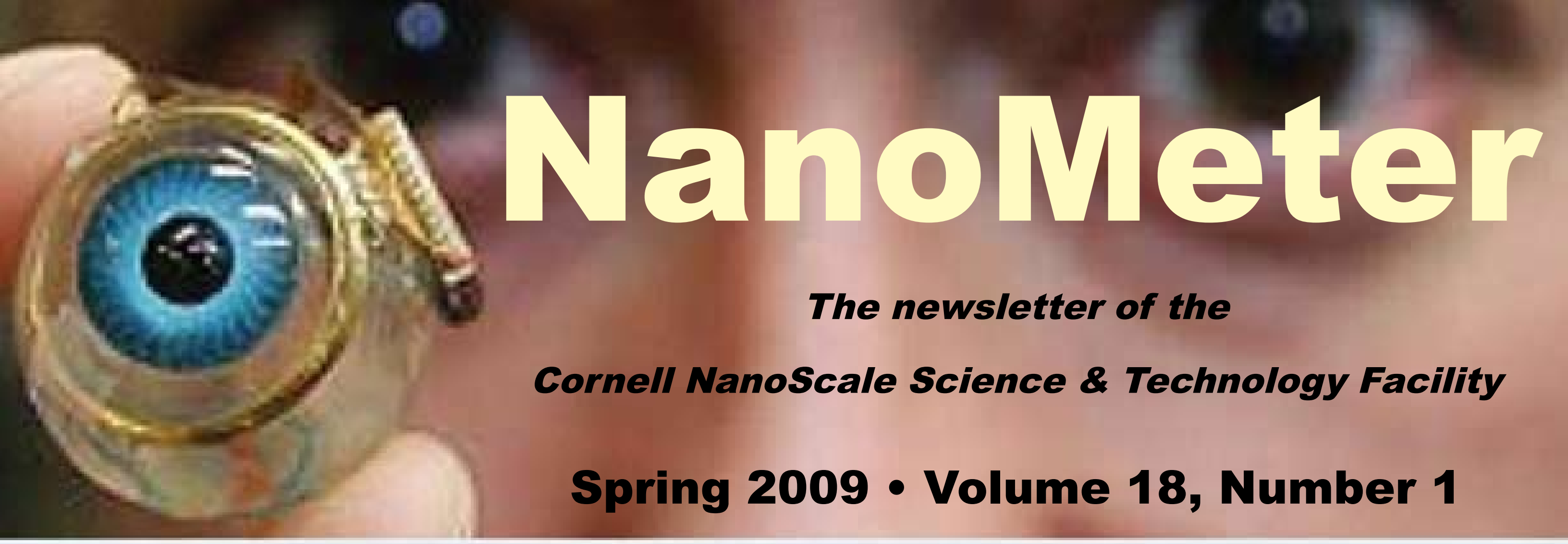


NanoMeter

The newsletter of the

Cornell NanoScale Science & Technology Facility

Spring 2009 • Volume 18, Number 1

Directors' Column

It is with great pleasure that we present the 2009 Spring issue of NanoMeter.

The big news item is the renewal of our NSF grant for the next five years. At its December meeting, the National Science Board approved funding for the renewal of the National Nanotechnology Infrastructure Network—our parent organization, which is being led by of our former director, Prof. Sandip Tiwari. All of us at CNF look forward to continuing to serve the nanotechnology user community.

2008 was a very exciting year in which we made an unprecedented opening towards the life sciences community. One of the highlights was the opening of our remote office at Weill Cornell Medical College in New York City. The office is located at the Institute for Computational Biomedicine, Room Y13-02, 1305 York Ave. The purpose of this office is to promote the use of nano- and micro- fabrication techniques for clinical and basic life sciences research. CNF staff is available for consultation and translating your ideas into a working device. We kicked off the effort last September by hosting a Mini-Symposium on Nanomedicine at the new office location. You can find more information on the NYC office in this issue (page 2) and from a link to the website at: www.cnf.cornell.edu.

It is recognized that paradigm shifts in understanding biological processes often occur when "novel" techniques from outside fields are openly adopted by the research community. In this vein, a symposium on ***Innovations in Nanotechnology for Cancer Research*** was hosted last September in collaboration with the National Cancer Institute. This one-day workshop brought together experts in cancer biology and nanotechnology to discuss problems in the clinical and basic science of cancer which nano- and micro- fabrication may be uniquely suited to address. The day showcased advances in nanotechnologies that have enabled forward strides in cancer research and treatment, and highlighted the current challenges in cancer research that nanotechnology can begin to address. The talks can be viewed at: http://www.cnf.cornell.edu/cnf_ncrsymposium.html.

We hosted a workshop on ***The Commercialization of Nanotechnology*** last April. This new endeavor for CNF, in which we partnered with the Central New York Technology Development Organization, had a dual purpose: to educate the CNF community on how to start a small company, and to educate small companies on the services provided by CNF and other state-of-the-art facilities at Cornell and in the region. The talks can be viewed at: http://www.cnf.cornell.edu/cnf_commercialization.html.

We are gearing up for an equally exciting year in 2009. In the works is a laboratory for organic electronics—made possible through a partnership with ReynoldsTech—and a symposium in this rapidly emerging field. More on this in the next edition of the NanoMeter.

Warm regards,

George Malliaras, *Lester B. Knight* Director

Donald Tennant, Director of Operations

In This Issue....

Photograph Above of Artificial Eyeball by Lisa Hornak; CNF Project # 657-97, CNF Research Accomplishments, page 26, http://www.cnf.cornell.edu/cnf_2008cnfra.html

All photographs in this issue were taken by Donald Tennant unless otherwise noted.

New nanotechnology office at Weill Cornell to help 'marry nanofabrication with life sciences'

By Anne Ju
Cornell Chronicle

To bring Cornell's cutting-edge nanotechnology capabilities closer to medical researchers, Cornell NanoScale Science and Technology Facility (CNF) has opened a satellite office on the Weill Cornell Medical College campus.

The office serves as yet another link between the Ithaca and Manhattan campuses, and provides staff support and specialized software for Weill scientists interested in using CNF to further their research.

"We are seeing an emergence of interest in medical applications of micro- and nano- technology," said George Malliaras, the Lester B. Knight Director of CNF. "We want to be among the first to capitalize on this and let it grow."

A September 24th celebration to mark the office's opening in New York City included an academic symposium, attended by more than 40 people, and a research poster session in the Archbold Commons next to Weill Auditorium. All the posters involved life sciences research, in an effort to demonstrate "what is possible when you marry nanofabrication with life sciences," Malliaras said.

George Malliaras, Beth Rhoades and Garry Bordonaro.

The new office is housed in the Weill Greenberg Center's Institute for Computational Bio-medicine, where Harel Weinstein, the Maxwell M. Upson Professor of Physiology and Biophysics at Weill, has donated some of his research space.

Beth Rhoades, CNF's life sciences liaison, and Michael Skvarla, CNF program manager, will spend several days each month at the New York City field office to provide consulting and support to Weill researchers.

Computers in the new office will allow researchers to design their devices or experiments, and Skvarla and Rhoades will be on hand to help if needed. The researchers can later travel to Ithaca to create their devices or perform their experiments using the CNF equipment.

Located in Duffield Hall on the Ithaca campus, CNF is known for its state-of-the-art clean room for micro- and nano-fabrication. It is considered a flag-ship facility of the National Nanotechnology Infrastructure Network, a national consortium of fourteen of the most advanced nanotechnology centers.

Professor Michael Shuler presenting at the mini-symposium

Of CNF's 700-plus users, about 33 percent conduct research in the life sciences—to some, "a surprisingly large figure, given nanotechnology's origins in engineering and physical sciences," Malliaras said. Life sciences researchers are also the fastest-growing user base at CNF he added.

Scott Blanchard, assistant professor of physiology and biophysics at Weill, said having a CNF office in New York City will likely "provide traction" for more of his medical colleagues to use CNF. Blanchard himself, along with three others in his lab, are already trained CNF users.

"Right now there's a gap between our two cultures of basic and medical science that needs to be overcome," Blanchard said. "I think this is a good first swing at it."

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

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

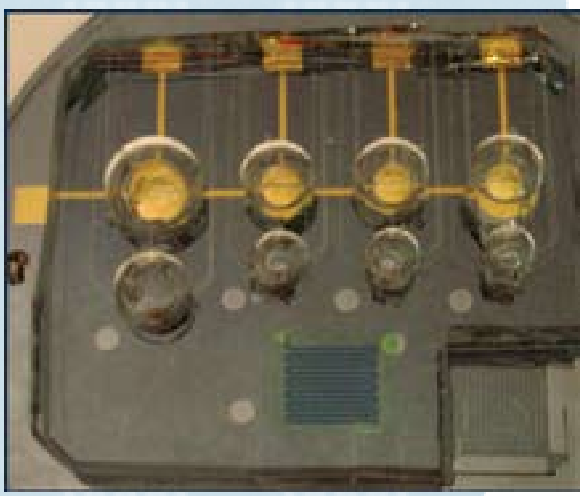
CNF's 2008 Nellie Yeh-Poh Lin Whetten Memorial Award Winner:

Clarissa Lui

Clarissa Lui is a currently a graduate student in the Department of Biomedical Engineering at Cornell, and is the 2008 recipient of the CNF's Nellie Yeh-Poh Lin Whetten Memorial Award. Nellie worked at the CNF for three years before her death, and this award honors her memory by recognizing an outstanding female graduate student working at the CNF— one who reflects the same exuberance, commitment to professional excellence, and professional and personal courtesy, embodied in Nellie's time here.

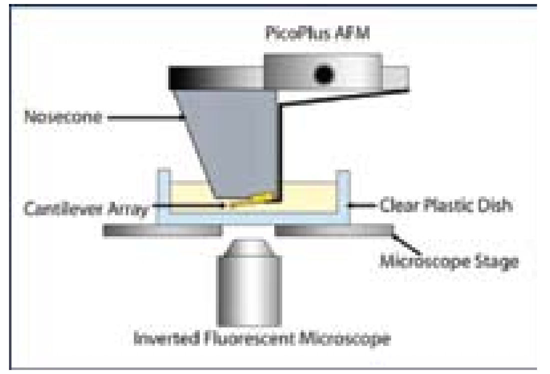
Clarissa Lui received her bachelor's degree in Electrical Engineering from the University of Texas at Austin in 2004. Her summer activities included internships at Freescale Semiconductor and Wang Engineering Services, as well as NSF undergraduate research in Dr. Shaochen Chen's laboratory in the Department of Mechanical Engineering at the University of Texas at Austin, which provided an opportunity for her to work on a portable microfluidic PCR (polymerase chain reaction) device.

Shortly after arriving at Cornell, Clarissa joined Professor Carl Batt's research group. She continued work in portable microfluidic PCR platforms for the rapid detection of pathogens. To further broaden the utility of the system, she helped develop a microfluidic sample preparation module to remove cells of interest from a raw sample by mixing with antibody-coated magnetic beads, electrolytic hydraulic pumps to aid the system with on-board fluid handling at a wide range of flow rates (1.25 µl/min to 30 µl/min), as well incremental improvements to the existing platform modules.



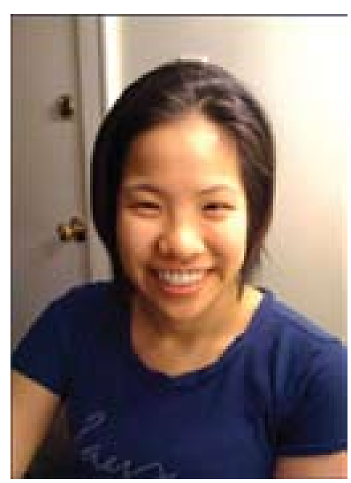
The vision for this project is to create a hand-held fully-automated DNA-detection device that could be easily used in the field for environmental microbiology, food safety, and rapid forensic evidence evaluation. Clarissa's work in the CNF included patterning of SU-8 for making PDMS molds, e-beam evaporation of gold electrodes on oxide wafers, and creating arrays of oxide-coated pillars for DNA purification chips. Currently, between 100 and 1000 *S. typhi* cells can be detected using this system, with a total testing time from raw sample to result of 1 hour at optimized pumping speeds.

In addition, Clarissa began a new project involving custom-fabricated AFM-based silicon nitride microcantilevers for the detection of biological activity. Tipless gold-coated silicon nitride cantilevers with an exposed nitride pad at the free end were fabricated in the CNF and used to study the activity of single cells. For this project, Clarissa's work in the CNF included furnace growth of thin films (thermal oxide and silicon nitride), patterning of thin films (oxide, nitride, gold), through-wafer acid etches, and scanning electron microscopy. The gold film allowed for the simple patterning of chemistry as well as enhanced signals from the thermal noise spectra due to the higher reflectivity. The research group has captured active single *E. coli* cells onto the free end of the cantilever for thermal-noise based vibration analysis of single-cell bacterial activity in liquid. Increases in the resonance frequency with the addition of low concentration leucine suggest an increase of cellular activity that induces stress on the cantilever, leading to spring-stiffening and subsequent detection. Currently, the cantilevers are also being employed to detect protein assemblies and biological activity of RBL mast cells.



In 2007-2008, Clarissa served as a CNF fellow, working primarily on photolithography processes. Besides research, Clarissa spends a good portion of her time volunteering to help generate interest in science engineering among middle and high school kids. In early 2006, she assumed the role of webmaster, and has since been heavily involved with ***Nanooze!***, a web magazine about science and nanotechnology that was made for kids. In the summer of 2008, she helped plan and lead a group of high school students through a week-long project titled "Micro and Nanotechnology for Biomedical Engineering Applications" for the CATALYST Academy, an initiative by the Office of Diversity Programs.

Throughout her impressive graduate and research career, Clarissa Lui has volunteered at science fairs, elementary schools, and at the Onondaga nation. Upon graduation, Clarissa hopes to continue working in the biosensors field, as well as staying actively involved in science education.



Figures on this page were provided by Clarissa Lui.

Using light to move and trap DNA molecules

By Bill Steele
Cornell Chronicle

A major goal of nanotechnology research is to create a "lab on a chip," in which a tiny biological sample would be carried through microscopic channels for processing. This could make possible portable, fast-acting detectors for disease organisms or food-borne pathogens, rapid deoxyribonucleic acid (DNA) sequencing and other tests that now take hours or days.

One obstacle has been the difficulty of moving stuff at the nanoscale. Mechanical pumps don't scale down well. So David Erickson, Cornell assistant professor of mechanical and aerospace engineering, and colleague Michal Lipson, Cornell associate professor of electrical and computer engineering, have turned to "optofluidics," using the pressure of light to move and manipulate biological molecules.

Now they have shown that a beam of light can trap and move particles as small as 75 nanometers in diameter, including DNA molecules—some of the smallest material ever manipulated by such a system, the researchers said. Their experiments are described in the January 1, 2009, issue of the journal ***Nature***.

This manipulation is possible because of the paradoxical dual nature of light. Light can be thought of as a stream of particles called photons that can exert a force, or as waves of expanding and contracting electric and magnetic fields. If light is confined to a waveguide narrower than its wavelength, the wave overflows and can exert a force beyond the guide. Imagine a nanoscale Indiana Jones chased down a nanotunnel by a photon instead of a granite sphere. If Indy climbs into a tunnel above the one in which the photon is moving, he is still being chased because the photon is bigger than its own tunnel.

Erickson and Lipson first cut microfluidic channels in a chip and placed waveguides directly under the channels. In earlier research published in ***Optics Express*** (Oct. 15, 2007), the researchers showed that light in the waveguide could move polystyrene spheres about 3 μm in diameter through the fluid-filled channels. But the "evanescent field" of a light wave that extends beyond the waveguide did not extend far enough or carry enough energy to capture and manipulate smaller biological molecules, they found.

So they turned to a new device created by Lipson: a "slot waveguide"—two parallel silicon bars 60 nm apart, serving as two parallel wave guides. Light waves traveling along each guide expand beyond its boundaries, but because the parallel guides are so close together, the waves overlap and most of the energy is concentrated in the slot. In addition to creating a more intense beam, this structure allows a beam of light to be channeled through air or water.

As a demonstration, graduate students Allen Yang, Sean Moore, Bradley Schmidt and colleagues in Erickson's and Lipson's research groups laid a slot waveguide across a microscopic fluid channel and showed that light from an infrared laser channeled through the wave guide could trap 75 nm diameter polystyrene spheres and comparably-sized DNA molecules out of a stream of water flowing across it. The light in the slot waveguide extends above the slot and exerts a downward force on a particle entering it, pulling the particle down into the slot. Since light pressure then moves the trapped particles along the slot, such a device could be used to separate biological molecules out of a stream and send them somewhere else for processing, the researchers said. Further development, they added, could make it possible to separate DNA molecules by length for rapid DNA sequencing.

The research was funded by the National Science Foundation, which also supports the Cornell NanoScale Facility where the devices were manufactured.

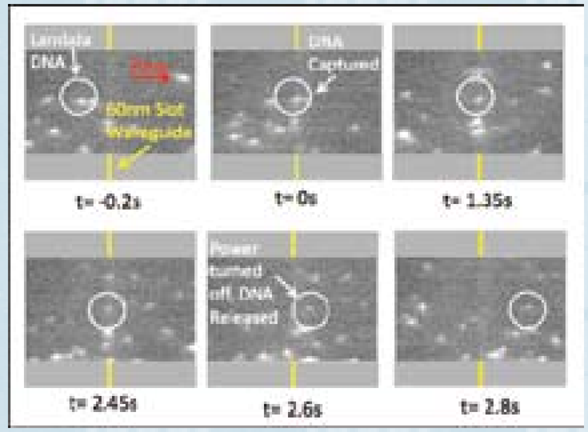


Figure 1: DNA tagged with a fluorescent dye, flowing through a channel 100 µm wide. Laser light in a slot waveguide laid across the channel traps some of the DNA, which is released when the light is turned off.

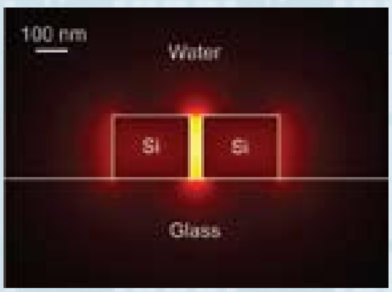


Figure 2: Two parallel silicon bars, each acting as a channel for a light beam, form a slot waveguide. Because the channels are smaller than the wavelength of the light an "evanescent field" extends outside each one, and energy is concentrated where the fields overlap.

Figure 3: When DNA molecules suspended in a tiny stream of water flow through a nanoscale channel, they can be captured by a field of light if that light is confined in a device called a slot waveguide. The pressure from the light can then propel the DNA along the waveguide channel to bring the molecules to new locations. Such manipulation could prove valuable for assembling nanoscale structures, driving powerful sensors and developing a range of other technologies. Credit: Nicolle Rager Fuller, NSF

Figures on this page were provided by Allen Yang, of the Erickson Research Group

Characterization of bistable electrostatically actuated microstructures using Zyvex nanoprobes

by Rob Ilic
CNF Staff

One of the main distinguishing features of microstructures actuated by inherently nonlinear electrostatic forces is that they can become unstable. Equilibrium instabilities of electrostatic devices, corresponding to fold or saddle-to-node bifurcations (i.e pull-in instabilities), limit the operational range of devices. Due to the unique combinations of mechanical and electrostatic nonlinearities the voltage deflection characteristics of the device may have two maxima. This implies the existence of sequential snap-through buckling, pull-in instability and of bistability of the beam.

In this work [1], using a scanning electron microscope (SEM) in conjunction with the Zyvex S-100 Nanoprobes, we observed the pull-in behavior of electrostatically actuated curved microbeams. Devices were fabricated from a 30 µm thick highly doped single crystal Si using silicon-on-insulator (SOI) wafers as a starting material and etched using a deep reactive ion etch (DRIE) based process. Two micron-thick buried silicon dioxide served as an etch stop layer during the DRIE step. Devices were released using hydrofluoric acid and critical point drying. The fabricated beams with a bell shaped curvature were 1000 µm long, nominally 3 and 4 µm thick, and 30 µm wide. Beams were fabricated in electrically isolated pairs with hook-shaped verniers placed at the midpoints of the beam to facilitate displacement measurement and prevent electrical shorting following electrostatic pull-in.

Actuation voltages were applied to micro probes connected directly to the highly doped Si using four Zyvex micro manipulators mounted inside a high resolution SEM (Zeiss Ultra) vacuum chamber. The beam and the substrate of the SOI wafer were at ground while the actuation voltages were applied to the electrode, Figure 1 (a). Several screen shots of the micro beam at differing actuation voltages are shown in Figure 1 (b). The voltage was linearly increased by 10V increments from zero to a value slightly exceeding the snap-through critical value of 65V. Next, the voltage was decreased and the release (snap-back) of the beam was observed at 48.8V. Increasing the voltage beyond the snap-through, a pull-in instability was observed at 102V. Model results obtained for the actual dimensions of the device were in good agreement with the experimental data (Figure 2). Designs incorporating bistable beams have clear functional advantages and may result in improved performance of switches, capacitive based sensors and MEMS/NEMS based nonvolatile memory devices.

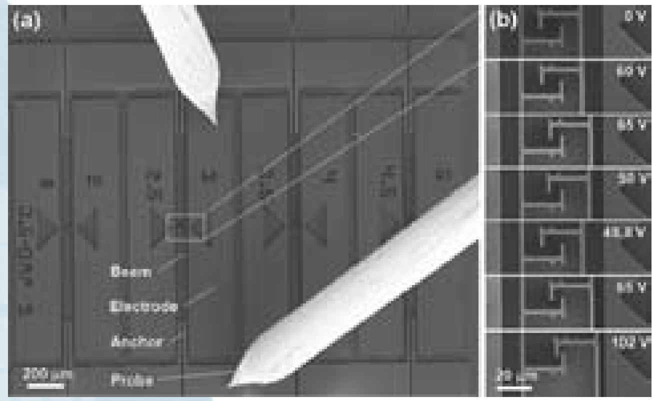


Figure 1: (a) Fabricated microbeams of different initial elevations actuated inside a SEM. The actuation voltage was applied using micro probes operated by micro manipulators mounted inside an SEM chamber. (b) Screen snapshots of the beam at different actuation voltages.

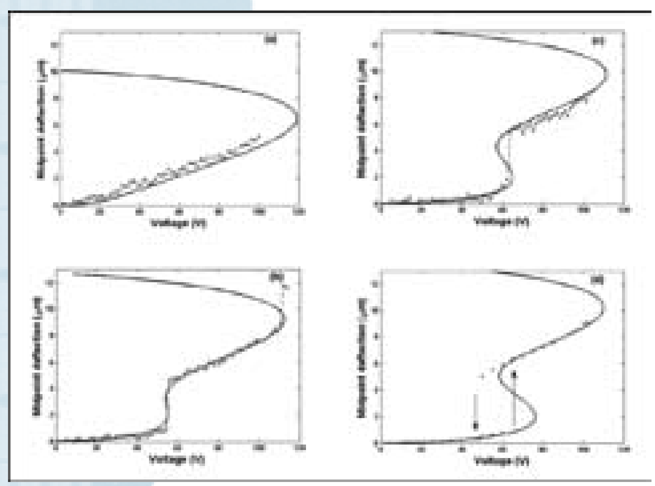


Figure 2: Experimental bifurcation diagram (markers) for initially straight bell shaped 1000 µm long beam for different initial elevations: (a) h = 0, (b) h = 2.6 µm, (c) h= 3 µm, (d) h = 3.5 µm. Solid lines correspond to model results obtained for the actual width of the beam of 2.4 µm and distance to electrode g = 10.1 µm measured using SEM.

Reference:

1. S. Krylov, B.R. Ilic, D. Schreiber, S. Seretensky and H. Craighead, J. Micromech. Microeng. **18** *No 5, 055026 (May 2008).*

CNF Plasma Etch Updates

We are pleased to announce new process developments and the installation of a new deep silicon etch system from Oerlikon.

In order to purchase the best research and development-based deep reactive ion etch (DRIE) system available, CNF initiated a comprehensive assessment of four major vendors with an established history of accomplishment in the field. Because CNF has a very large user and project application base, the new system had to have a large process latitude with outstanding process figures of merit.

The performance of each candidate system was evaluated by a comprehensive design of experiments (DOE) conducted on eighteen wafers with photoresist and silicon oxide masking. The detailed mask layout contained a variety of lines/spaces, shapes and sizes, in both isolated and nested formats in order to evaluate sidewall quality, aspect ratio dependent etching, microloading, and RIE-lag. Based on the analysis of this assessment, the ideal solution was determined to be ***Oerlikon's Versaline DSE-III*** system, which uses a time division multiplex (TDM) process.

This platform enables sub-second etch and deposition steps with a patented fast gas switching technique to produce sidewalls with minimum scalloping (< 50 nm). A highly sensitive optical emission spectroscopy (OES) system developed by Oerlikon is used with patented endpoint algorithms to facilitate silicon-on-insulator (SOI) etch capability. This unique SOI solution eliminates notching at the silicon/buried oxide interface. The process performance, determined by our ongoing characterization of the tool, yields etch rates of at least 7-8 μm/min with selectivity to oxide and photoresist in excess of 600:1 and 150:1 respectively (see A). Aspect ratios of 38:1 on 2.5 μm lines and spaces were easily obtained and we believe that aspect ratios > 50:1 are achievable over the extended process parameter space (see B). In addition, artifacts such as RIE-lag were minimized to 10% or less over a wide feature size range (see C).

This advanced DRIE system will promote cutting-edge research and innovation in microelectromechanical systems (MEMS), complementary metal oxide semiconductor (CMOS), nanotechnology, and packaging applications. This tool is currently being facilitated to meet all safety and environmental requirements, and will be available this spring.

To complement our recent acquisition of an atomic layer deposition (ALD) system from Oxford Instruments, we initiated a comprehensive plasma etch study of some ALD films including HfO_2.

This high-κ dielectric is part of an advanced CMOS gate structure that includes metal gate electrode materials such as TaN and TiN, is used to replace the more traditional polysilicon/silicon oxide gate stack. For high-κ material integration, plasma etch processes need to be thoroughly studied

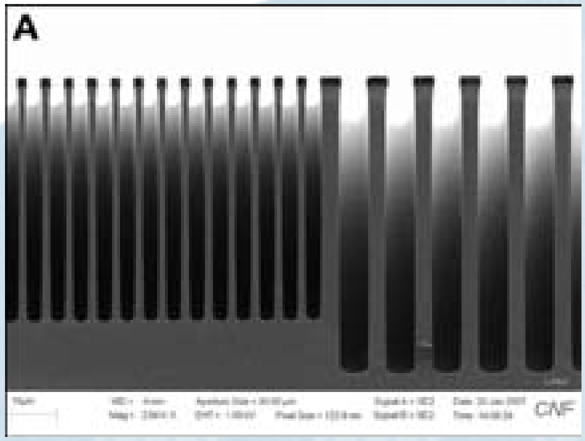


Figure A: Resist masked 2.5 µm & 5.0 µm features etched at 8 µm/min to 52 µm & 65 µm respectively with a selectivity of 111:1.

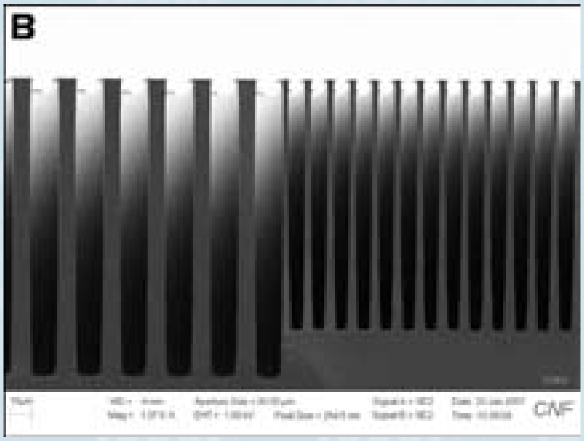


Figure B: Oxide masked 5 µm and 10 µm features etched at 7 µm/min to depths of 120 µm and 140 µm respectively with a selectivity of 340:1.

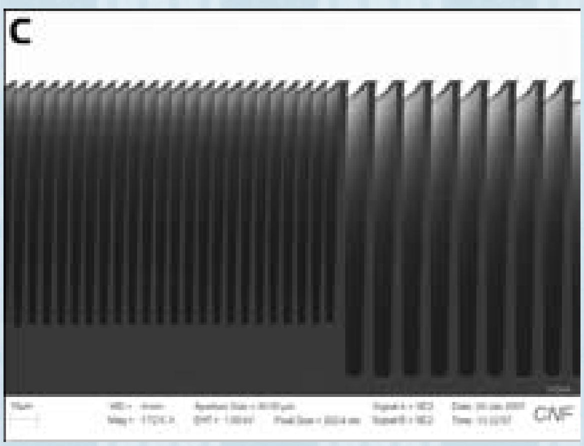


Figure C: Oxide masked 2.5 µm and 5.0 µm features etched to 90 µm and 110 µm depths at 7 µm/min, with a selectivity of 333:1 and aspect ratio of 35:1.

and developed to address issues such as etch rate, uniformity, and selectivity to the underlying and masking layers. A Taguchi L9 based DOE was used to study the mechanisms of chlorine based reactive ion etching of HfO_2, TaN, and TiN in our PlasmaTherm 740 system.

The influence of DC bias, process pressure, and gas chemistry on etch rates, selectivity, and profile evolution was determined in order to establish the governing etch mechanisms (see D).

In addition, a fluorine (C_4F_8/Ar) based plasma etch chemistry study of HfO_2 was recently conducted in the Oxford 100-380 ICP system, yielding controllable etch rates and favorable selectivity to underlying silicon. The ICP based system enables us to independently control the ion densities and ion energies, resulting in improved etch rate control and selectivity. As a result of this study, a range of process conditions can be selected from in order to meet individual device design requirements for both electronic and MEMS based applications. Future plasma etch studies on new ALD materials such as AlN, Al_2O_3, and HfN are planned.

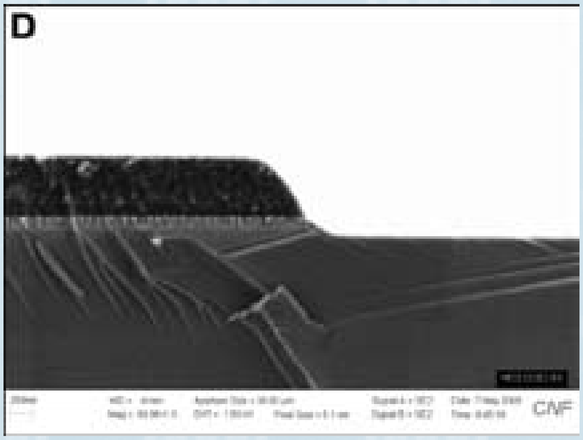


Figure D: Resist masked 110 nm thick HfO_2 on silicon etched in BCl_3/Cl_2/Ar chemistry in PT740.

As part of CNF's ongoing cooperative development agreement with Oxford Instruments, we have continued our investigation of fused silica etching in the Oxford 100-380 ICP system. Our investigation is based on the optimized Cr etch process, developed in the Trion Minilock III, which serves as the etch mask, and includes a thorough study and comparison of three etch chemistries including CHF_3, C_2F_6, and C_4F_8. Additive gases such as CO_2, O_2 and Ar are used to control the fluorine/carbon ratio, which directly affects the degree of polymerization, profile evolution, and the overall plasma dynamics. DOE studies determined the influence of input parameters such as gas composition, source and electrode powers, and pressure on etch rate, selectivity, and feature profile.

Our efforts have yielded fused silica etch rates as high as 260 nm/min, selectivity to Cr as high as 300:1, along with anisotropic profiles of 90 ± 2°. The developed etch processes have been applied to both microscale and nanoscale features defined with photolithography and electron beam lithography respectively (see E).

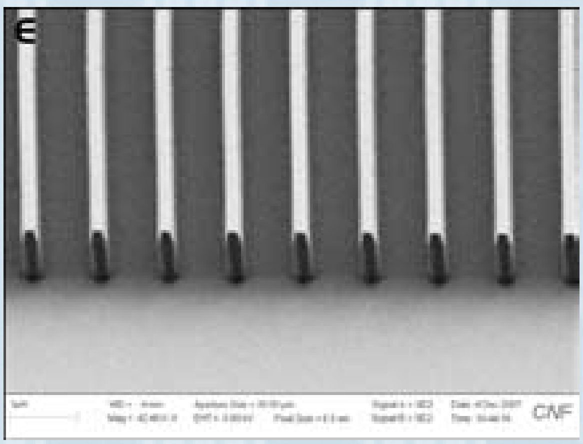


Figure E: Electron beam lithography patterned 100 nm structures patterned in fused silica etched to 650 nm using CHF_3/Ar chemistry in Oxford 100 with 20 nm Cr mask.

The silica etch processes have many applications including microfluidics, optical waveguides, optical gratings, and nanoimprint functions (see F).

In addition, we have developed selective silicon oxide to silicon nitride processes in the Oxford 100. This is traditionally quite difficult and challenging since silicon nitride typically has a much higher etch rate than silicon oxide in fluorine based gas etchants. This effect can be achieved by modifying the plasma chemistry so as to make it carbon rich. Hence, this requires carbon rich precursors such as C_4F_8 and additives such as CO, CO_2, and H_2 to alter the F/C ratio.

Our study has yielded oxide etch rates as high as 300 nm/min with selectivity to nitride up to 5:1. This process can be used in many applications but is especially useful in advanced integrated circuit fabrication. A low stress silicon nitride etch was also recently developed in the Oxford 100. This etch is based on $CHF_3/CF_4/O_2$ chemistry and yields etch rates in excess of 200 nm/min with selectivity to photoresist up to 3.5:1.

For further information on any of these process developments, please contact Vince Genova, CNF Etch Engineer (genova@cnf.cornell.edu).

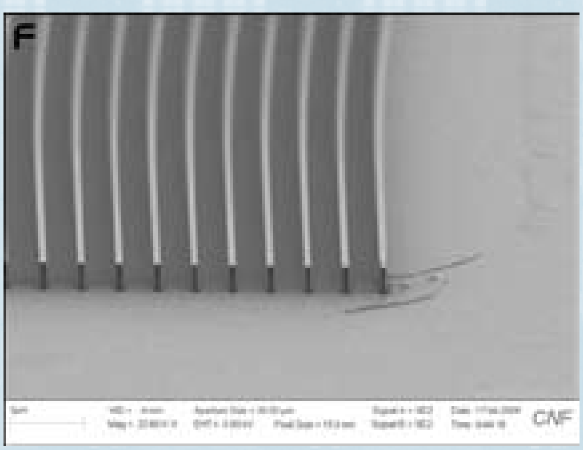


Figure F: 100 nm electron beam lithography structures etched to 820 nm in fused silica using C_2F_6/CO_2 chemistry in Oxford 100 with 20 nm Cr mask.

AMD Gift Money Brings Computer Improvements to the CNF

Thanks to AMD, the CNF has been working on several improvements to the computing resources available for CNF users. While some enhancements are more directly visible than others, these improvements help to keep CNF at the forefront of being a world-class research lab.

CNF has purchased three "Express Terminals," the first of which is now available in the clean room. Two more will be installed in the clean room shortly. Without the overhead of a normal computer login, the Express Terminals give users quick and easy access to a web browser for web scheduling of equipment. The Express Terminals also provide quick and easy access to a VAX terminal for enabling and disabling tools.

Sunrays now deployed throughout the CNF give users the freedom to move about CNF spaces while taking their computer sessions with them. Through the use of a Sunray card, which is inserted into a Sunray terminal display, the user's session and running applications are instantly transported to whichever display terminal the user is in front of. Sunray display terminals are already utilized in the CNF clean room, the CNF cad room, and the CNF office spaces. Additional Sunray display terminals will be deployed soon to the CNF clean room.

The real power behind the Sunray display terminals is the back-end Sunray server box. With AMD money, CNF purchased a dual dual-core Opteron 2216 server with 16GB of RAM. This server is upgradable to quad-core Opterons and up to 128GB of RAM.

Coral is in the beginning phase of production deployment. Coral is a next-generation lab management system primarily written at Stanford University with code contributions from other NNIN sites, including the CNF. Earlier in the year, user, project, and account data was imported into Coral. As of December 1, Coral is tracking usage on the CNF Ion Implanter. The first interlocked tool expected to be moved to Coral is the MVD 100. Coral is accessible via the Sunrays as well as most Java enabled web browsers from a link on the CNF Users website.

CNF used gift money from AMD to purchase the back-end Coral servers. These servers are the main Coral application and database server and three Equipment Controller servers. Each Equipment Controller is capable of interlocking up to 75 separate tools. The custom manufactured interlock control boards and interlocks themselves have also been purchased with AMD gift money.

For more information, contact: David Botsch, Programmer/ Analyst, CNF Computing, botsch@cnf.cornell.edu.

CNF & High Performance Computing

As part of the simulation effort for the NNIN, the CNF provides a high performance computing cluster to help users accelerate their research.

The cluster hosts a diverse suite of simulation tools for nanoscale systems, including codes for nanophotonics (FDTD), microfluidics, molecular dynamics, electronic transport, quantum chemistry, and density functional electronic structure codes.

A full list of modeling and simulation capabilities is available at http://www.cnf.cornell.edu/cnf_modeling_options.html. We are also willing to work with users to install other simulation packages that may help advance their research. If you would like to learn more about the computing capabilities at the CNF or get an account on the cluster, please do not hesitate to contact Derek Stewart (stewart@cnf.cornell.edu) for more information.

Testimonials

Hi Don

I wanted to tell you - I won an Air Force Office of Scientific Research Young Investigator Program (AFOSR YIP) award this year. Nearly all of the fabrication and metrology on the initial results that fed into this award was performed at the Cornell NanoScale Facility. CNF's cleanroom and help from the staff have been key enablers for this research over the past few years. The CNF has been and remains an amazing national resource.

Feel free to quote me. Best, Michael

Michael Hochberg
Assistant Professor
Electrical Engineering
University of Washington
http://nanophotonics.ee.washington.edu

CNF Fellows

Since early 2007, three Cornell graduate students have served as CNF Fellows, working with CNF staff member Alan Bleier. Their responsibilities have been to provide information for CNF users about new techniques, recipes, and procedures, and also to monitor the state of various tools.

Steve Hickman has worked primarily on characterizing etch rates for numerous processes on the Unaxis, PT72, and two Oxford 80 etchers. In Professor John Marohn's group, Steve does research on fabrication of magnet-tipped cantilevers for magnetic resonance force microscopy. He hopes to be working in the fabrication industry in the Pacific Northwest soon.

Rick Brown worked on process development for making low-stress cantilevers for MEMS applications. His adviser is Professor James Shealy, and his research topic is alternative passivations for AlGaN/GaN HEMTs. He hopes to find a research position in industry when he is finished with his Ph.D.

Clarissa Lui worked primarily on photolithography processes, measuring spin speed curves for 10 photoresists, checking the power output of contact aligner lamps, documenting recipes for 1827 photoresist, and examining the performance of the steppers using standard test patterns. Clarissa's adviser is Professor Carl Batt, and her Ph.D. research is on integrated microfluidic biosensing platforms and microfabricated cantilevers for sensing of biological activity. After graduation, she hopes to continue research work on biosensing, either in industry or academia. Clarissa was also the recipient of the Nellie Whetten award at the most recent CNF annual meeting (see page 3).

The results of their efforts on our behalf are in notebooks near the etchers or online on the CNF user web site, via links on individual tool web pages. Users who have requests or suggestions for documentation of processes or tools that could be done by the CNF Fellows may contact Alan at bleier@cnf.cornell.edu.

The CNF staff and user community are grateful to Rick, Clarissa and Steve for their efforts. We look forward to working with the next group of CNF fellows.

Charles Harrinton Photography

CNF Staff Updates

In January of 2009, the CNF bid a fond farewell to two long-time employees—Jim Clair (left) and Carol Cleveland (below, pointing to her replacement's official CNF staff ID!). We will miss Jim keeping an eye on user safety, and Carol's eye on our paychecks. But we now have two new capable staff to introduce to you.

Rebecca Vliet (above right) is the newest member of CNF's Administrative Staff. Rebecca has gained experience in purchasing, accounting, administrative processes and systems throughout her rising eleven year career at Cornell. She adeptly organizes and manages her worklife and homelife, enjoying her husband and twin daughters.

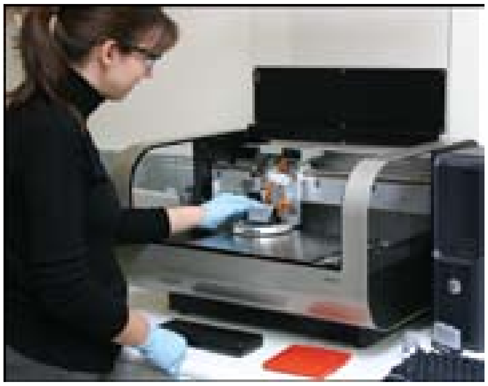
Aaron Windsor is the newest Thin Film Process Engineer at CNF. After graduating from SUNY Oneonta, Aaron spent the next eight years working as an analytical chemist before coming to Cornell in 2004. He was most recently a Research Support Specialist at the Laboratory of Elementary-Particle Physics where he worked on the Energy Recovery Linac and performed electropolishing on Superconducting Radio-Frequency cavities.

New Equipment

Since the last *NanoMeter*, CNF has bee very active in upgrading its equipment resource base in Duffield Hall, both expanding our capabilities and replacing older instruments to maintain the base capabilities of the facility. Intel continued its strong support of the CNF with a semiconductor equipment grant to acquire a **Kurt Lesker ITO Sputter Deposition System** dedicated to forming thin films of Indium Tin Oxide an optically transparent conductive material.

Our **Oxford FlexAl plasma assisted ALD** tool is now installed and providing high quality films of hafnia, aluminum oxide, and aluminum nitride. CNF staff, users, and Cornell faculty and students will be working with Oxford's process engineers to develop new processes on the ALD tool and to implement existing processes of interest to CNF.

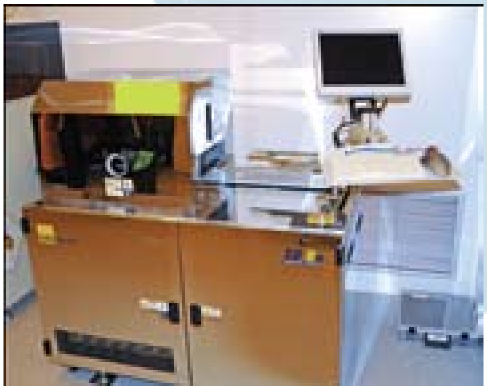
A new **Oerlikon VERSALINE Deep Silicon Etch** tool is a third generation Bosch etcher is installed and baseline processes are being developed. The early results were reported by staff member Vince Genova in a co-authored a paper in the trade journal, CHIP. A new **VCA Optima XE** contact angle goniometer has been installed. The VCA is able to measure the water contact angle on wafer surfaces up to 6 inch in diameter. It is a useful metrology tool for measuring the quality of various surface treatments.



This year we upgraded our **Dimatix chemical ink jet printer**. The system is now compatible with solvent based inks, see Beth Rhoades for training. The new **YES single wafer resist strip system** is installed and operational. It has several pre-programmed recipes for cleaning wafers rapidly while not damaging the backside. See Jerry Drumheller for training.

CNF is going organic! REYNOLDS TECH has partnered with CNF to build a **Cluster Tool for Organic Materials**. The system has arrived and is being tested. A **Suss SB8e Wafer Bonder** has arrived and facilities work to install it has begun. The system is expected to improve the quality and reliability on a wider range of substrate sizes and types.

We have received our **Nanonex NX2-500 Nanoimprint Lithography system**. This acquisition is made possible by a grant from KAUST and will allow us to do thermoplastic NIL, UV cure NIL, and embossing all in the same platform. The NINN effort to facilitate educational outreach in Nanotechnology resulted in a ***Nanotechnology Showcase***—a collection of portable imaging instruments. As part of this "roadshow" we have built a small demonstration area in room 231 which houses a desktop SEM, several microscopes, and a portable STM. We are turning these to good use as we demonstrate imaging from macro to atomic size scales to visiting groups -- all in one room.



The 2008 NNIN REU Interns, at the network convocation at Cornell University, August 2008. Charles Harrington Photography

The NNIN REU Program

We are presently in full swing on the 2009 NNIN REU Program, which is new and expanded, now that there are fourteen partners in the National Nanotechnology Infrastructure Network (NNIN). We've received 625 applications this year, for approximately 75 internships, so the award process is very competative.

The 2008 NNIN REU Program was as rewarding and successful as we could hope for it to be. 74 interns worked at twelve sites, amassing an impressive array of reports, which you can find at: http://www.nnin.org/nnin_2008reu.html

The CNF Break Room

Daniel Woodie
CNF Lab Use Manager

When Knight Lab was demolished to make way for Duffield Hall, the CNF community felt a sense of loss for the old conference room they used to meet in. Although Duffield Hall has many spaces to sit and relax in the atrium, the user community for many years has requested a place just for CNF users to relax, allowing researchers to get to know each other as more than just another person in a white bunny suit.

The CNF break room opened in January and is available 24 hours a day / seven days a week to all CNF users. Besides providing a space for users to chat and relax, the break room has a sink, microwave, coffee and tea service, a whiteboard, as well as wired and wireless network connections.

With this remodeling, we were also able to put a drinking fountain into the togging room.

It is our hope that, in addition to being a welcome respite for our hardworking researchers, the CNF break room will also be a place for users to get to know one another.

SAVE THE DATE!

The June 2009 CNF Short Course: Technology & Characterization at the Nanoscale (CNF TCN)

will be held June 2-5, 2009. Info and registration will be available in May.

The 2009 CNF Annual Meeting

will be held on Thursday, September 17th. Info and registration will be available online in mid-July.

The Cornell NanoScale Science & Technology Facility (CNF) has been serving the science and engineering community since 1977. The CNF is supported by the National Science Foundation, the New York State Office of Science, Technology & Academic Research (NYSTAR), Cornell University, Industry, and our Users.

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To be added to our mailing list, send your request via email to: information@cnf.cornell.edu.
Your comments are welcome! You will also find the NanoMeter on our web site at: http://www.cnf.cornell.edu

CNF Cornell NanoScale Science and Technology Facility

250 Duffield Hall
Ithaca NY 14853-2700
information@cnf.cornell.edu
http://www.cnf.cornell.edu