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The Newsletter of Cornell Nanofabrication Facility

Volume 14 January 2003 Number 1

Director's Column

Our September annual meeting brought forth a number of important characteristics of the Cornell Nanofabrication Facility. The quality and the variety of the talks and the posters was cause for a lot of satisfaction to the staff. The digest of research amply demonstrates these characteristics for those who could not attend the event.

Behind these research accomplishments is a diversity of technical work and usage that demonstrate the strengths of CNF. There are 66 Cornell faculty and 132 external faculty who actively use the facility. During the year, the number of active users in biology (87), chemistry (36), electronics (111), materials-process-characterization (143), MEMS (109), optics (47), and physics (42) showed the breadth of the usage. And, the number of hours spent by the users: biology (7932), chemistry (2226), electronics (15718), materials-process-characterization (13181), MEMS (7518), optics (5633), and physics (4314) shows a similar breadth of usage. These statistics from the past year reflect a continuing growth that is slightly below 20% per year in the past 4 years.

Such usage and growth require very significant planning and execution. Duffield Hall will bring a large improvement in tool-set as we finally get a chance to place new updated equipment in the facility in an expanded area. We have new expanded furnace stacks (5 banks of 4 tubes) to address the diversity of research and to divide according to the expectations of the processes, expansion in etching capabilities (fast oxide etchers,

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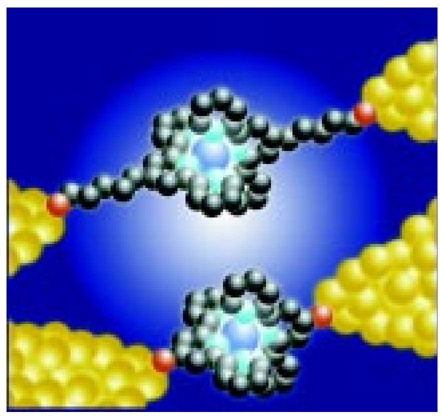
CU Scientists Create Single-Atom Transistor with a 'Designer' Molecule



At Left: Artist's conception of the two molecules used by Cornell scientists to create a single-atom transistor. In each molecule, a single cobalt atom (dark blue) is held by pyridine molecular handles. Sulfur atoms (red) are used to anchor the molecule to gold electrodes. Electrons flow from one electrode to the other by hopping on and off the Cobalt atom.

Cornell Center for Materials Research.

A long-sought goal of scientists has been to shrink the transistor, the basic building block of electronic circuits, to smaller and smaller size scales. Scientists at Cornell have now reached the smallest possible limit: a transistor in which electrons flow through a single atom.

The Cornell researchers have created a single-atom transistor by implanting a "designer" molecule between two gold electrodes, or wires, to create a circuit. When voltage was applied to the transistor, electrons flowed through a single cobalt atom within the molecule. Paul McEuen, professor of physics at Cornell, describes the process by which electrons pass from one electrode to the other by hopping on and off the atom as "a virtual dance of electrons."

McEuen and his colleagues at Cornell's Center for Materials Research, including Dan Ralph, associate professor of physics, and graduate students Jiwoong Park and Abhay Pasupathy, report on their creation of a single-atom transistor in the latest issue (June 13) of the journal *Nature*.

McEuen cautions that the device cannot yet be described as having all the functions of a traditional transistor, such as amplification. But he sees a potential application for the new transistor as a chemical sensor because a change in the environment around the molecule could cause a measurable alteration of the conductance of the device.

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www.cnf.cornell.edu

At the heart of the Cornell group's transistor is the "designer molecule" synthesized by Héctor Abruña, professor of chemistry and chemical biology, and graduate student Jonas Goldsmith. At the molecule's center is a cobalt atom surrounded by carbon and hydrogen atoms and held in place on either side by molecular "handles" made of pyridine, a relative of benzene. On their outer side, the "handles" are attached to sulfur atoms, which act like "sticky fingers," to bond the molecule to the gold electrodes. Two different molecules were studied, one with longer "handles" than the other. The shorter molecule was found to be a more efficient conductor of electrons.

"As chemists, we can deliberately design and manipulate molecules to achieve a specific function," said Abruña. "This is very important because we are now able to incorporate the properties of these molecules into electronic devices."

The challenge faced by the Cornell researchers was to place a molecule less than two nanometers long (about the length of five silicon atoms) between two gold electrodes. To do this they used a technique called electromigration, by which an increasingly large current is run through a gold wire, forcing the atoms to migrate until the wire breaks. The molecule is then "sucked" into the gap by the high electric field present, and the sulfur "sticky fingers" bond the molecule to the gold. "Using this technique you can very reliably get wires with a gap on the order of one nanometer," or about three silicon atoms, said McEuen.

The technique was invented by McEuen and his former postdoctoral colleague, Hongkun Park, when both were researchers at the University of California-Berkeley. Park, now at Harvard University, reports in the same issue of Nature on a similar development in molecular electronics, using a different molecule. Both teams were able to start and stop the flow of electrical current by adjusting the voltage near the bridging molecule.

Although the single-atom transistor demonstrates the potential for shrinking the size of components well beyond what is possible using conventional lithographic techniques, said McEuen, there are major technological hurdles to be overcome in order to build such a transistor for electronic applications. One problem to be solved, for example, is gain, the ability to amplify a small signal.

The Cornell group plans next to focus on engineering a molecule with two different geometries (or shapes) that could act as a switch, changing between the two forms with the application of a voltage. "No one has yet put a single molecule in a circuit and activated it electronically," McEuen observed.

Other collaborators on the Nature paper, titled "Coulomb blockade and the Kondo effect in single atom transistors," are, at Cornell, James Sethna, professor of physics; postdoctoral associate Yuval Yaish; and graduate students Connie Chang and Jason Petta; and Oberlin College undergraduate Marie Rinkoski. The research was funded by the National Science Foundation, the Department of Energy, the Department of Education and the Packard Foundation.

Related World Wide Web Sites:

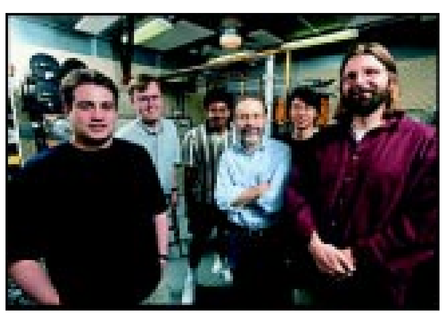
The following sites provide additional information on this news release.

McEuen Group:
http://www.lassp.cornell.edu/lassp_data/mceuen/homepage/welcome.html

Ralph Group:
http://www.ccmr.cornell.edu/%7Eralph/

Abruña Group:
http://abruna.chem.cornell.edu/

David Brand
Cornell News Service



Nicola Kountoupes/University Photography

The Cornell research group, in Clark Hall, working on the single-atom transistor incudes, from left, graduate student Jonas Goldsmith, Associate Professor Dan Ralph, graduate student Abhay Pasupathy, Professor Hector Abruna, graduate student Jiwoong Park and Professor Paul McEuen.

The NanoCulture Has Taken Root at Cornell

Spun off originally from work and activity within the Materials Science Center, the Cornell Nanofabrication Facility has, in its turn, spun off centers, such as NBTC and CNS that rely heavily on the skills, expertise, and unique equipment in the facility. It is the epitome of the shared facility concept. It encompasses a staggering array of equipment and tools. Even more critical is the collection of procedures and protocols for manipulating material at length scales down to the nanoscale, which has been developed within the facility by earlier users and is now embodied in the staff expertise. Indeed, the strength of the facility is more in the staff expertise than in the instrumental base, good though that may be.

Currently, the CNF has more than 600 users each year from 82 universities across the country (14 in New York); six companies are critically dependent on research at the facility, and an additional 72 companies conduct research there. Five federal institutions use it, as do four foreign institutions. Twelve companies have been seeded from research at the facility. This is clearly a major success story.

Cornell did not become nanosmart overnight. Cornell's record shows a history of imagination and action that seizes opportunities when they arise. It builds on a culture of interdisciplinary research that is difficult to generate because it is hard work and there has to be a commitment to the effort. At Cornell, the interdisciplinary culture is genuine. It has required commitment from many faculty to building both the environment and the resources that encourage its further growth; it has also demanded an administrative ability to move quickly when necessary. As new individuals join the Cornell faculty, they often learn how to participate in the multidisciplinary culture. How fragile is the culture that enables this to happen? This is difficult to assess. In my view, the culture was initiated by a farsighted leader, Robert L. Sproull, ably supported by the faculty and administration of his day and not least, by a substantial and forward-looking support package provided by the federal government. Cornell was not the only university awarded one of the original grants, but few of these groups are still active. Although we may not be able to judge how fragile the growth, the nano-culture seems to have taken root at Cornell.

John Silcox
Vice Provost for Physical Sciences and Engr.

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CNF Annual Meeting & Career Fair

CNF's 2002 Annual Meeting and Career Fair was held on September 23rd and 24th on Cornell campus.

In all, over 130 CNF users and staff, Cornell faculty and staff, corporate recruiters, invited speakers and NSF advisors attended the all-day event on Monday at the Statler Hotel.

The day started with a keynote talk on "Some Perspectives on Nanoscience in the 21st Century" by Venkat Narayanamurti, dean of engineering and applied sciences at Harvard University. Then sixteen CNF users from fourteen different research groups spoke on their research progress. During the Poster Session and reception, over 30 posters were presented and discussed with a large audience. Last, but not least, the after-dinner speaker, Prof. George W. Hudler, Plant Pathology, Cornell, took us through "Great Moments in History and How Fungi Got Us There", with piano accompaniment from his daughter, Elizabeth. The day was filled with thought-provoking research and remarkable efforts in the advancement of nanotechnology.

On Tuesday, five companies—Advanced Micro Devices, Applied Materials, IBM, Intel and Kionix—met with CNF's users to share interests and opportunities. The intimate setting of the CNF Career Fair allows for a practical one-on-one discussion of corporate needs and user abilities. While separate interview spaces were provided, the exchange of resumes and business cards at each booth kept the event lively.

Melanie-Claire Mallison, AM&CF Coordinator

Left: Dr. Venkat Narayanamurti, dean of engineering and applied sciences at Harvard University. Right: Prof. George W. Hudler, Plant Pathology, Cornell.

CNF Plans for 2003 'Complicated' Move Into Duffield Hall

Details of how researchers in the Cornell Nanofabrication Facility (CNF) plan the delicate, complex move into Duffield Hall, well before the new high-tech building on the engineering quad is completed, were made public last week by Sandip Tiwari, director of CNF.

"Our aim is to not have any capability down for any significant amount of time," he said.

Speaking at the national user facility's annual meeting at the Statler Hotel Sept. 23, Tiwari said that Duffield's progress is on track for CNF to begin installing its new equipment—including an E-beam machine and hot-processing stacks for growth and deposition in the building's 1st floor clean room starting August 2003.

Existing CNF equipment, from other lithography and plasma processing tools to vacuum systems and characterization tools, will then be moved between September and November 2003. After Nov. 30, CNF's present location at Knight Lab will be demolished to make way for Duffield's atrium connecting Phillips and Upson halls.

Duffield, a $58.5 million nanotechnology research and teaching facility, is due for completion in the summer of 2004. Construction began in June 2001 and building is now on schedule for completion of phase 1 by August 2003, which will allow the transfer of CNF to its new quarters.

The new home of CNF will be a 17,000-square-foot clean room, taking up the entire first floor of Duffield, almost doubling the square footage at Knight Lab. The new clean room will include space for CNF research such as thin film and chemical processing (10,000 sq ft), Nanobiotechnology Center research (1,000 sq ft) and an instructional lab for undergraduate education (1,000 sq ft). There also will be a togging room, where clean-room suits are put on or discarded.

The move from Knight to Duffield, said Tiwari, "will be a very complicated project and a lot of different elements have to work well together."

Although the goal is almost no interruption in service for users, a few of the lab's capabilities will be unavailable at any given time, said Tiwari. Indeed, for a while, most capabilities will be available in either or both simultaneously functioning locations, he said, The worst case is that very specialized tools, such as the Leica VB6, one of the most advanced electron beam lithography tools in the world, will be out of commission for a month or longer.

The design of the new CNF clean room will allow the lab "to accomplish what we want over the next 10 to 15 years," said Tiwari. The facilities will be "much, much cleaner" and allow full electronic access control. There will be huge upgrades in areas such as de-ionized water and nitrogen supply, an intelligent toxic gas detector system, backside chemical storage and underground transport of equipment and chemicals through dedicated corridors.

Despite the impending move, CNF continues to experience a 15 to 20% annual expansion in users, said Tiwari. A dominant fraction of users is academic, and this usage continues to grow, from large research universities to Cornell under-graduates.

Indeed, he said, CNF has had to acquire an additional 700 square feet of wet chemistry research space in Langmuir Lab in Cornell Business and Technology Park, which will be used until the move into Duffield Hall.

The featured speaker at the CNF event was Venkat Narayanamurti, Dean of Engineering and Applied Sciences at Harvard University. His talk was followed by reports from facility users on cutting-edge research, from single-molecule electronic devices to carbon nanotube transistors.

David Brand
Cornell News Service

Charles Harrington/University Photography

Alyssandrea Hamad, left, a Cornell graduate student in Materials Science and Engineering, describes her research project to Dr. Lawrence S. Goldberg, senior engineering advisor with the National Science Foundation, during the poster session for the CNF's annual meeting, Sept. 23., in Clark Hall.

User Profile: Mihaela Balseanu

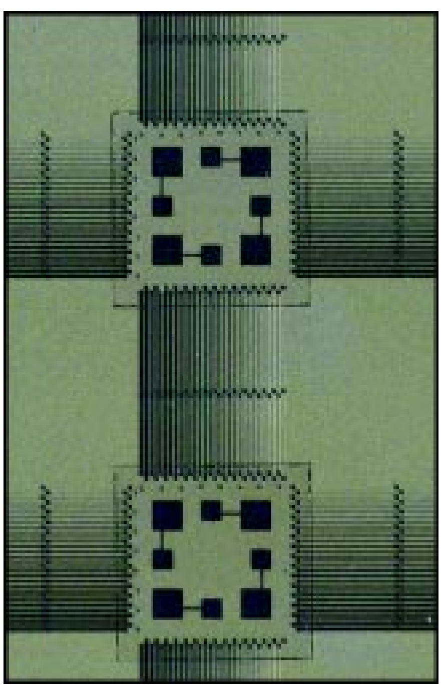
Mihaela Balseanu is currently a graduate student in the materials science and engineering dept. at Cornell University, and is this year's recipient of the CNF Nellie Yeh-Poh Lin Whetten Award. The Whetten Award recognizes an outstanding female graduate student at CNF, who shows spirit, commitment to professional excellence, and professional and personal courtesy.

Mihaela came to Cornell after receiving her bachelor's degree from University Politechnica Bucharest (Romania) with a major in Materials Science and Engineering. In 1999 she joined Professor Kornegay's research group as a Ph.D. candidate. Since then she has been working on homogeneous integration of off-the-shelf IC's on a silicon substrate. In 2001 she received her Master's degree in Materials Science with a minor in Electrical Engineering.

Wafer level integration is an appealing alternative to traditional second-level packaging solutions such as multi-chip-module design or printed wiring boards. Typically, the major problems of semiconductor packaging are complexity of the structures, size of the package and thermal mismatch between semiconductor and packaging materials. The integration of discrete circuits with different functionality within a silicon substrate is inherently more reliable than traditional packaging because it eliminates wire bonds and discrete packages, allowing for higher density interconnections. Shorter, higher density interconnects associated with a low k interlayer dielectric would enable the top interconnect layers to be transferred from the chip to the package, thus increasing the number of known good dies per wafer, and hence the yield. This approach also reduces the size, weight and volume of the assembly. Integrating Si chips in a Si substrate greatly reduces the thermal mismatch and the associated reliability problems.

Over the last two years, Mihaela successfully developed a fabrication process for homogeneous integration of silicon chips on a silicon substrate using wafer bonding. One of the challenges of this project has been to fabricate a silicon housing structure with very smooth surfaces to allow silicon chips to be thermally bonded without the use of any adhesive. Standard dry etching techniques leave behind an extremely rough surface while successful wafer bonding requires very flat, smooth and clean surfaces. Low temperature bonding is critical for this process in order to preserve the metallization already present on the chip. Another challenge of this project was the development of the isolation and planarization methods. Spin-on epoxies available in CNF have been used for this purpose with good results. Currently, more traditional filling materials along with interlayer dielectric materials with lower CTE are under investigation.

The new structure exhibits excellent isolation and a high interconnect density of the integrated Si components. Line continuity from one chip to another has been proven with a minimum line width of 15 µm. Development of a homo-geneous integration method opens the door to heterogeneous integration of SiC, GaAs, etc., chips into a silicon substrate provided that a suitable wafer bonding technique is developed.



More about Mihaela's research can be found on Professor Kornegay's group web page: http://aims.ece.cornell.edu/

Parylene for Nanopatterning and Nanofluidic Applications

As steady increase is made of integrated microelectronics in many measuring and control systems, extensive research has been conducted to further the penetration of microfabrication techniques into new products and markets.

One of the results of the increased research activity is the new class of silicon based sensors for microfluidic applications. Potential applications include: drug delivery, biological flow channels, biochemical reaction systems, liquid and gas chromatography, microfluidic mixing, electrophoresis systems, and other fluid flow systems. Compact fluidic devices offer an increase in speed of analytical device operation while consuming low volumes of both samples and reagents. Additionally, precise placement of biochemicals on device structures and control of the cell culture environment are important for tissue engineering, sensors and fundamental studies of cell behavior.

These engineered biomolecular systems are important, since they provide a vehicle for understanding molecular interactions and could lead to the ability to change the functionality of biological agents on the nanometer scale. Additionally, precise structuring of biological molecules opens a route for the fabrication of a new generation of highly sensitive diffraction-based biological sensors.

In this work, methods developed at the CNF were used to create both nanofluidic channels and patterning of chemically sensitive biological materials on various substrates using a Parylene polymer as a base layer.

In the former case, we use highly developed microfabrication techniques, yielding excellent dimensional control, to pattern a pinhole-free vapor phase deposited Parylene polymer in order to shape and confine our biologically sensitive layer [1]. Since Parylene is both chemically inert and thermally stable over a wide range of temperatures, selective immobilization of a wide variety of biomolecular materials and any other chemically sensitive layers is possible.

The patterned Parylene layer acts as a template to physically pattern subsequently deposited chemically sensitive biomolecular materials. Parylene is then peeled from the substrate and the result is a geometrically confined region, the negative tone of the Parylene pattern, of immobilized biological material. We have patterned antibodies, poly-L-lysine and aminopropyltriethoxysilane (APTS) self assembled monolayers. These surfaces were respectively used to pattern *Escherichia coli* serotype O157:H7 bacteria cells, rat basophilic leukemia (RBL) cells and 20nm diameter aldehyde-sulfate coated fluorescent polystyrene beads.

Various other multiplayer structures were patterned. Typical patterns consisted of arrays of 5mm long parallel lines of bacteria confined to stripes with widths varying from 200nm to 20µm. Such patterns can be made over large areas, and we have done this on areas up to $3cm^2$.

In the latter case, we employ a room temperature vapor-phase deposition of a Parylene polymer to fabricate centimeter-long, self-sealing tubes with sub-micrometer lateral dimensions in either isotropically or anisotropically etched silicon molds [2]. Tubes are formed as the material "pinches off" during the deposition progresses to leave closed tubes or other volumes. Once the tube is formed, access holes for fluidic interconnects can be created using standard lithographic processes and the resulting tubes are either removed from the mold or left integrated with preexisting devices. Channels were formed in templates with a variety of cross sectional profiles, including vertical and re-entrant profiles. In one approach we replicated fluidic systems in polymer by detaching free-standing flexible Parylene tubes from the silicon mold.

Rob Ilic, CNF Process Engineer

1. B. Ilic and H. G. Craighead, Biomed. Microdev. 2, 317, 2000.
2. B. Ilic, D. Czaplewski, M. Zalalutdinov, B. Schmidt and H. G. Craighead, TBP in Nov/Dec issue of J. Vac. Sci. Technol. B 2002.

The 2002 NNUN REU Program

The 2002 NNUN REU Interns at the August network-wide convocation, Cornell University, Ithaca, NY

Providing a focused experimental research experience program in nanotechnology and its basic subjects in a 10 week period is a challenging task; the 2002 Research Accomplishments for the National Nanofabrication Users Network's Research Experience for Undergraduate Program demonstrates that with effort from staff, faculty, graduate students, and the participating students, not only can it be successfully achieved, but also it can lead to significant accomplishments by students just starting on the path of technical education.

The NNUN partnership, through our complementary strengths, cross-fertilization, multi-site education, and use of each other's resources, provides exciting projects and the means to achieve them in a reasonable time. Each student in the program completes an independent research project with strong technical support and faculty supervision, undergoes hands-on training and education, and participates in convocations at individual sites and at an NNUN site to present their research efforts.

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. 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; NNUN hopes to see them build on this summer's experience. And my thanks to the staff, the graduate student mentors, and the faculty for their participation and involvement.

Sandip Tiwari, *Director, NNUN*

The NNUN REU Program is made possible by National Science Foundation Grant # 9987915, NNUN and the following Corporate Sponsors: AMD, Agilent Technologies, AMP (Lytel), Analog Devices, Applied Materials, Canon, Hewlett-Packard, Hitachi, IBM, Infineon, Intel, Matsushita, NSC, Panasonic, Philips, Robert Bosch, Taiwan Semiconductor, Tektronix, Texas Instruments, Toshiba, Varian Semiconductor, and Xerox Inc.

The 2002 NNUN REU Research Accomplishments are available on the web at www.nnun.org

New Staff at CNF

Rob Ilic, Theresa Andersen & Kelly Baker

Mr. Robert Ilic received a B.S. in Engr Physics, an M.S. in EE from University of Illinois, and an M.S. in Applied Physics from Cornell University in 1996, 1998 and 2002 respectively. He has authored and co-authored over 60 journal publications and has refereed many articles for J. Appl. Phys., Appl. Phys. Lett., J. Electrochem. Soc., J. Vac. Sci. Technol., Nanotechnol and many other prestigious journals. Currently, as a staff member of the CNF, Rob is finishing a Ph.D. in Applied Physics at Cornell. His research interests are on the development of nano-fabrication technologies for building fully integrated molecular scale devices, use of micro- and nano-mechanical resonant sensors for novel chemical and biological detection schemes, nanofluidics, atomic force probes, and nanomagnetics.

Ms. Theresa Andersen received her B.M. in Vocal Performance from Ithaca College in 2000. She spent the year following graduation as an intern with Campus Crusade for Christ at IC and Cornell, and has since become a "towny." Theresa joined the CNF staff this past July as the Receptionist and User Program Administrative Assistant.

Mr. Kelly Baker has been working for Cornell University for three years, on the Engineering Quad buildings and now at the CNF, where he has joined the staff as a lab technician. Before coming to Cornell, Kelly worked at Huffy Bike Company, in part because he was and still is a professional BMX bike rider. Kelly and his free-style riding have been featured in Ride BMX, BMX Plus, Faction, and Dig magazines. He was even in a Reebok commercial. While on the ground, Kelly enjoys spending time with his wife, Laura, and his three children, Molly, Ben and new arrival, Clinton, born on Halloween!

New Equipment: Dicing Saw

CNF's dicing saw is a model from Kulicke & Soffa's 7100 series, that allows users to separate dies from substrates as large as 8" squares. The system features a front mount spindle that operates with reduced vibration and thermal expansion, thereby providing high accuracy in cut placement. An integrated vision system and software capable of pattern recognition allows for rapid alignment as well as inspection of completed cuts. The blade load is monitored continuously throughout the dicing process and an intelligent blade wear curve learning system automatically compensates for blade wear. The system is currently set up with processes and blades for substrates such as silicon, quartz, gallium arsenide and indium phosphite.

Director's Column, continued from page 1

etc.), expansion in characterization capabilities (SEMs, optical characterization, focused-ion-beam, and chemistry-oriented tools), in-situ process monitoring capabilities, expansion and more automation in the variety of the usages of resists (developing and rinsing stations), new lithography tools (a new state-of-the-art e-beam lithography machine thanks to a significant NSF award and Cornell and state support), etc. The rules of usage of the facility (safety-related as well as those that allow equitable access) will continue to change as we try to meet the growing demand.

Moving into Duffield Hall will be a very critically timed and planned process that I have described in this column earlier. The staff of CNF has put considerable effort in the planning process so that our ability to support the user while moving is maintained at a high level. I hope that we will get the support from our user community that will assure that we minimize research disruption and the equity that the facility strives for.

Sandip Tiwari, *Director, CNF*

New Chemical Waste Policies & Training Video

We are implementing new chemical waste policies at the CNF. The two main changes we are making are:

1) New bottles for chemical waste
2) Special venting caps for bottles containing nitric acid waste

The new chemical bottles are sturdier and more chemically resistant than the empty used chemical bottles we are currently using. Also we have new vented caps for them that should help prevent pressure build up in the bottles.

Additionally, we have created special venting caps for nitric acid waste (Aqua Regia & Polysilicon etch).

A Chemical Waste Procedures Training Video has been created to go over these changes, http://www.cnf.cornell.edu/nanocourses/safety/safety.htm. Please watch the video before your next visit to the CNF or watch it in the terminal room prior to entering the clean room.

If you have any questions, please contact Dan Woodie, CNF Safety Manager at woodie@cnf.cornell.edu or 607-255-2329.

The 2001-2002 CNF Research Accomplishments

The 2001-2002 CNF Research Accomplishments are now available on our web site in pdf.

http://www.cnf.cornell.edu/2002cnfra/2002cnfra.html

We would like to thank all the researchers who submitted their reports, making this the most complete summary yet of the work being done at the CNF.

If you would prefer hard copy, please send your request to Melanie-Claire Mallison and she'll be happy to mail one to you. *(Mallison@cnf.cornell.edu)*

A Selection of 2002 CNF Publications and Presentations

W.M. Saltzman and W.L. Olbricht, “Building Drug Delivery into Tissue Engineering”, Nature Rev Drug Discovery 1:177-186 (2002).

J.M. Ballantyne, “The Center for Biochemical Optoelectronic Microsystems”, Optoelectronic Industry Development Association Annual Forum, Wash. D.C., Nov. 28, 2002.

J. Han, H. Craighead, “Characterization and Optimization of an Entropic Trap for DNA Separation”, Analytical Chem 74 (2): 394-401, Jan. 15, 2002.

S.W.P. Turner, M. Cabodi, H.G. Craighead, “Confinement-Induced Entropic Recoil of Single DNA Molecules in a Nanofluidic Structure”, Physical Review Letters, 88 (12): N. 128103, Mar. 25, 2002.

M.O. Kimball and F.M. Gasparini, “Critical Behavior and Scaling of Confined 3He-4He Mixtures”, J. Low Temp. Phys. 126, Nos. 1/2, 103-108, 2002.

A. Pattekar, and M. Kothare, “Design and Fabrication of a Microreactor for Hydrogen Production by Catalytic Methanol Reforming”, Presented at the AIChE Annual Meeting, November 2002, Indianapolis, Indiana.

A.F. Dias, G. Dernick, V. Valero, M.G. Yong, C.D. James, H.G. Craighead and M. Lindau, “An Electrochemical Detector Array to Study Cell Biology on the Nanoscale”, Nanotech 13: in press. (2002)

C-F Chou, J.O. Tegenfeldt, O. Bakajin, S.S. Chan, E.C. Cox, N. Darnton, T. Duke, and R.H. Austin, “Electrodeless Dielectrophoresis of Single and Double Stranded DNA”, In Press, Biophysical Journal. (2002)

C.D. James, “Electrophysiological and Developmental Studies of Reconstructed Neuronal Cell Networks Using Microfabrication Techniques”, Biomedical Engr Seminar, National Inst of Standards and Tech, Gaithersburg, MD. March 22, 2002.

D. Tanenbaum, “Fabrication of Glass Nanostructures: Nano-Mechanical Systems and Microfluidics”, Physics Colloquium at CSU LA, 24 January 2002.

D. Tanenbaum, “Fabrication of Glass Nanostructures: Nano-Mechanical Systems and Microfluidics”, Physics Colloquium at UC Riverside, 8 May 2002.

H. Cao, Z. Yua, J. Wang, E. Chen, W. Wua, J.O. Tegenfeldt, R.H. Austin, and S.Y. Chou, “Fabrication of Self-Sealed Nanofluidic Structures”, Applied Physics Letters. (2002)

A.Hamad, Y.Bae, X.Liu, C.Ober, F. Houlihan, G.Dabbagh, and A.Novembre, “Fluorinated Dissolution Inhibitors for 157 nm Lithography”, SPIE 2002, Paper # 4690-53.

A. Dias, G. Dernick, M. Yong, V. Valero, C. James, H. Craighead and M. Lindau, “Improved Electrochemical Detector Arrays for Analysis of Spatio-Temporal Dynamics of Exocytosis in Chromaffin Cells”, Biophys. J. 82: 11a (2002).

A. Yaradanakul, Z. Çelik-Butler, and D.P. Butler, “Infrared Sensing Microbolometers on Flexible Substrates”, accepted for publication in IEEE Transactions on Electron Devices.

L. Chen, G.E. Kohnke, and Y. Suzuki, “Integrated Platform for Photonic Crystal Devices at Near Infrared Wavelengths”, Applied Physics Letters 80, 1514 (2002).

A. Yildiz, Z. Çelik-Butler, D.P. Butler, and C.-U. Kim, “Investigation of the Temperature Coefficient of Resistance and Crystallization of YBaCuO Thin Films Using Pulsed Laser Annealing”, Journal of Vacuum Science and Technology B 20, 548 (2002).

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