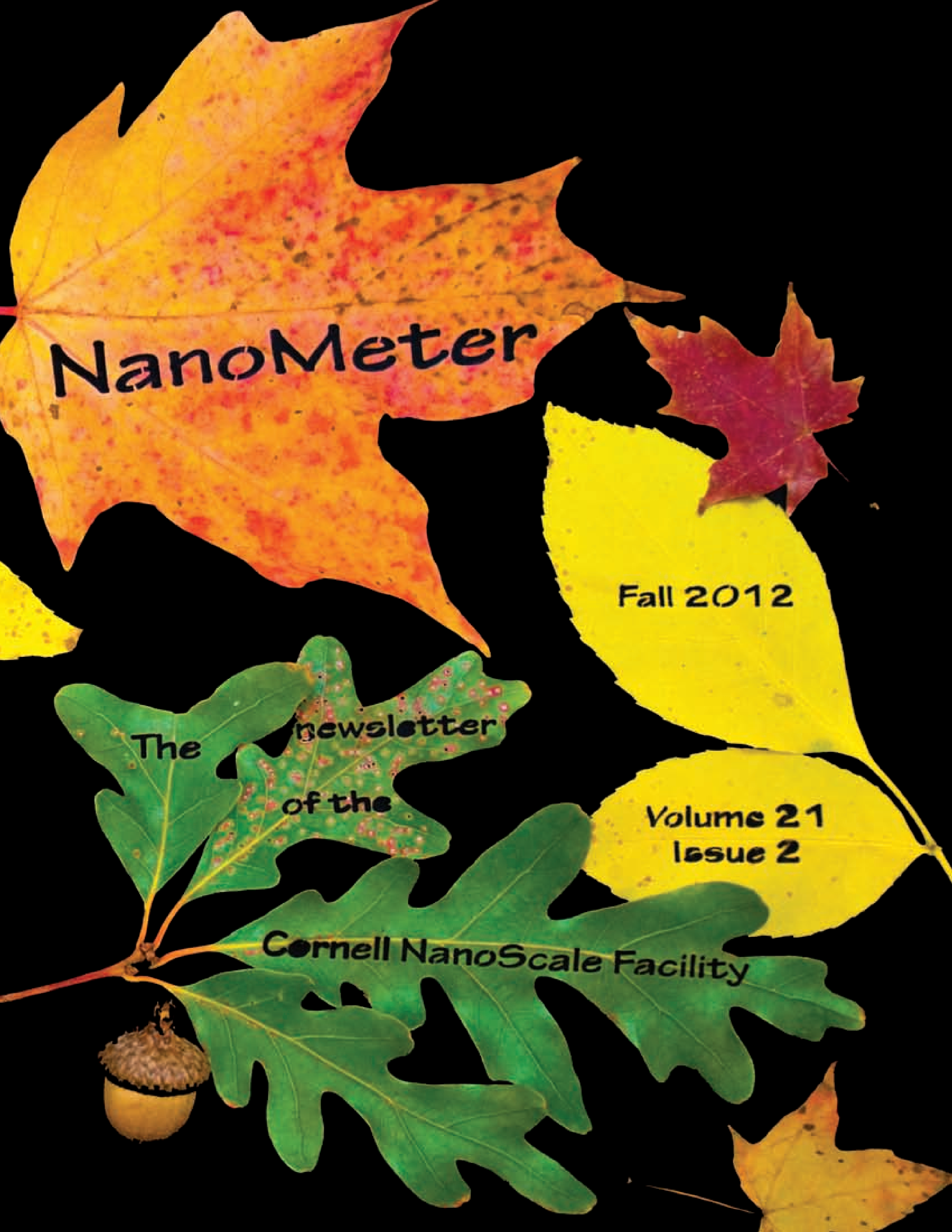
NanoMeter
Fall 2012
The newsletter
of the
Cornell NanoScale Facility
Volume 21
Issue 2

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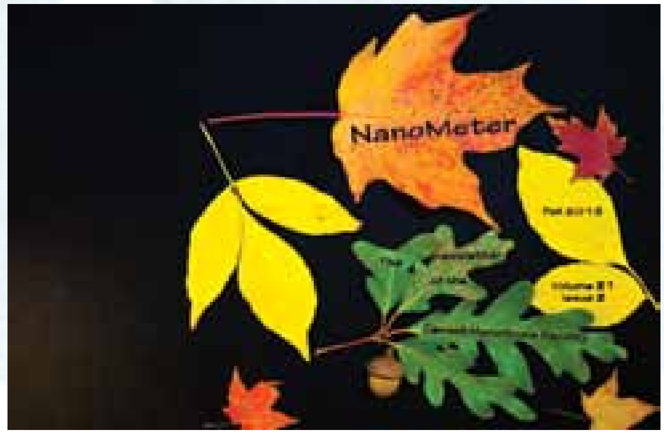

The cover of the Fall NanoMeter was made with actual leaves collected on Cornell campus. The CNF's VersaLaser 3.50 was used to cut text in them (setting: 8% power, 10% speed, 500 pulses per inch, 0.6 mm Z-height), showing, once again, how cool this laser is.

The VersaLaser 3.50 is a CO_2 laser that emits in the infrared range with a spot size of 25 µm. Line art CAD designs can be translated into substrate to cut or etch patterns. Typical substrates include heat-resistant glass and fused silica wafers, polymers (including Delrin, polyimide and acrylic) and adhesive tapes. Line widths can be as narrow as 40-120 µm depending on the substrate, and through holes smaller than the spot size can be produced on the backside of thin substrates. Processing times are typically on the order of minutes!

What would you like to cut or engrave? Contact Beth Rhoades for information and training.

The fall leaves were arranged by Beth, and the actual photograph of the leaves was taken by Don Tennant, who also took this picture of Beth!

The background image for this NanoMeter (NM) is from 2012 CNF REU Intern Elisa Russo. This past summer, Elisa worked with Prof. Paul McEuen on "Monolayer Molybdenum Diselenide." Her full report is available online at http://www.nnin.org/nnin_reu.html.

The photographs of the CNF 35th celebration are by Robert Barker from University Photography, and Sam Wright, who is on the CNF Staff. All other photograph credits are noted.

The NM is printed on 10% post-consumer paper, using soy-based inks. Please do your part to reduce, reuse, and recycle. Send address changes to information@cnf.cornell.edu

Welcome to the 2012 Fall Edition of the NanoMeter

This issue will highlight several important items of news about the CNF, as well as examples of outstanding science and engineering being done by CNF users.

The most important item of news is that the National Nanotechnology Infrastructure Network (NNIN), which provides base funding from the NSF to the CNF, is approaching the end of its 10-year lifetime, and starting soon, there will be an open recompetition for new network funding. The guidance we have received from the NSF is that they should announce a call for proposals in November, with proposals due in approximately May 2013, and with evaluations completed in time to begin new network funding in early 2014. Over the next few months we will therefore be working with cleanroom facilities from around the country to organize the strongest possible new network. The accomplishments over the last decade from users of the existing NNIN cleanrooms, including CNF, will be vital for organizing a successful proposal. So please respond promptly to any information requests we will make over the next several months as we assemble this proposal.

A second very important item is that the CNF will have an extended winter shutdown to completely replace the Duffield Hall processed cooling water systems. The shutdown will begin on approximately December 15, 2012, and will last until approximately January 15, 2013. All CNF laboratories, both in the cleanroom and on the second floor of Duffield Hall, will be closed to all users for this entire time. Please plan your work to take this schedule into account. (See more on this closure on the back page.)

Finally, in happier news, during this winter shutdown we will also begin the installation of the first of a new generation of electron beam lithography tools to be produced by JEOL, the JEOL JBX 9500FS. This will replace our existing JEOL JBX 9300FS. The new system has been developed jointly in a partnership between CNF and JEOL, and funded by an NSF instrumentation grant. The 9500 should be improved relative to current-generation tools in nearly every category of specification: smaller spot size, larger writing fields, increased speed, dramatically improved placement accuracy and stitching, and more user-friendly software. We hope to begin training users on this system early in 2013. We are also pleased to announce that a new Oxford Plasma-Enhanced Chemical Vapor Deposition system is due to be commissioned in the next few weeks. This new PECVD system replaces an IPE system that served us for more than 20 years. Other new capabilities coming online are a set of dedicated electroplating stations made by Reynolds Tech. Please see a separate article in this issue of the NanoMeter about this upgrade.

Please note the dates for upcoming events on the last page and check our web site often for news updates.

Dan Ralph, Lester B. Knight CNF Director
Don Tennant, Director of Operations

NNIN
www.nnin.org
Serving Nanoscale Science, Engineering & Technology

CNF Cornell NanoScale Science and Technology Facility
CELEBRATING 35 years OF NANOSCALE SCIENCE AND TECHNOLOGY
1977–2012
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Logo created by Jennifer Infante Designs

Cornell NanoScale Facility Celebrates its Thirty-Fifth Anniversary!

By Anne Ju, 07/20/2012, Cornell Chronicle

William Brinkman, director of the Office of Science at the U.S. Department of Energy, gave the CNF's 35th anniversary keynote address.

Nanoscientists will be the ones getting to the bottom of the world's energy problems because all elementary steps of energy conversion take place on the nanoscale, said William Brinkman, director of the Office of Science at the U.S. Department of Energy during July 19 remarks. "Nanoscience will help solve the serious problems facing mankind."

The meeting was a thirty-fifth anniversary celebration featuring distinguished speakers, research presentations, and reflection on nanoscience and nanofabrication at Cornell, past and present. Brinkman described many ways in which the Department of Energy is leading efforts to harness nanoscience capabilities at the most cutting-edge institutions and facilities, including Cornell, to work on energy-related issues.

For instance, the DOE has created Energy Frontier Research Centers, one of which is the Energy Materials Center at Cornell, to help nanoscientists make interdisciplinary progress on everything from better batteries to more efficient photovoltaics. He went on to detail many research breakthroughs, and expressed awe at today's computational technologies that can allow scientists to analyze several thousand material properties at once. Brinkman congratulated the Cornell NanoScale Facility on thirty-five years of success in many facets of the nanoscience field.

Before Brinkman spoke, CNF Director of Operations Don Tennant summarized the year's high points, technical summits, outreach programming, changes in leadership, purchases of new equipment, and the ongoing dedicated work of the CNF staff, particularly Michael Skvarla, who joined the CNF thirty years ago.

Dan Ralph, the Lester B. Knight Director of CNF, opened the day by welcoming the more than 200 participants to the meeting. Ralph asked them to reflect on how CNF could improve as it starts developing a new proposal for continued operation.

The CNF is indebted to the following corporate sponsors of the 35th Celebration: Applied Materials, ASML, Corning, CorSolutions, CVD / First Nano Division, GLOBALFOUNDRIES, Heidelberg, Hitachi HTA, JEOL, KAUST-CU, Kionix, Kurt J. Lesker, Lockheed Martin, Olympus, Oxford Instruments, Plasma-Therm, Raith USA, ReynoldsTech Fabricators, RTS Technologies, SUSS MicroTec, XACTIX

Impact of Nanotechnology Heard Globally at Online Briefing

By Anne Ju, 07/23/2012, Cornell Chronicle

Michal Lipson, ECE associate professor, described her field of silicon photonics for journalists live and online. Lindsay France/University Photography.

Some of Cornell's leading nanoscience researchers expounded on the promises and challenges of their fields during a mostly virtual online briefing for journalists July 20.

The panel of experts spent an hour chatting with journalists, from Minnesota Public Radio to The Chronicle of Higher Education, and answering such questions as: What are the challenges associated with scaling up nanoscale electronics? And, what is the relationship between nanoscience and sustainability?

The event also served as a wrap-up of the CNF 35th anniversary, marked by a series of academic speakers and research presentations the previous day.

Each panelist provided listeners with a general flavor of their areas of expertise. Juan Hinestroza, associate professor of fiber science and apparel design, described his focus on the interface between natural and synthetic materials at the nanoscale, particularly cellulose. Hinestroza has led efforts into bridging fashion design and nanoscience: His students have made dye-free clothing infused with nanoparticles to take on colors, antibacterial properties or even electrical conductivity.

William Brinkman, director of the Office of Science in the U.S. Department of Energy, talked about the DOE's commitment to investing in nanoscience to solve energy problems. Lindsay France/University Photography.

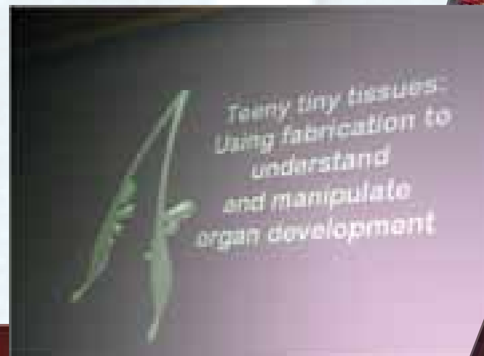
Panelist Michal Lipson, ECE associate professor and member of the Kavli Institute at Cornell for Nanoscale Science, discussed her field of silicon photonics, aimed to greatly decrease power consumption of computers by using optics instead of electrical wires as interconnects. These so-called nano waveguides will enable optics to become part of the next generation of microelectronics, she said.

And Christopher Ober, professor of materials science and engineering, discussed new techniques his group is investigating for making nanostructures, such as a new nanoparticle photoresist, as well as the application of lithography to the developing area of polymer electronics.

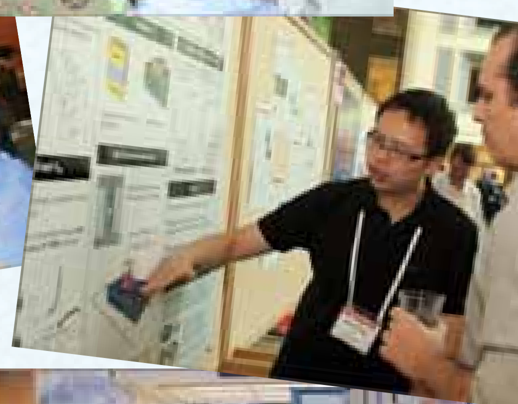
Roger Howe, professor of engineering at Stanford University and director of the National Nanotechnology Infrastructure Network, addressed the National Science Foundation's efforts to fund nanoscience research. Lindsay France/UP.

Also joining the panel was Roger Howe, NNIN director and faculty director of the Stanford Nanofabrication Facility. Howe talked about how the NSF-supported NNIN, of which CNF is the flagship member, connects nanofabrication and other infrastructure resources with researchers all over the world.

The final panelist was William Brinkman, director of the Office of Science at the U.S. Department of Energy, who described the DOE's particular commitment to nanoscience research as a means of addressing energy-related challenges including battery technology and solar power.


Teeny tiny tissues:
Using fabrication to
understand
and manipulate
organ development


HGST



Nellie Yeh-Poh Lin Whetten Memorial Award: Samantha Roberts

Samantha Roberts is a graduate student in the Department of Physics at Cornell University and is the winner of CNF's 2012 Nellie Yeh-Poh Lin Whetten Memorial Award.

Of all the accolades written about Nellie Whetten, the one Samantha most resonates with is "…An exuberance for life." Research is about facing a new challenge everyday — and meeting the resulting successes and failures head on. Without an overarching attitude of passion and excitement, research would feel laborious, and much less fun!

Sam received an associates degree in Computer Science in 2000, and her Bachelors in Science in Physics and Math at Stony Brook University (NY) in 2005. She worked at the Stony Brook Nuclear Accelerator Facility for two years, using gamma ray spectroscopy to study nuclear chirality. She was an REU student at Brookhaven Nation lab's Relativistic Heavy Ion Collider, searching for evidence of the hot quark gluon plasma predicted to exist instants after the big bang. In 2003, Sam joined a multi-institutional US team in Japan to aid in the reconstruction of the Super-Kamiokande Neutrino Detector. Later, drawn to solid state physics, she studied under theorist Professor Konstantin Likharev, using density functional theory calculations to predict single electron transfer in single molecule field effect transistors (FET).

Sam's research of single molecule behavior quickly revealed the emergent multidisciplinary nature of nanoscale physics — and particularly exciting was the diverse field of biophysics. This was foremost in her mind when Sam chose Cornell University for her graduate studies in 2005, and she was awarded a fellowship from Cornell's Nanobiotechnology Center to pursue her bio-related interests. In 2006 she joined the research group of Professor Paul McEuen, who primarily studies carbon systems such as carbon nanotubes and graphene.

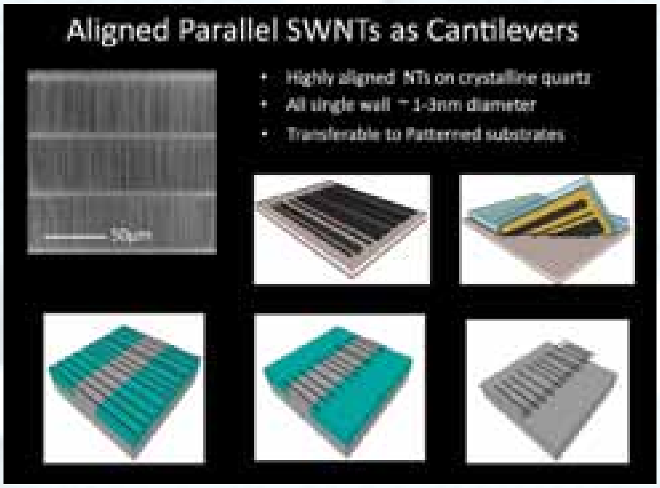
Samantha currently studies the mechanical properties of single wall carbon nanotubes (SWNT) for use in quantitative measurements of biological phenomena. At 0.7-2 nm in diameter, a SWNT is comparable in size to a single lipid molecule and the diameter of a single strand of DNA. This small size comes with unparalleled strength, which allows NTs to be rigid up to several microns in length. The long term vision for this project is to be able to create SWNT probes that can be manipulated in biological conditions, such as a quantitative study of the force it takes for a NT to penetrate a cell membrane. Knowledge of this sort would allow us to understand the NT's proven ability to translocate across the cell membrane in spite of the cells inherent resistance to entry by foreign molecules.

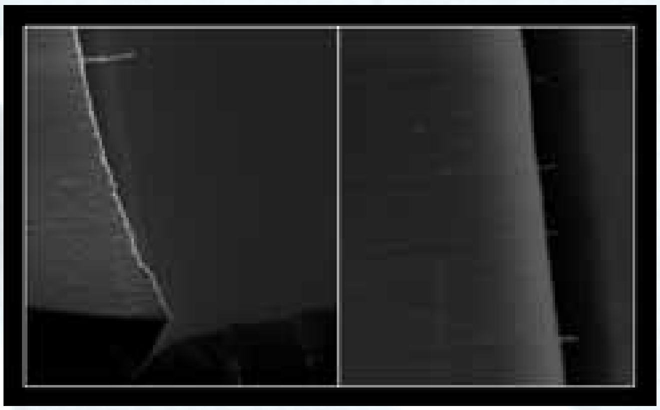
Sam was able to take a large step toward this goal by working with Alex Ruyack, a second-year undergraduate student who helped create arrays of SWNT cantilevers. Using methods for aligned SWNT growth, SWNTs with ~ 1 nm diameters and up to hundreds of microns in length were grown on quartz substrates with densities of one tube per micron. These NTs were transferred to substrates that had alternating stripes of Si and SiO_2. Patterning the NTs and then etching away the SiO_2 produced suspended SWNT cantilevers up to 700 nm in length.

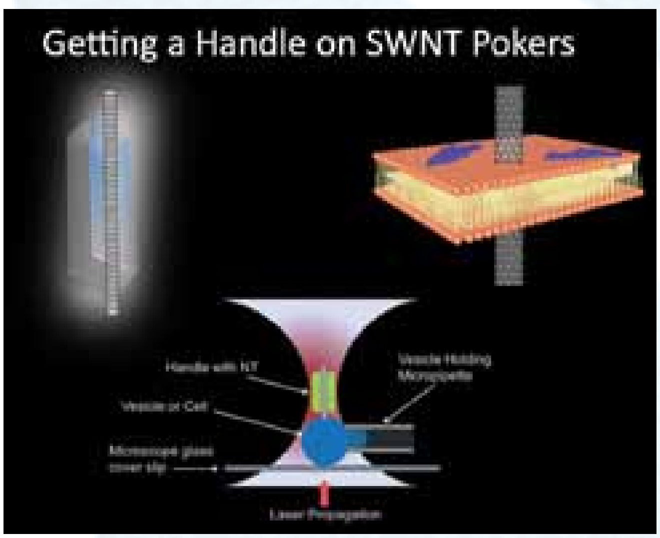
Robert Barker / University Photography

These aligned cantilevers have a high yield that is unparalleled for devices of this kind, and is also a major step toward making a NT probe.

Sam is now attaching a "handle" to the NT that can be held and manipulated by an optical trap (OT). She was an integral part of the design and construction of the McEuen Lab's optomechanical setup, which includes just such capabilities. An OT is currently the







All images on pages 8 and 9 were provided by Samantha Roberts unless otherwise noted.

most precise actuator that can work with nanometer accuracy in solution. Sam attaches handles to SWNTs by lithographically patterning 1 µm thick SU-8 in rectangular shapes onto the end of the aligned NT cantilevers. SU-8 has a high index of refraction which lends itself to strong optical trapping, and the shape anisotropy allows the handle to align with its long end in the direction of light propagation. This creates a NT probe that can be used in a poker-like fashion.

Sam is now adding magnetic tweezers to the experimental setup, which will be used in the next generation of devices to manipulate SWNTs with magnetic handles.

Samantha intends to take physical principles and the tools that she has learned from the physics community into biological research for direct medical application. Sam had a dose of personal experience with experimental medicine when she sustained a fractured neck in 2007 in a hiking fall. Faced with cervical fusion using metal rods and screws, she instead turned to science, and found Dr. Susan Bukata at Rochester University who was studying bone regeneration in rabbits using a protein called PTH1-34 — which works by enhancing the rate of stem cell differentiation of osteoblast cells. Samantha signed on as the first experimental human subject, and injected the protein into herself daily. She was fully healed without surgery within a year — results so astounding that they were presented at the National Academy of Science. Seeing science at work firsthand has inspired Samantha to impact people's lives at an individual level in her postgraduate studies.

As a high-altitude alpine climber and a competitive triathlete and long-distance runner, Sam seeks to explore the boundary conditions in all she does. Her current project is living in an off-the-grid cabin she built in Ithaca, where utilities such as electricity and water do not come from a power line or a well. She finds that solving problems such as energy storage in batteries, implementing photovoltaic devices, and gravity-fed water systems all inspire ideas for her experiments. For her, living off the grid is a macroscopic experiment whose challenges are solved by implementation of phenomena that occur on the nanoscale.

As Sam often says about research and life, "I'm so excited — I can't wait to see what happens next!"

Samantha is deeply grateful to her advisor, all members of her research group, and the CNF and Cornell community, without which her research could not have come so far.

The CNF Nellie Yeh-Poh Lin Whetten Memorial Award

"This award is given in fond memory of Nellie Whetten, a CNF staff member from 1984 to 1987, who died March 24, 1989. This award recognizes outstanding young women in science and engineering whose research was conducted in the CNF, and whose work and professional lives exemplify Nellie's commitment to scientific excellence, interdisciplinary collaboration, professional and personal courtesy, and exuberance for life."

(From the Whetten Award plaque in the CNF main office, which lists all the Whetten Award winners since 1978.)

New Technique Could Mean Super Thin, Strong Graphene-Based Circuits

By Anne Ju, 08/29/2012, Cornell Chronicle

Integrated circuits — which are in everything from coffeemakers to computers and are patterned from perfectly crystalline silicon — are quite thin, but Cornell researchers think they can push thin-film boundaries to the single-atom level.

The materials of choice are graphene, single atom-thick sheets of repeating carbon atoms, and hexagonal boron nitride, similarly thin sheets of repeating boron and nitrogen atoms. Researchers led by Jiwoong Park, assistant professor of chemistry and chemical biology, have invented a way to pattern single atom films of graphene and boron nitride, an insulator, without the use of a silicon substrate. The work is detailed in an article in the journal Nature, published online August 30, 2012.

The technique, which they call *patterned regrowth*, could lead to substrate-free, atomically thin circuits — so thin, they could float on water or through air, but with tensile strength and top-notch electrical performance.

"We know how to grow graphene in single atom-thick films, and we know how to grow boron nitride," Park said. "But can we bring them together side and side? And when you bring them together, what happens at their junctions?"

As it turns out, researchers' patterned regrowth, which harnesses the same basic photolithography technology used in silicon wafer processing, allows graphene and boron nitride to grow in perfectly flat, structurally smooth films — no creases or bumps, like a well-knitted scarf — which, if combined with the final, yet to be realized step of introducing a semiconductor material, could lead to the first atomically thin integrated circuit.

Simple really is beautiful, especially in the case of thin films, because photolithography is a well-established technique that forms the basis for making integrated circuits by laying materials, one layer at a time, on flat silicon.

Patterned regrowth is a bit like stenciling, Park said. He and colleagues first grew graphene on copper and used photolithography to expose graphene on selected areas, depending on the desired pattern. They filled that exposed copper surface with boron nitride, the insulator, which grows on copper and "fills the gaps in very nicely."

"In the end, it forms a very nice cloth you just peel off," Park said.

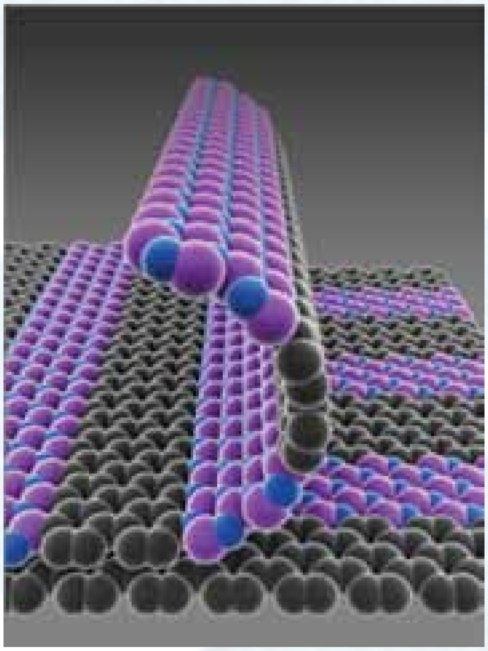


Figure 1: Schematic illustration of single-atom-thick films with patterned regions of conducting graphene (gray) and insulating boron nitride (purple-blue). Provided/Park.

The research team, which includes David A. Muller, professor of applied and engineering physics, is working to determine what material would best work with graphene-boron nitride thin films to make up the final semiconducting layer that could turn the films into actual devices.

The team was helped by already being skilled at making graphene — still relatively new in the materials world — as well as Muller's expertise in electron microscopy characterization at the nanoscale. Muller helped the team confirm that the lateral junctions of the two materials were, indeed, smooth and well connected.

The paper's co-first authors were chemistry graduate student Mark Levendorf and postdoctoral associate Cheol-Joo Kim, who fabricated the graphene and boron nitride samples and also performed the patterned regrowth at the Cornell NanoScale Science and Technology Facility.

The work was supported primarily by the Air Force Office of Scientific Research, and the National Science Foundation through the Cornell Center for Materials Research.

Synthetic Blood Vessels Could Lead to Breakthroughs in Tissue Engineering

By Anne Ju, 05/29/2012, Cornell Chronicle

Human tissue, be it in the heart, brain or bones, can't function without a vascular system — the intricate network of vessels that circulate life-sustaining blood and nutrients.

And it's notoriously hard to introduce vascularization into synthetic tissue for use in regenerative medicine, like tissue replacement surgery.

Enter Cornell engineers, taking an engineer's approach to making synthetic blood vessels. They've designed tiny, 3-D microchannels in a soft biomaterial and injected human umbilical vein endothelial cells into the channels. They embedded tissue cells from the brain into the surrounding gel and watched the interactions between the "vessels" and cells, which commonly surround microvessels in the body.

Signals from these tissue cells led to new blood vessels sprouting from the originals — a living network of blood vessels engineered completely *in vitro*.

The results, which could lead to new techniques in regenerative medicine and better drug delivery strategies, are from the lab of Abe Stroock, associate professor of chemical and biomolecular engineering and member of the Kavli Institute at Cornell for Nanoscale Science.

The work is published in Proceedings of the National Academy of Sciences May 28. (See cover on page 12.)

Such live, in vitro microvessels could be a step toward developing human tissues both to study biological processes in the lab and to serve as replacement tissues for implantation into the body during surgery.

"The hope is we can start with something this simple, and the cells will then grow into the capillary structures and higher order vessel structures required for a fully deployed vascular system," Stroock said.

The researchers also experimented with mimicking diseases like cancer or thrombosis in the vessels by infecting them with certain compounds or proteins known to promote vessel growth or create an inflammatory response.

In a collaboration with the Jose Lopez lab at the Puget Sound Blood Center, the researchers showed that healthy vessels proved to be a good, non-sticky interface for transporting blood smoothly, even around corner vessels, which are traditionally where blockages due to disease occur. The researchers found that when the vessels were treated with an inflammatory compound, they became thrombotic — similar to when real vessels become inflamed.

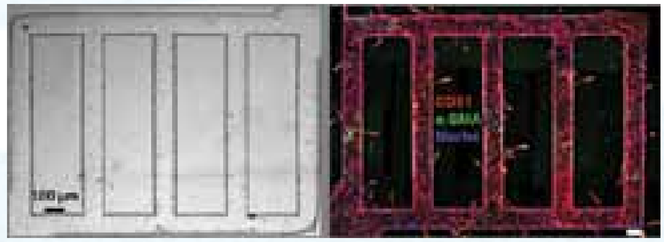


Figure 1, left: An optical micrograph of an endothelialized microfluidic network. Cells are visible as graininess along channels. Provided/Stroock lab.

Figure 2, right: Reconstruction of fluorescence confocal micrographs of a microvascular network with endothelial-cell lined channels (red) and perivascular cells (green) in collagen. After two weeks in culture, the presence of the tissue cells drove sprouting of new vessels from the original endothelium. Provided/Stroock lab.

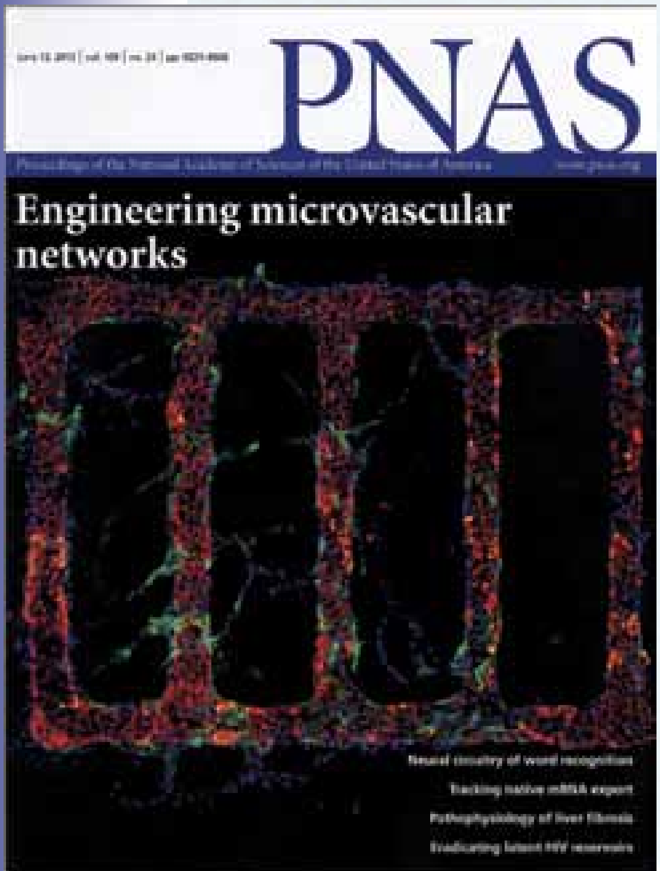
To further inform their study, the researchers collaborated with Claudia Fischbach-Teschl, associate professor of biomedical engineering, who studies how tumors grow. A signaling protein called VEGF, when added to the microvasculature, led to development of new blood vessels sprouting from the originals — a hallmark of how tumors grow.

"One of the evil geniuses of tumors is knowing how to grow new vasculatures," Stroock explained.

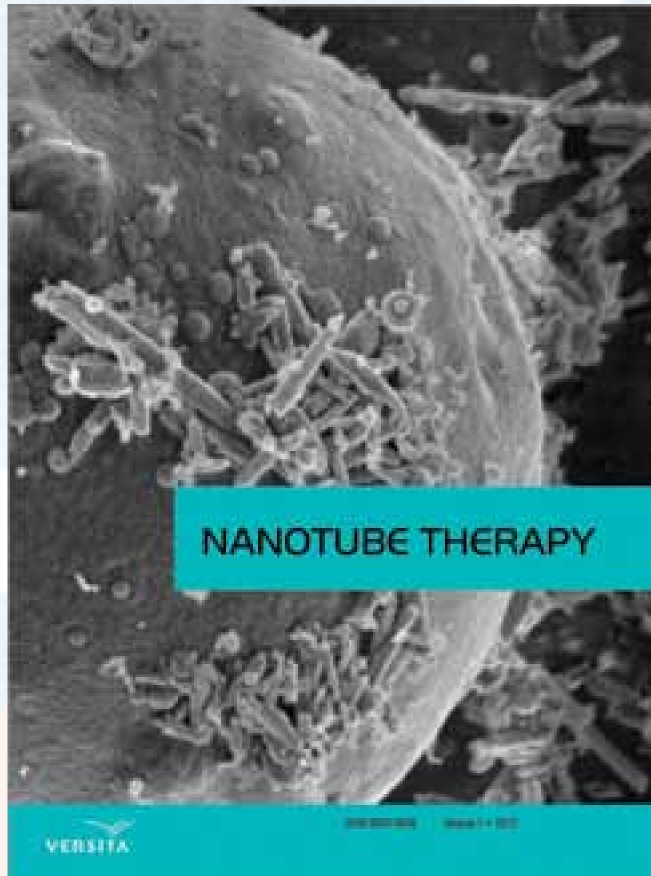
He said he was interested in developmental vascular biology from an engineer's perspective because of the hypothesis that physical flow informs the development of microvessels even from an embryonic stage. In order to understand how a simple grid of tubes in a placenta transforms into the geometry of the microvasculature in humans, it is important to understand how the physical environment influences these initial vessels, he said.

"The mechanics of the flow play a central role in defining what the network will be," Stroock said.

The paper's first author is Ying Zheng, a former postdoctoral associate who is now at the University of Washington in Seattle. The work at Cornell was performed in part in the Cornell NanoScale Facility, and supported by the National Institutes of Health through the Cornell Center on the Microenvironment and Metastasis, Human Frontiers in Science Programme, the New York State Division of Science, Technology and Innovation, and the Arnold and Mabel Beckman Foundation.



The paper "Synthetic Blood Vessels Could Lead to Breakthroughs in Tissue Engineering," by Ying Zheng and Abe Stroock, was published in the *Proceedings of the National Academy of Sciences* on May 28, and was used for the cover art-work. *(See page 11 of this newsletter for more information.)*



Hi Melanie-Claire:

An SEM taken in the CNF by Andrew Hughes, a Ph.D. student in the King Laboratory, has become the permanent cover image of the new journal *Nanotube Therapy*.

The image depicts halloysite nanotubes interacting with a human white blood cell.

Michael R. King
Associate Professor
Biomedical Engineering
Cornell University

Long time CNF user Dr. Scott Verbridge has begun work in his new position as Assistant Professor in the Virginia Tech – Wake Forest School of Biomedical Engineering and Sciences (SBES), in Blacksburg, VA.

Dr. Verbridge completed his Ph.D. in 2008 with Professors Harold Craighead and Jeevak Parpia, studying energy dissipation in NEMS, followed by postdoctoral research with Professors Claudia Fischbach and Abraham Stroock, using microfabrication tools to build 3D tumor models.

Dr. Verbridge (shown at left with SBES Ph.D. student Megan Cox) is now continuing with his interests in micro/nanofabrication and cancer biology, as part of a broader thrust at Virginia Tech focused on advancing nanoscale science and technology for biomedical applications.

(Photo credit: Stefan Duma, Virginia Tech)

Nikolas Hoepker took part in the 62nd Nobel Laureate Meeting, dedicated to Physics, in Lindau, Germany, July 2012.

The meeting gave him the unique opportunity to interact one-on-one with Nobel Laureates as well as to engage in discussions with top young researchers, both from the standpoint of their varying scientific interests and from their seemingly limitless variety of cultural and environmental backgrounds.

Nik is funded by the NSF through the Cornell Center for Nanoscale Systems.

These three photographs of the event were provided by Nicolas.

2012 Research Prize and Medal Recipient

The NJIT Board of Overseers will present the fifth New Jersey Institute of Technology Excellence in Research Prize and Medal to nationally acclaimed expert in biophysics and materials science.

REGINALD FARROW, PHD

October 4, 2012

Reginald C. Farrow, PhD, a research professor of physics at New Jersey Institute of Technology, is affiliated with the Biophysics and Materials Science Programs. Dr. Farrow's research explores the interface between nanotechnology and biophysics and biomedical engineering. His primary focus is to develop a method to investigate the fundamental properties of biological cells at the nanoscale using an array of carbon nanotube probes.

Dr. Farrow's goal is to further our understanding of how cells communicate both internally and with other cells. This communication drives the individual and collective function of the cells at the most basic level. Dr. Farrow and his team have used the same carbon nanotube array platform to fabricate the world's smallest biofuel cell which may be used in the future to power in vivo versions of the nanoprobe array and other biomedical devices. Three patents have been awarded based on Dr. Farrow's research at NJIT and others are pending.

Dr. Farrow's experience in nanofabrication that he obtained as a scientist at Bell Laboratories is particularly well suited for the development of such advanced devices. However, to realize the ultimate goals, he has brought together a multidisciplinary team from five institutions whose expertise includes biophysics, chemistry, biology, biomedical engineering, materials science, and electrical engineering. Over seven years

his research programs have provided funding for eight faculty, three postdoctoral fellows, nine graduate students, and five undergraduates from sources that include the Defense Advanced Research Projects Agency, the National Institutes of Health, and the U.S. Army's Armament Research, Development and Engineering Center. Dr. Farrow was the President and Conference Chair of the 2012 International Symposium on Electron, Ion, and Photon Beams and Nanofabrication.

He obtained a BS in physics from the University of Rochester, a master's degree in physics from Rutgers University, a PhD in physics from Stevens Institute of Technology and joined NJIT in 2004 after over 25 years at Bell Labs.

NJIT Board of Overseers Excellence in Research Prize & Medal

The NJIT Board of Overseers Excellence in Research Prize and Medal is awarded in recognition of a sustained record of contributions that has enhanced the reputation of NJIT. The prize and medal winner will deliver a lecture based on this record of accomplishment, and the lecture will be webcast and recorded on CD for distribution.

The prize and medal winner must have been a member of the NJIT faculty for at least 5 years.

Images from NJIT web site

The support that the NJIT team has received from the CNF has been invaluable to this research. The platforms for the carbon nanotube devices were fabricated at the CNF. Once we understood from theory the structural parameters for our devices it was clear that we needed a facility that has a full suite of process technology for nanoscale CMOS architectures, but is flexible enough to handle variations specific to our needs.

Alokik Kanwal (now Research Assistant Professor at NJIT) fabricated arrays of nanoscale windows in a thin layer of silicon nitride of damascene metal interconnects. Later at NJIT carbon nanotubes were electrophoresis deposited on the metal at the base of these windows.

These structures formed the basis for both the cellular nanoprobes and the biofuel cells.

Thanks. Reggie

Reginald C. Farrow, Ph.D.
Research Professor
Department of Physics
New Jersey Institute of Technology

New Staff Member: Saikat Mukhopadhyay

Don Tennant

Saikat Mukhopadhyay, Cornell Post-doctoral Fellow, is our newest staff member, assisting Dr. Derek Stewart.

Saikat earned his BS in Physics from the University of Calcutta, Kolkata, India, his MS in Physics from the University of Pune, Pune, India, and his Physics Ph.D. from Michigan Technological University. He has worked as a Graduate Research Assistant for the Theoretical Division of Los Alamos National Laboratory, and the National Chemical Laboratory in Pune, India. Saikat offers this introduction:

I mainly use *first principles* approaches to understand, predict, and design novel nanostructured materials toward their applications in biosensing, electronic and thermal transport. My recent interests fall under the following prevalent categories:

- Interaction of biological matter with nanomaterials: Biosensing
- Quantum transport in molecular devices and spintronics
- Metallic and semiconducting surfaces
- Materials for energy storage, conversion and transportation
- Phonon dispersion in crystalline and disordered materials: Thermal transport

Currently, I am working towards implementation of a theoretical approach based on ab initio techniques to calculate lattice thermal conductivity in crystalline and disordered materials considering both harmonic and anharmonic, whenever required, interatomic force constant with no adjustable parameters.

Staffers Skvarla and Glanville Recognized for Dedicated Service

Lindsay France/University Photography.

By Eric Lee and Nancy Doolittle, 06/2012, Cornell Chronicle

Two Cornell staff members who deal daily with sensitive matters were recently honored with the George Peter Award for Dedicated Service. They are: Michael Skvarla, user program manager for the Cornell NanoScale Science and Technology Facility (CNF), who teaches new students and researchers about toxic chemicals and expensive, detailed research processes; and Cindy Glanville, consultant in the Faculty and Staff Assistance Program (FSAP), who deals with such issues as employee, student and spousal deaths, layoff notifications, mental health crises and work performance.

On June 28, Skvarla received the 180th George Peter Award for Dedicated Service, at a gathering in the Phillips Hall lounge. Presenting Skvarla with a signed copy of Cornell historian Carol Kammen's book "Glorious to View," Mary Opperman, vice president for human resources and safety services, said that Skvarla's diligence, understanding and ability to face challenges have remained constant through his more than thirty years of working at CNF. Skvarla has also given forty years of service to the Pennsylvania National Guard.

Skvarla's colleague Melanie-Claire Mallison, who nominated him for the award, said that he has an excellent ability to work with and guide people unfamiliar with nanotechnology and nanofabrication.

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In her nominating letter, Mallison called Skvarla her "go-to guy" for guiding high school groups on a tour of the facility, noting his "infinite patience with our users and visitors." Donald Tennant, CNF's operations director, wrote that Skvarla is "friendly, philosophical, intellectually curious, and helpful to everyone he works with," including the thousands of students he has taught how to safely and mindfully conduct research projects.

In other letters of support, Michael Thompson, associate professor of materials science and engineering, wrote that Skvarla's "enthusiasm and his can-do attitude have remained a constant," while Harold Craighead, the Charles W. Lake Jr. Professor of Engineering, wrote that Skvarla has "added his energy and effort to make the environment of the CNF a better place to work and performed outstanding service as an ambassador of CNF to the international research community."

CNF Acquires the Latest in Microfluidic Testing Stations

We are currently installing a CorSolutions Fluidic Probe Station. This tool will be useful for testing the functionality of microfluidic devices. The station has a variety of probe attachments to make quick, non-permanent and leak-proof connections to practically any port. The tool also has two highly accurate pumps that deliver fluids with nanoliter-scale precision in the 1-50 microliters/min range. The pumps are feedback-controlled to eliminate flow artifacts that are seen using typical syringe pumps. Pump software can even program the flow to mimic biological flow phenomena. The station is mounted under a low-magnification, bright-field stereoscope with a digital camera and image capture software. The station will also be available for cleaning and preparing device channels with approved fluids such as ethanol and protein solutions.

We intend to introduce this fluidic probe station to the microfluidic research community and respond to the specific needs of CNF users. To this end, we have partnered with CorSolutions, LLC, an Ithaca-based company. This new tool will enhance CNF's rapid prototyping capability in the area of microfluidics. In the partnership, the CNF will promote the use of the tool, and the extensive variety of researchers will provide valuable input on the design of new capabilities to accommodate new applications. In return, CorSolutions will work closely with CNF users to design custom solutions and hardware to be evaluated by the research community.

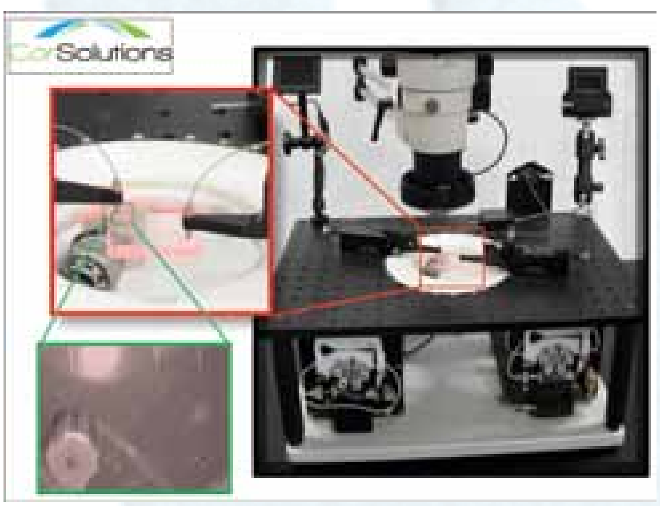


Figure 1: CorSolutions fluidic probe station connected to an acrylic device. Peristaltic pumps are located underneath the station, and independent flow meters are mounted above. The precision ground table allows probe arms to be mounted in practically any configuration. A stereoscope with digital camera and image capture software is mounted over the device. The red inset shows two top-side ports in an acrylic device that are covered by pressure arm attachments that can connect various sizes of tubing to the channels. A CCD camera is mounted under the transparent chuck to visualize the ports. The green inset is a close-up view of a pressure arm attachment on a port. Provided/Rhoades.

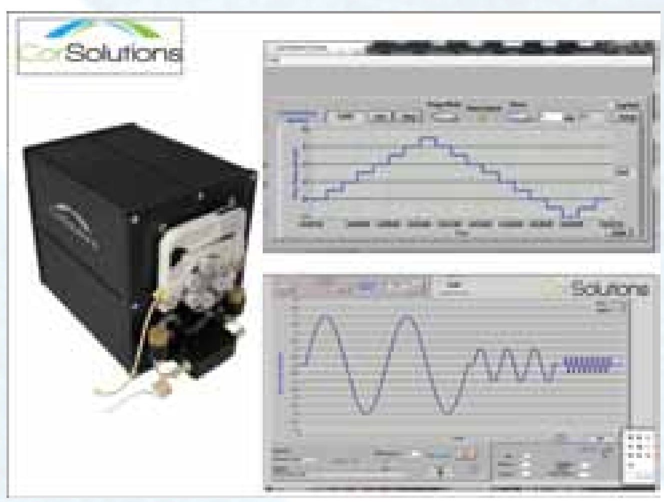


Figure 2: Peristaltic flow control pump features. Independent pumps that were designed in-house by CorSolutions, LLC, are available that deliver 1-50 microliters/min with nanoliter accuracy. Higher flow rates can also be delivered with less accuracy (cleaning or functionalizing channels, for instance). The pump control software allows precise control of flow rates, including the ability to hold flow at zero microliters/min which is not possible with ordinary syringe pumps. Complex flow patterns can also be programmed such as the step-wise or sine function flow rates shown that are shown in the insets. Provided/Rhoades.

ReynoldsTech Electroplating Stations

This Fall, we are bringing three new electroplate stations online; these were made custom for us by ReynoldsTech. These three hoods will replace the baths that have been used in the furnace area, and will be located in Room 102, in the CNF cleanroom. In addition to the gold and copper that we already can plate, we are adding nickel processing. Each hood will be specific for a particular metal.

In each metal-specific hood, we will have dedicated metal-specific bath, hardware, and wafer/piece fixtures for the electroplating of gold, copper and nickel. The baths will have immersion heaters and a filtered recirculating pump system to help minimize particulates.

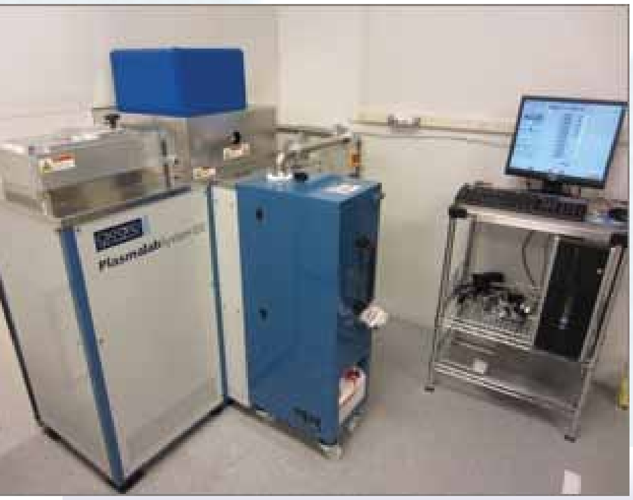
Each hood will have a versatile Dynatronix power supply that can provide continuous or pulsed power regimes to user-specified parameters. Also built into the hood deck is a quick dump rinse tank and N_2 and DIH_2O spray guns to clean and dry samples. A spin rinse dryer will also be available next to the plating stations for 4″, 6″ and 8″ wafers.

Process control and uniformity should be greatly improved with these new systems.

Furthermore, we are planning an electroplating workshop and seminar with Vince Reynolds in the coming months, so please keep an eye open for an announcement on the CNF webpage regarding this event.

Don Tennant

Oxford PECVD System



Don Tennant

A new Oxford Instruments Plasma System 100 load locked PECVD tool has been purchased to replace the Ion and Plasma Equipment PECVD (IPE PECVD) tool. The tool is currently installed and will be started up by Oxford and characterized during the second half of October.

The tool is capable of processing pieces (with use of a sample plate holder) up to 6-inch full wafers. The tool is a parallel plate PECVD configuration with a maximum platen temperature of 400°C. The tool is configured to deposit silicon oxide, stress controlled silicon nitride via a dual frequency RF generator, amorphous silicon, silicon carbide and amorphous carbon. The hardware is set up to provide deposition rates of 100-200 nm/minute that are comparable to the GSI PECVD tool.

Dopant gases for doped oxide and doped silicon films will be added later in the fall, as well a TEOS based oxide capabilities.

The tool will not be a restricted materials tool and will follow the material guidelines of the now removed IPE PECVD tool.

Speak to Phil Infante for more information.

Nanonex NX-2500 Nanoimprint Lithography Update

Nanoimprint lithography (NIL) has the advantage of high throughput with sub-10 nm resolution. NIL is included on the ITRS roadmap for 45 nm and below nodes for advanced electronic devices. In addition to electronics, NIL is a benefit to many applications including displays, nanophotonics, biotechnology, and MEMS.

The Nanonex NX-2500 has both thermal imprint (T-NIL) and photocurable imprint (P-NIL) capabilities. The thermal imprint module can reach temperatures up to 300°C with rapid heating and cooling rates. The photocuring module uses a narrow band 200W UV lamp with automatic control. It has submicron overlay alignment accuracy and has the ability to handle irregular shaped and sized substrates up to 100 mm diameter.

Recently the efforts of CNF Fellow Carol Newby and CNF technical staff members Vince Genova and John Treichler have resulted in the development of an established baseline process for photocurable nanoimprint lithography (P-NIL) on the NX-2500.

For P-NIL, the starting template material is quartz. The quartz wafer is blanket sputter deposited with 20 nm of chrome. The established process uses the ASML DUV stepper for patterning features to less than 200 nm on the template. The applied resist is UV210 along with an anti-reflective layer AR3 yielding a combined thickness of around 660 nm. After selectively etching the ARC layer in the Oxford 80 RIE system, the pattern is transferred into the chrome using Cl_2/O_2 based chemistry in the Trion ICP etch system. Once the remaining resist is removed from the chrome, the pattern is then transferred into the quartz to a depth of around 80 nm using CF_4 chemistry in the Oxford 80. The resulting etch profile is critical for successful imprinting. After wet etching the chrome, the quartz template is coated with a fluorosilane anti-stiction layer FOTS in the MVD 100. The anti-stiction layer enables the easy removal of the template after the imprint and eliminates the need for rigorous cleaning of the template.

The P-NIL process can be applied to many types of substrates, but has been demonstrated on silicon. The P-NIL process utilizes a bi-layer resist system in which the first resist layer (200 nm) is purely organic and the upper UV resist layer (90 nm) contains silicon.

Following the replication of template features into the upper layer of resist, a very critical pattern transfer process must occur in the residual and transfer layers of resist. The amount of residual UV resist remaining is a function of the applied imprint pressure. The pattern transfer consists of a selective fluorocarbon etch chemistry for the residual layer and the use of oxygen plasma to clear the organic resist layer in the Oxford 80. These etches must preserve the critical dimensions (CD) defined by the imprint process.

The patterned imprint resist is then used as a mask to transfer the pattern into the silicon using an established "photonics etch" of combined SF_6/C_4F_8 chemistry in the Unaxis 770 ICP system. Linewidths around 180 nm have been etched into 500 nm of silicon with perfect anisotropy and line edge resolution.

This process will be further demonstrated with pattern transfer into silicon oxide and silicon nitride. The process is directly applicable to SOI-based devices. Further development of the imprint process will be applied to features patterned by electron beam lithography.

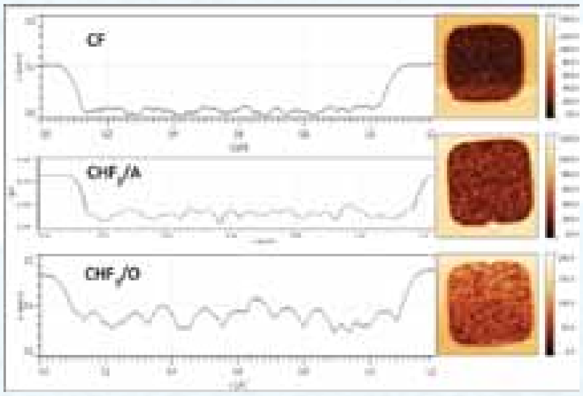


Figure 1: AFM of 1 µm features etched into the quartz template using different etch chemistries. The CF_4 etch shows the lowest roughness and is therefore most suited to the template preparation. Provided/Genova.

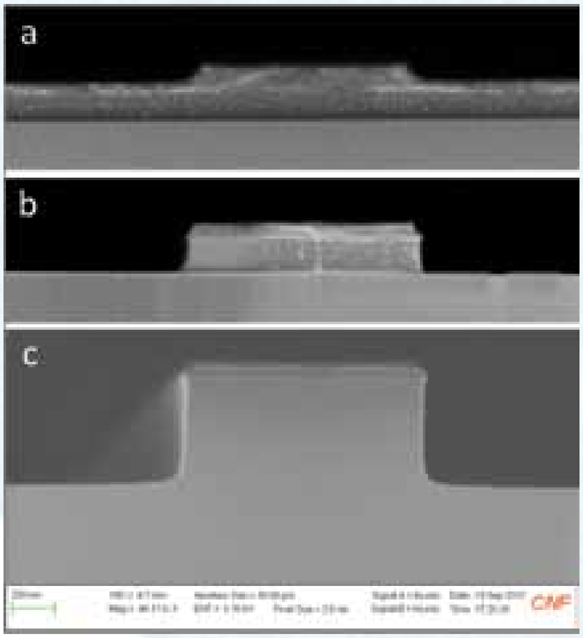


Figure 2: SEM cross-section images of a 1 µm feature; a) in the bilayer resist after imprinting, b) after descum and underlayer etches, and c) after transfer into silicon. Provided/Genova.

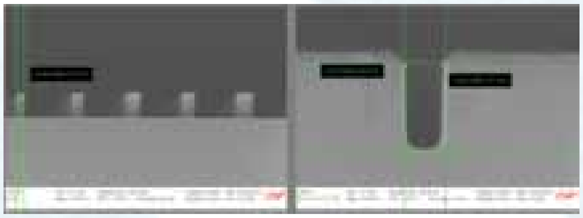


Figure 3: SEM cross-section images of sub-200 nm features transferred into silicon. Provided/Genova.

For further information on this process, please contact the CNF technical staff.

Melanie-Claire Mallison

The 2012 NNIN REU Program

Melanie-Claire Mallison

Don Tennant

The 2012 National Nanotechnology Infrastructure Network Research Experience for Undergraduates (NNIN REU) Program has come to an end, but it is not forgotten!

In total, 112 students took part in the NNIN's three research experience programs. We had 94 REUs this year, while seventeen of last year's REU interns took part in the international REU (iREU) Program. And last but not least, at NNIN site, The University of Texas at Austin, one graduate student from Japan took part in our "exchange" program, the International Research Experience for Graduates (iREG) Program.

Above are the ten CNF REU interns, in the CNF clean room and at the network convocation, held in August. Interns and staff gathered in Washington, DC, for presentations, posters, panel discussions, free time exploring our nation's capital, and most important — insight from the NSF's Lawrence Goldberg (below) and Mihail Roco. An informative and fun time was had by all.

Find all the interns' final reports, in PDF, at nnin.org.

To all our interns: Keep in Touch!

Melanie-Claire Mallison

NNIN to Hold ALD Symposium at Harvard University

An NNIN Atomic Layer Deposition (ALD) Symposium will be hosted at Harvard University, and is being coordinated by Mac Hathaway (Harvard), Vince Genova (Cornell), and Michelle Rincon (Stanford).

The date is set for November 29 and 30.

The symposium will comprise a two-day program consisting of the following:

- Day 1: A current status review of NNIN ALD systems and process capabilities. Advanced topics in ALD will also be discussed such as selective area deposition, graphene functionalization and nucleation efforts, and Al-doped ZnO.
- Day 2: A series of brief ALD vendor presentations and a two-hour Harvard user seminar. Invited talks will include Professor Roy Gordon of Harvard as well as a presentation from a leading industrial scientist.

An outcome of the workshop will be the creation of a database of NNIN ALD capabilities to guide users with specific needs to the correct NNIN site. This effort will also serve as a template for similar entries in a broad "NNIN Process Capability" database, ultimately covering other processes such as dry etching, CVD, PVD, etc.

For further information on the workshop, contact any one of the coordinators or go online to nnin.org.

Charles Harrington Photography

All CNF Labs Closed December 15-January 15

The Duffield Hall Cleanroom, home of CNF, has had numerous problems with the process cooling water system since its inception.

Beginning December 15, CNF will be closed for a major upgrading of the process cooling water system. This will involve considerable work in both the cleanroom and the rest of the building. CNF staff will be working during that period on cleaning the process tools along side of the contractors who will be doing the main system installation/modification. Our plan is to return to operation on January 15, although that date depends on progress.

We are sorry for this interruption and apologize for the inconvenience.

However, we look forward to better system operation and less tool down time after completion.

Dr. Lynn Rathbun
NNIN Deputy Director
CNF Laboratory Manager

Cornell NanoScale Facility
250 Duffield Hall
343 Campus Road
Ithaca NY 14853-2700

information@cnf.cornell.edu
http://www.cnf.cornell.edu

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Your comments are welcome!

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