion in the Clinton presidential library.

The memento actually contains 287,900 tiny saxophone images, each 6-by-8 millionths of a meter, or about the size of a red blood cell. The tiny images are arranged on a "presidential blue" silicon nitride chip to form an 8-millimeter-wide silhouette of the president playing the saxophone at the Arkansas Ball inauguration festivities in January 1993.

"We are confident this is the smallest gift any president has ever received," Rawlings said.

The nanosaxophone, he explained, was made to illustrate CNF's ability to manufacture the world's smallest devices, used in biology, medicine, chemistry, electronics, optics and physics.

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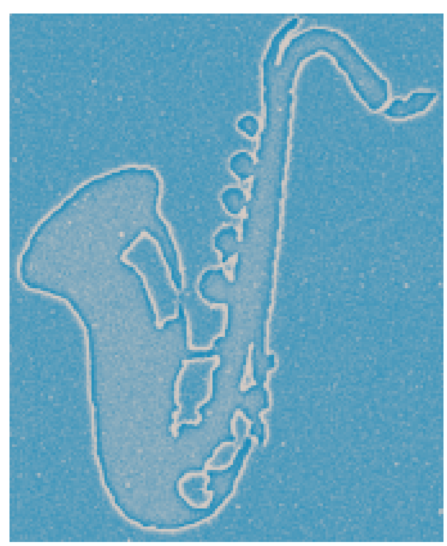
The nanosaxophone chip, below, was created by Cornell Nanofabrication Facility staff members Richard Tiberio, Michael Skvarla, Karlis Musa and Melanie-Claire Mallison, and undergraduate research intern Teresa Emery. The paperweight in which it is mounted was crafted by the Advanced Design and Fabrication Facility of the Cornell College of Engineering, and it was designed by Michael Harding, director of the facility. The project was directed by Alton Clark, associate director of the Cornell Nanofabrication Facility.

The profile of the President, above, was created by lining up 287,900 silhouettes of the saxophone, below. Each nano-sax is 6 µm by 8 µm or about the size of a single human blood cell.

The smallest feature of the nanosaxophone is about 25 nanometers (or 1 one-millionth of an inch) across.



The NNUN REU Program

Early in 2000, the National Science Foundation accepted the National Nanofabrication Users Network Reseach Experience for Undergraduates proposal, and we moved forward with our second series of programs, this time with three helpful and successful years to lead us.

For the NNUN REU Program 2000, we awarded forty-two internships to students from thirty-five colleges and universities — nineteen women, and twenty-five minority students — and we gave each of them the unique opportunity to try on a challenging, frustrating, and exciting new career, for ten weeks. Each site offered up a summer of exploration and research, encouraging their interns to absorb a vast amount of information, sometimes in disciplines new to the student, and involving them with our cutting-edge nanotechnology resources. And as if that were not enough, we then gathered them all together at the Pennsylvania State University for a network-wide convocation (see photo below) where the interns presented research reports and enjoyed some of the local color. PSU provided some great weather and the interns provided some very interesting talks.

But perhaps we should let the students speak for themselves — from the evaluations. Here are a few of their responses:

"The REU made me seriously consider solid state and my subfield in Physics. Plans: Masters and Doctorate in Physics."

"The research will be very useful to me, most especially the hands-on, experimental aspect of it ... "

"I value the research experience I've gained ... it's an excellent opportunity."

"This was my first active research experience and it was great exposure. Encouraged me to pursue research in grad school."

"I am considering a career in microelectronics manufacturing. It has strongly influenced my choice to go to grad school ... I would strongly recommend [the program]."

"Before this summer I was a pre-med student, where now, after I've seen different opportunities through REU, I'm considering grad school in my future."

"It was really good to see what graduate level research was like and work on a real project."

We are indebted to Drs. Theresa Maldonado and Rajinder Khosla, NSF, for their support and guidance. We also received financial support from the following corporations:

Agilent Technologies, Advanced Micro Devices, Analog Devices, Applied Materials, Bosch Corporation, Ericsson, Hewlett Packard, Infineon, Hitachi Ltd, IBM, Intel, Integrated Devices Technology, Lam Research, National Semiconductor, Panasonic, Philips, Taiwan, Semiconductor Manufacturing Co., Texas Instruments, Varian Semiconductor Equipment Associates, and Xerox.

And now we are preparing for the NNUN REU Program 2001. Applications are arriving daily and facility users are lining up projects for the new interns. If your company would like to be part of the excitment, please contact me regarding our CNF REU Sponsorship Program.

Melanie-Claire Mallison
NNUN REU Program Coordinator

The CNF REU 2000 Interns

The NNUN REU 2000 Research Accomplishments are available in hardcopy from Melanie-Claire, or in pdf at: www.cnf.cornell.edu/2000REU/2000NNUNREU.html

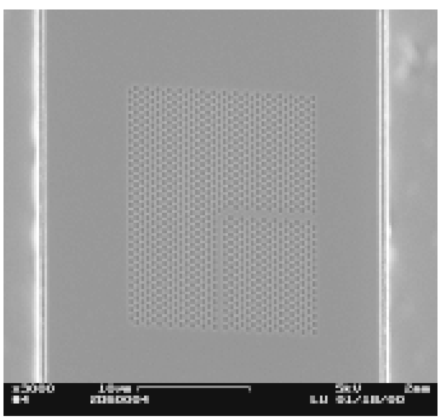
User Profile: Lu Chen

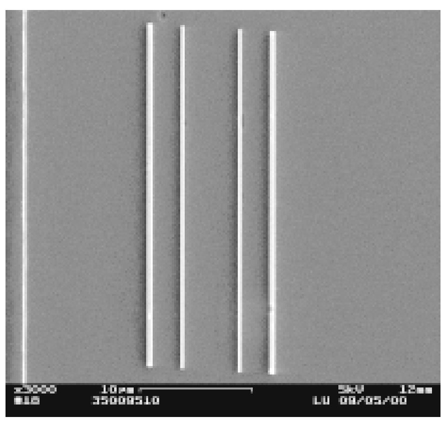
Lu Chen, winner of the 2000 Nellie Whetten Award, received her bachelor's degree at Central South University of Technology (PRC) in metal physics and her master's degree at Tsinghua University (PRC) in inorganic nonmetallic materials. In 1998, she joined the Department of Materials Science and Engineering at Cornell as a PhD candidate, and has been working on photonic bandgap crystals (PBC's) under the supervision of Prof. Yuri Suzuki.

Photonic bandgap materials have been the focus of an enormous amount of research recently. Through dielectric constant modulation, PBC's offer control of light propagation by the introduction of gaps in the density of electromagnetic states, in analogy to energy bandgap for electrons in a crystal lattice.

Such structures have the potential to become the basis of an all-optical integrated circuit technology.

In the past two years, Chen successfully developed a fabrication process for one and two dimensional PBC structures at the Cornell Nanofabrication Facility. The challenge has been to combine the PBC structure, fabricated by electron beam lithography, with optical fiber grooves, fabricated by optical lithography. Light introduced by optical fiber is directly coupled to the PBC structures without planar waveguides. This work has already resulted in a patent application on a new type of optical fiber groove. Recent optical measurements reveal photonic bandgaps that can be predicted by simulation.





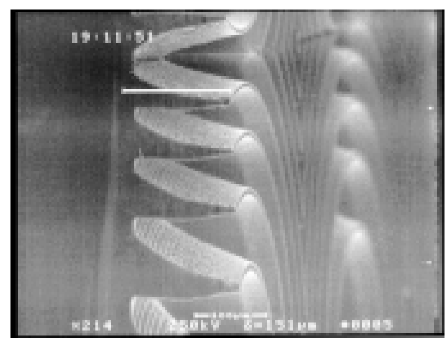
The CNF Annual Meeting & Career Fair

Over 125 people attended the Fifth CNF Annual Meeting and Career Fair, partaking in fourteen CNF user talks, a keynote speech by Dr. Yoshio Nishi, and an after-dinner talk by Dr. Mihail Roco. There were also over 30 posters at the poster session, and a great deal of great food courtesy of Cornell Catering. Ten companies set up booths at Friday's Career Fair — many new comers plus returning recruiters.

We enjoyed each other's company and the research networking — and we still have nanoguitar and nanosaxophone pens available if you didn't get yours!

The 6th CNF Annual Meeting and Career Fair will be held on Thursday and Friday, September 20 and 21, 2001, at the Statler Hotel on Cornell campus. Join us and find out what's new in nanotechnology and see how Duffield Hall is progressing.

If you would like to attend the next annual meeting — either as an observer or a recruiter — please contact Melanie-Claire Mallison, Corporate & Public Relations, M102 Knight Lab, CNF, Cornell Univ., Ithaca, NY, 14853. Phone: 607-255-2329, x106 or FAX: 607-255-8601 or Email: mallison@cnf.cornell.edu.



Deep silicon etched gray scale Fresnel lens, Peter S. Erbach, MEMS Optical, LLC

Selected Presentations and Publications

"AlGaN/GaN HEMT MMIC Development", B.M. Green, K.K. Chu, V. Tilak, H. Kim, E.M. Chumbes, J.A. Smart, R. Dimitrov, J.R. Shealy, L.F. Eastman, GOMAC 2000, Pg. 1(March 2000)

"Charge induced pattern distortion in low energy electron beam lithography," K M.Satyalakshmi, A. Olkhovets, M. G. Metzler, C. K. Harnett, D. M. Tanenbaum , and H. G.Craighead, presented at the 44th International Conference on Electron, Ion, and Photon Beam lithography, June (2000).

"Dense Array of Ordered GaAs Nanostructures by Selective Area Growth via Block Copolymer Lithography," Chaikin Group, Applied Physics Letters, vol 76, p.1689, 2000.

"The Effect of Surface Passivation on the Microwave Characteristics of Undoped AlGaN/GaN HEMTs", B.M. Green, K.K. Chu, EM Chumbes, J.A. Smart, J.R. Shealy, L.F. Eastman, IEEE Elect. Devices, Pg. 1, (February 10, 2000)

"Electromigration modelling of Blech experiment with comparison to recent experimental data", Z. Fan, M. A. Korhonen, and C.-Y. Li, MRS Fall Meeting, Boston, Dec. 1999; to appear in MRS Symp. Proc. 594 (2000)

"Fabrication of biologically active nanostructures by electron beam lithography of self- assembled monolayres," C. K. Harnett, K. M. Satyalakshmi, and H. G. Craighead, presented at the 44th International Conference on Electron, Ion, and Photon Beam lithography, June (2000).

"GaN/SiC heterojunction bipolar transitors", W. J. Schaff, H. Wu, C.J. Praharaj, M. Murphy, T. Eustis, B. Foutz, O. Ambacher, L. Eastman, Solid-State Electronics 44 (2000) 259-264

"Low energy electron beam patterning of amine-functionalzed self-assembled monolyers," C. K. Harnett, K. M. Satyalakshmi, and H. G. Craighead, Appl. Phys. Lett. 76, 2466 (2000).

New Equipment

EV 501

The EV501 wafer bonding system is designed to accommodate wafer-to-wafer bonding processes up to 550°C. This system can accomplish silicon direct bonding (Si-Si, Si-SiO_2-, SiO_2-SiO_2), anodic bonding, and thermal compression bonding (*i.e.*, glass frit bonding).

It is PC controlled with manual and automated process execution. All process parameters and accessories, such as vacuum pumps, automatic valves and gauges are software controlled, monitored and recorded.

The anodic bond chamber includes an anodic bond cover and a heating chuck for temperatures up to 550°C. The bond chamber also supports bonding in vacuum or controlled atmosphere.

Independent temperature control of top and bottom wafers compensates for different thermal expansion coefficients, hence provides stress-free bonding.

For both pressure and anodic bonding, a universal cover is available, which includes a high precision piston, high power top side heater and high voltage feed-through.

EV 620

EV620 mask and bond aligner system incorporates a Windows based graphical user interface with three levels of process control software access (operator, engineer and maintenance). Instruction menus, alignment vision and process monitoring are shown on a single monitor and allows easy navigation by operator promptings.

To achieve the highest alignment accuracy and exposure results, the mask and wafer surfaces must be extremely parallel. EV's unique three-spindle, software-controlled stage allows exact positioning through hall effect sensors, for extremely parallel alignment. Very low, controllable contact pressure, independent of printing method, eliminates any shift between mask and wafer. This also eliminates wafer and mask damage, which is especially important for sticky resist or fragile materials (GaAs, SiC, InP, *etc*.).

Top-to-bottom side alignment can be performed with split field microscopes using the visible range of light. To perform this alignment when the mask is hidden, the mask image is stored and the microscope is secured. Alignment viewing can use either stored mask images, cross hairs or custom alignment keys. Objectives are electronically controlled by a joystick and can be independently moved in the X, Y and Z direction and are easily interchangeable from 3.6x to 20x.

The EV620 mask aligner can easily be changed over from lithography to bonding by running a wafer bonding recipe and by simply exchanging the mask frame with the wafer bonding chuck.

It can accomplish bottom side alignment with a split field microscope and can be used for alignment for all wafer bonding techniques (anodic, silicon direct, pressure, *etc*.).

GCA Autostep 200 DSW i-line Wafer Stepper

The Autostep 200 is a production wafer exposure tool configured for up to 8" wafers. All operations are automated, including wafer loading (4" wafers) and aligning, and reticle loading and aligning (5"). Wafer leveling is used to provide optimum focus range.

The focus system uses broadband light and is repeatable to within 0.2µm. Overlay is specified as <0.125µm using local alignment; we have seen well below that. All tool calibrations are performed automatically, and the focus system uses elaborate compensation for lens heating and barometric shifts. With N.A. of 0.45 and Sigma of 0.5, the tool is specified for 0.65µm features; we have printed <0.5µm.

FEATURES:

- 8" wafer stages
- 0.45 NA. Tropel lens
- <0.65µm resolution
- 15mm field
- Wafer leveling
- Automatic Wafer Handler (set for 4" wafers)
- Reticle Management System (up to 10 reticles)
- µDFAS wafer alignment (<0.125µm overlay)
- INSITU tool setup
- Smart Set metrology software

Technology Transfer Opportunities

Periodic Templates For Nanostructures D-2261 (EN636) class: 540 Nanofabrication and Semiconductor, U.S. Pat. Appl. No. 60/169,951. Inventors: Stephen Sass, Yuri Suzuki, Christopher Ober. Method of making a periodic template with spacing as small as a few nanometers. Such method is enabled by novel use of a block copolymer material. The resulting periodic templates are useful in the study of magnetic behavior in data storage and growth processes in polymer films.
Contact : Scott Macfarlane, ssm8@cornell.edu

Ionspray Interface For Chip-Based Separations D-2565 (VE171) class: 575 Microelectro-mechanical, U.S. Pat. Appl. No. 60/163,264, Inventors: Jack Henion, Timothy Wachs. A nano-scale electrospray system used to introduce solution into Mass Spectrometers. The system effectively couples a miniaturized phase separation system to a miniaturized spraying device without causing interference with the separation device. This system may be of use in proteomics, forensic drug analysis, and other applications where important chemicals of interest may be characterized by electrospray-mass spectrometery.
Contact : Scott Macfarlane, ssm8@cornell.edu

Filtration-Detection Device for Rapid Hybridization Assays, D-2560 (AG617) class: 575 Microelectromechanical, U.S. Pat. Appl. No. 60/162,371, Inventor: Antje Baeumner. A hand-held, portable device that enables the rapid detection of biological compounds, e.g. nucleic acids. The device facilitates the rapid hybridization of compounds in question to target analytes. Electrochemical and/or optical detection can be incorporated within the device. The device completes an entire assay between 3 and 7 minutes. The device has been tested on Cryptosporidium parvum. May be suitable as a field assay for environmental testing or food processing applications.
Contact : John Brenner, jb77@cornell.edu

Enzymes as a Power Source for Nano-fabricated Molecular Motors, D-2341 (AG562) class: 575 Microelectromechanical, U.S. Pat. Appl. No. 60/152,983 U.S. Pat. Appl. No. 09/416,775, Inventor: Carlo Montemagno

Utilizing a molecular motor, this technology powers a nano-electrical-mechanical system (NEMS) without an external energy source. The enzyme F1-ATPase is used to create energy from living organisms for use in a variety of NEMS applications. Modifications can allow the enzyme to be powered by a secondary chemical system, thereby creating an effective on-off switch. This unique technology has innumerable uses within the human body, notably for drug delivery and in cases where outside power sources are unwieldy or inaccessible. For example, cochlear implants cannot operate on batteries because of signal processing requirements needed to translate incoming sound waves into understandable outputs.
Contact : John Brenner, jb77@cornell.edu

Multiple Optical Channels for Chemical Analysis, D-1777 (EN286) class: 575 Microelectromechanical, U.S. Pat. No. 5,867,266, U.S. Pat. Appl. No. 08/897,442
Inventors: Harold Craighead
A miniaturized apparatus in which the separation means and optical components for nucleotide detection are integrated. Fabricated using microfabrication techniques of chemical etching and deposition allowing inexpensive mass production. Particularly significant is the innovative means of producing the separation medium in the etching process step, avoiding cumbersome gel-filling steps.
Contact : John Brenner, jb77@cornell.edu"/

CNF Cornell Nanofabrication Facility™
607.255.2329 www.cnf.cornell.edu

Knight Lab, CNF
Cornell University
Ithaca NY 14853-5403