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Cornell thinks small with big initiatives in nanoscale science and technology

As construction proceeds on Duffield Hall, which will house units in nanotechnology and nanobiotechnology on the Engineering Quadrangle, funding for specific centers and projects continues to come in.

In September the NSF announced the designation of Cornell as the Center for Nanoscale Systems in Information Technology, with funding of \$11.6 million over five years. This center, along with the Cornell Nanofabrication Facility and the Nanobiotechnology Center, will be located in Duffield when the building is completed by the end of 2003.

The new NSF-sponsored center is one of six Nanoscale Science and Engineering Centers (NSECs) to be established in the U.S. The others will focus on nanoscale research in medical, manufacturing, and environmental technologies, and molecular and quantum electronics. Areas of research designated for the Cornell center are nanoscale science and technologies, silicon and carbon nanoelectronics, nanophotonics, and nanomagnetism.

Two MS&E faculty members—George Malliaras and Yuri Suzuki—are among those from several departments who are leaders in the 17 research groups initially involved in the new center at Cornell. Malliaras' research program includes work in molecular electronics (see the article on page 4). Suzuki described her research

MS&E research groups are prominent among those at Cornell that are probing the extraordinary promise of nanoscale science and technology. Some of the projects in these areas are noted in this issue.

as part of "the big thing now in optical communication"—the effort to develop all-optical devices rather than hybrid devices which involve the conversion of photons to electrons. All-optical systems would have much greater capacity, she said, since information at many different wavelengths could be transmitted on the same optical fiber.

Suzuki was one of six faculty members who presented the Cornell proposal in Washington in June. Others in the delegation included Robert Buhrman of Applied and Engineering Physics, who will serve as director of the center.

The total NSF support over five years for the six NSEC facilities is \$65 million; Cornell's grant is the largest of the six. Additional support for the Cornell center is being provided by the New York State Office of Science, Technology and Academic Research.

"This latest NSF grant emphasizes once again that Cornell is the national leader in nanotechnology research," said Cornell President Hunter Rawlings. He cited the establishment of the Cornell Nanofabrication Facility and two decades later, in 1999, the NSF grant to found the Nanobiotechnology Center.

Right: A view of the architectural model of Duffield Hall as viewed from the road.

The three-story structure will include a penthouse and a large atrium connecting Duffield with Phillips Hall to the east and Upson Hall to the south. Construction is budgeted at about \$58.5 million.

Information about Duffield and views of the construction activity and the future appearance of the building are on the web at www.duffield.cornell.edu. Features under Previews are an interactive digital model, a virtual tour, model photos, drawings, and WebCam, which shows ongoing activity.



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Clark steps in as interim administrator

Alton H. Clark, who recently retired as associate director of the Cornell Nanofabrication Facility, has been serving as a part-time replacement for Robert A. Geyer since July.

Clark has had a long association with the MS&E department, beginning during the early 1960s when he was a graduate student in physics and did his thesis research under the supervision of MS&E Professors Che-Yu Li and Jack Blakely.

After many years in academia and industry (Sprague Electric, British Petroleum, Standard Oil, Carborundum, University of Maine), he returned to Cornell as a visiting scientist in MS&E in 1993 and assumed his position with the Nanofabrication Facility in 1994. He has also held an appointment as an adjunct professor in MS&E since 1994.

FROM THE DIRECTOR

The past 12 months have seen many successes and some events of great sadness for MS&E. It is impossible to ignore the World Trade Center attack. Through great fortune, no one directly associated with the department was hurt. More directly, Robert Geyer, our director of administrative operations, died from cancer just a few months ago. Bob was a personal friend and a tremendous asset to the department and he will be greatly missed.

But the department has experienced successes as well as challenges. MS&E has always had an important focus on teaching, and this year that dedication was recognized with three major teaching awards. Both George Malliaras and Michael Thompson received College of Engineering teaching awards, and Stephen Sass was selected from the university faculty as a Weiss Presidential Fellow. We are currently updating the laboratory component of our courses; Mike Thompson has agreed to work on reorganizing the student lab and to help in a fundraising effort for the acquisition of new equipment. Leadership in the academic component of our program is provided by our faculty members who are serving current terms as associate directors: Uli Wiesner for graduate education and Emmanuel Giannelis for undergraduate education.

I am also pleased to report that the world-class research carried out in MS&E, a hallmark of our department, will benefit from multimillion-dollar research grants through the awarding of NSF-funded NSEC and NIRT research programs (see the articles on pages 1 and 4). Members of our faculty are heavily involved in both these efforts. These and the other research projects reported in this newsletter demonstrate the major activities in nanotechnology carried out in Bard Hall. MS&E faculty have also spearheaded the acquisition of funds to purchase a state-of-the-art electron microscope to be located in the Cornell Center for Materials Research electron microscopy facility.

Over the past few months, I have become particularly impressed by our alumni and their involvement in departmental affairs. Last May the department convened the first meeting of its Advisory Board; two alumni, Bill LaFontaine (featured in this newsletter) and Duane Dimos, agreed to serve on it. Recently we were visited by a delegation from Singapore, an event coordinated by Amy Ho, an alumna. And Al Clark, an alumnus and friend of the department, is helping us out in the administrative office until we find a replacement for Bob Geyer. As we proceed into the year 2002, it is heartening to be able to count on so many terrific members of the greater Cornell MS&E community. — *Christopher Ober, Director, Department of Materials Science and Engineering*

Administrator Robert A. Geyer dies at 53

Robert A. Geyer, director of administrative operations in the MS&E department for more than a decade, died on August 6 at the age of 53. For many months after his diagnosis of cancer, he had continued to supervise departmental operations as much as possible.

"Bob was a model for how an administrator should function," said Professor Jack Blakely, who was director of the department at the time Geyer was appointed. "In dealing with people, Bob was always totally honest, congenial, and extremely competent. I look back at the many times he came to my office to tell me about some project—a building improvement, a lab facility, some student fellowships—that he had negotiated for the department. We have lost a valuable colleague and a good friend."

Among Geyer's activities in the department was serving as an editor of *MS&E News*.

A Cornell graduate of 1970, Geyer spent his entire career at the university. He was an avid traveler and outdoor enthusiast, and had wide-ranging interests including home improvement,



Photo by Voelker Arnold

classical music, and the study of philosophy and comparative religion. He was a founding member of Wisdom's Goldenrod Center for Philosophic Studies near Ithaca.

His survivors include his wife, Cynthia J. Gration, and his nine-year-old daughter, Julie. A memorial fund for the benefit of his family is being collected; details can be obtained from the MS&E office.

Degrees in MS&E awarded in May and August



Photo by Jon Reis

Members of the MS&E class of 2001 posed for their group portrait on graduation day last May. Following the commencement exercises, a reception for the graduates and their families and friends was held on the Quadrangle in front of Bard Hall.

Graduate degrees were awarded in both May and August.

Those who received M.S. degrees are Chester

Huang, Daniel Fredrick Schmidt, Yulong Shen, Yan Wu, Lu Chen, and Prita Pant.

M. Eng. degrees were awarded to Patrick Ernest Spence and Evan Laurence Williams.

Three Ph.D. degrees were awarded. The recipients and their committee chairs are: Martin Joseph Murtagh (Professor Stephen Sass), Danny Li-Peng Chen (Professor Dieter Ast), and Doohan Lee (Professor Jack Blakely).

Two MS&E professors cited for excellence in teaching

George Malliaras and Michael Thompson of the MS&E department were among 20 College of Engineering faculty members to receive alumni-sponsored Excellence in Teaching Awards for the 2000–01 academic year.

Malliaras received the Fiona Ip Li '78 and Donald Li '75 award and Thompson received the James and Mary Tien award. This was the second time Thompson was honored: in 1995 he was chosen for the J. P. and Mary Barger '50 award.

Dieckmann named fellow of American Ceramic Society

Rüdiger Dieckmann, professor of MS&E, has been named a fellow of the American Ceramic Society.

His research includes studies of transport of matter and charge in ionic crystals and oxide glasses, ceramic single-crystal growth, metal–ceramic composites, solid-state reactions, and phase equilibria.

He earned a doctorate at the Technical University of Clausthal and completed a habilitation at the University of Hannover. Before coming to Cornell in 1987, he held research positions at Hannover and at the Nuclear Research Center at Jülich.

The Class of 2001

Available information about the planned destinations of the graduates is indicated.

- Jun Aoki (Accenture, Tokyo)
- Kirvan Chao (Hewlett-Packard)
- Nap Chau
- Nathan Eisinger (Special Metals Corp.)
- Ryan Hale (Hagen & Co.)
- Daniel Jacobs (IBM)
- Vikram Joshi
- Ryan Luby
- David Lwu
- John Mills (Massachusetts Institute of Technology)
- Rojana Pornprasertsuk
- David Portner (Corning)
- Eugene Rhee
- John Riley (Georgia Institute of Technology)
- William Robinson
- Deborah Schorr (General Electric, Aircraft Engines)
- Phillip Smith (Naval Flight School)
- Eileen Wojtal (Northrup Grumman)
- Stephen Wolf (U.S. Navy Nuclear Power School)

STUDENT NEWS BRIEFS

- Man Hoi Wong, a member of Professor George Malliaras' research group, was selected to receive a grant of \$1,500 as a winner in the Intel Research Award Contest for Undergraduate Students. The award was made on the basis of a proposal Wong submitted for support of research on "Optimization of Charge Injection in Organic Semiconductor Devices."
- Holding down a job in industry while still on campus for his junior year is the unusual accomplishment of MS&E major Alex Veneman, another of Malliaras' students. It all began last year in an undergraduate laboratory. "I sent Alex to work for my friend Niki Ioannidis at Xerox during the summer," Malliaras explained. "Apparently, he did an amazing job and Xerox decided to hire him for one day a week, working from Cornell. Pretty cool, isn't it?"

Ober heads NSF-funded project on polymer microphotonics

The research has the potential to revolutionize lithographic nanopatterning.



Ober

A research team headed by Christopher Ober, professor of MS&E and director of the department, has been awarded a \$1.3-million, four-year grant by the National Science Foundation to study polymer microphotonics and develop ways to fabricate electro-optical devices. Uli Wiesner, associate professor in the department, is also a member of the team.

The grant was awarded under the NSF's Nanoscale Interdisciplinary Research Team (NIRT) program.

Polymer microphotonics permits the production of precision optical devices or elements using low-cost materials and simple processing steps, Ober said. He believes that the research has the potential to revolutionize the way routine lithographic nanopatterning—patterning at the near-molecular level—is carried out, and to open up new strategies for integrating soft materials, such as polymers, onto a silicon substrate, such as a chip.

The Cornell project involves specialists in several areas. Ober, Wiesner, and Geoffrey Coates, associate professor of chemistry and chemical biology at Cornell, have experience in

polymer synthesis. Expertise in characterization will be contributed by Sol Gruner, Cornell professor of physics and director of the Cornell High Energy Synchrotron Source.

Also on the team are Edwin Thomas of the Massachusetts Institute of Technology and Nitash Balsara of the University of California, Berkeley, both experts in the study and control of block copolymer microstructures. Industrial partners and the research areas in which they will contribute are Rohm & Haas in lithography, and Wright Materials Laboratory in the optical behavior of materials.

The objective of the team research, Ober said, is to create block copolymer electro-optical structures, at both two- and three-dimensional levels, that have features on length scales ranging from the molecular (measured in nanometers) to the macroscopic (measured in millimeters).

“The patterning of block copolymers,” Ober said, “offers remarkable possibilities for size and geometry control on much smaller length scales than is currently possible with conventional lithography.”

DARPA funds molecular electronics research by Malliaras' group

In theory, each element, such as a transistor, could be replaced by a molecule.



Malliaras

A four-year, \$400,000 contract in support of research in molecular electronics has been awarded to George Malliaras, assistant professor of MS&E, by the Defense Advanced Research Agency (DARPA), the central research and development organization of the U.S. Department of Defense.

The aim of the research, Malliaras said, is to investigate the electrical properties of individual molecules in order to gain an understanding of how to make molecules work like switches in microchips.

The project represents Cornell's first entry into molecular electronics research. In addition to experimental work, it will include a theoretical study conducted in collaboration with researchers at the University of New Mexico.

The project is part of a large multi-disciplinary DARPA program with the goal of demonstrating the feasibility of building functional molecular electronic devices. Also involved in the overall effort are the Naval Research Laboratory, the Air Force Research Laboratory, the University of North Texas, and Scripps Research Institute.

The hope, Malliaras said, is to develop molecular electronics devices that would surpass current silicon chip technology by increasing the number of transistors on a chip to hundreds of

millions; the densest chips in use today contain on the order of 7.5 million transistors.

In theory, it would be possible to develop circuits in which each element of a system, such as a transistor, diode, or conductor, would be replaced by an individual molecule. Such molecular microchips could provide greatly improved computing speed and immense storage with a minimum of power demands, and could lead to such applications as a camera that could store millions of pictures or a watch-sized computer with the power of a desktop PC.

Malliaras cautioned, however, that molecular electronics is “a fairly long shot” that could take a decade or more to develop.

The experimental program of Malliaras and his group calls for building test structures containing a very small number of molecules between two metal electrodes. A probe station integrated with a cryostat and electrical characterization equipment will be used to measure currents as low as 400 atto-Amperes (aA) flowing through the molecules (one aA is a flow of about 5 electrons a second). The cryostat will keep the molecules at temperatures as low as 4 degrees Kelvin. It is expected that the electrical properties of a single molecule can be extrapolated from these measurements.

Pushing nanofabrication to the near-atomic length scale

The fabrication of nanoscale structures six times smaller than those that can now be produced commercially has been accomplished by a team at Cornell directed in part by Stephen Sass, professor of MS&E.

The team of researchers in MS&E and chemistry has developed a fundamentally new technique—called *controlled etching of dislocations* (CED)—that they believe can be used to produce silicon nanostructures at the length scale of biologically important molecules, such as human antibodies. It appears that the technique could be used to produce millions of devices at a time and so be suitable for commercial application.

Collaborating with Sass in heading the project is Melissa Hines, associate professor of chemistry and chemical biology. Much of the corporately funded research is carried out at the Cornell Nanobiotechnology Center.

Already the team has fabricated, as proof of the concept, an array of single-crystal silicon nanostructures about 25 nm in diameter and spaced about 38 nm apart. The diameter of these “nanobumps,” as the researchers call them, is equivalent to the width of about 100 silicon atoms.

In principle, the CED technique could be used to fabricate structures spaced as close as 2 nm apart. This size range is on the scale of the smallest biological lengths; for example, the distance between binding sites on a human antibody is about 10 nm. In comparison, the smallest feature on the best commercial microprocessor is 150 nm wide.

The CED process is based on the production of a “twist-bonded bicrystal” in which atoms that are not well aligned form regularly spaced regions in which the chemical bonding is weak.

These regions correspond to dislocations—lines of poor chemical bonding. When these dislocations are removed by a chemical etching process, a periodic array of “nanobumps” is left behind.

These nanotextured surfaces will have applications in the fields of microelectronics, magnetics, and photonics, the researchers predict. But the most exciting uses of microfabrication, they say, have yet to be imagined.

“I like to think of this process as creating nano-Lego surface structures, which ultimately we can build on to make a variety of devices,” Sass said. “We would hope to develop properties and applications we can’t even imagine today.”

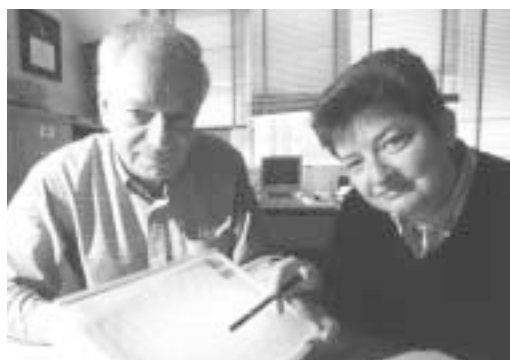


Photo by Nicola Kountoupes, University Photography

Stephen Sass, professor of materials science and engineering, and Melissa Hines, associate professor of chemistry and chemical biology, collaborate in directing the research project. Support is provided by Philip Morris USA.

A scientific paper by the researchers appeared in Applied Physics Letters 78: 2205–2207 (2001). A QuickTime movie illustrating the fabrication of the twist-bonded bicrystal is available on the web at www.chem.cornell.edu/mah11/Nanofab.html.

The “nanobumps” produced so far are the width of about 100 silicon atoms.

Stephen Sass was recently selected as a Stephen H. Weiss Presidential Fellow at Cornell, in recognition of “a sustained record of effective, inspiring, and distinguished teaching of undergraduate students and of contributions to undergraduate education.”

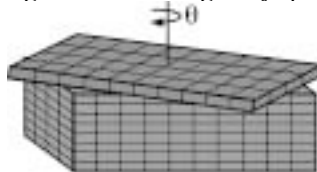
The fellowship, sponsored by the Cornell Board of Trustees, is based on recommendations of students and faculty members. It provides a grant, to be used for programmatic purposes, of \$5,000 a year for five years.

Among Sass’ contributions was the organization of a program in which undergraduates participate in ongoing faculty-directed research.

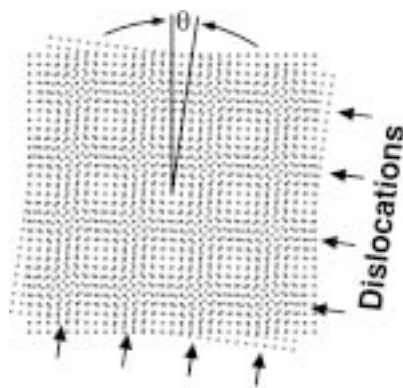
The CED Process

The process of controlled etching of dislocations is based on the production of a “twist-bonded bicrystal” formed by bonding a very thin silicon crystal to a thick one in such a way that the two crystals are misoriented by an angle θ .

As a result of this mismatch, some of the atoms are not well aligned and form regularly spaced

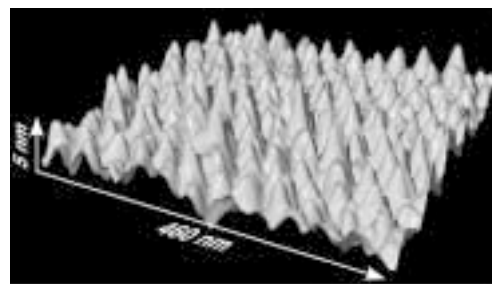


square grids or Moiré patterns that correspond to dislocations—lines of poor chemical bonding. Control of the angle θ between the top and bottom crystals



allows precise control of the spacing of the dislocations. Large misorientation angles correspond to small dislocation spacings and vice versa.

To form a nanotextured surface, the researchers use a special etchant that selectively attacks the dislocations. The result is a surface covered with a periodic array of “nanobumps.”



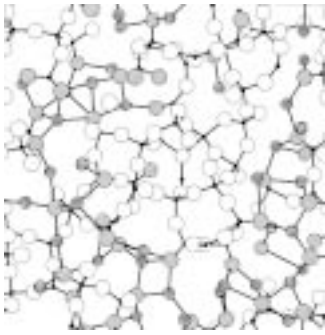


Figure 1. Section through a sodium silicate glass simulated by molecular dynamics (courtesy of Alastair Cormack of Alfred University). The smallest (black) spheres are Si, the largest are O, and the intermediate (cross-hatched) are Na. O atoms not bonded to two Si are shaded gray. The segregation into Na-rich and Si-rich regions is evident.

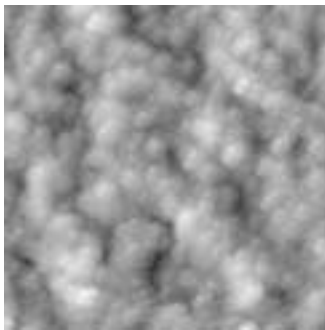


Figure 2. An AFM image, 200 nm x 200 nm, of the fracture surface of a calcium aluminosilicate glass. Well defined features 0.5 nm in height with diameters of 5 nm may be evidence of compositional clustering at the nanoscale.



Figure 3. AFM images of micromachined corrugations on glass before (upper image) and after (lower image) annealing at 810°C. The thermal treatment has had a smoothing effect.

The image is 40 μm wide.

Studies reveal structure and properties of glass and SiO_2 surfaces

by Jack Blakely and Kit Umbach

Glass surfaces are crucial in a wide range of technologies and in basic research. Nearly all biological testing systems involve silicate glass substrates and the use of these materials in optical communications and displays is now widespread. Yet our understanding of amorphous solid surfaces lags well behind that for crystals.

These solids are all expected to have some degree of short-range order, largely influenced by preferences for particular bond lengths and angles associated with nearest-neighbor interactions. However, because of the lack of long-range order in the form of periodic atomic arrangements, many of the techniques used to study crystals are difficult to apply to amorphous solid surfaces. The mechanisms by which material is transported can also be radically different in crystalline and amorphous solids; viscous flow, in which groups of atoms or molecules move as a unit, is much more likely than diffusive “hopping” of individual atoms or molecules.

We are studying the structure, composition, and mass transport processes associated with the surface of SiO_2 -based glasses. This research is part of a coordinated program of studies of glass surfaces and their interfaces with thin films that is supported in part by the Cornell Center for Materials Research. We are also studying the mode of growth of amorphous SiO_2 on specially prepared atomically flat Si surfaces.

Atomic and mesoscopic structure of glass surfaces

It appears that in some multicomponent glasses, the positions of the atoms are not entirely random, but have a “medium-range order” on the scale of several nanometers. This intriguing possibility is evident in a molecular dynamics simulation (Figure 1) of a sodium silicate glass; and x-ray and neutron scattering measurements have hinted at the existence of this type of ordering in the bulk of real glasses.

We are developing sensitive probes to detect this ordering in the glass surface structure. One of these probes uses a new form of scanning tunneling microscopy (STM) with instrumentation that, unlike current models, can image low-conductivity surfaces. We expect that photon or electron radiation of glass surfaces can bring about transient conductivity that is sufficient for the imaging. Already we have demonstrated the principle by inducing a long-lived change in the surface conductivity of a commercial aluminoborosilicate glass by bombarding it with ultraviolet radiation, thereby creating electrically active surface defects.

Another probe that can be applied to glass surfaces is atomic force microscopy (AFM), which does not require a conducting surface and can, under ideal conditions, resolve atomic-scale features. We have applied AFM to the surfaces of glasses that have been smoothed by fracturing in ultra-high vacuum and so are free of mechanical damage from polishing.

Of particular interest to us and other Cornell researchers are calcium aluminosilicate glasses (formed from certain mixtures of SiO_2 , Al_2O_3 , and CaO) that are simple but closely related to the advanced glasses used, for example, in computer displays. When the ratio of Al_2O_3 to CaO is maintained at 1:1 in these “model” glasses, a fully linked network structure like that of SiO_2 is obtained, and this network is preserved even when the SiO_2 content is varied over a wide range. In our study, we used samples of calcium aluminosilicates prepared by collaborators at Corning. A typical AFM image of the fracture surface of such a glass is shown in Figure 2. Well defined features with a lateral length scale of 5 nm may be evidence of compositional clustering; similar features are also observed in commercial display glasses.

How does mass transport occur at glass surfaces?

How does mass transport occur at glass surfaces?

The cleaning and heating of the glass surfaces are important for their integration with other technologies. Glass is increasingly being used not just as a passive substrate, but as an active part of micromachined systems. For instance, glass can be patterned to provide optical components that can be integrated with thin-film transistor electronics for devices such as sensors.

To find out how such micromachined elements can be improved by thermal treatment, we have used AFM to follow the change in shape that occurs when glass surfaces with a periodic surface shape (formed initially by optical lithography) are smoothed by annealing. In the example shown in Figure 3, the amplitude of corrugations is diminished. By determining how the amplitude decay rate changes as the wavelength of the periodic corrugation changes, it is possible to determine which mass transport mechanism is dominant at the surface; at these wavelengths, viscous flow appears to be dominant.

One widely used method for cleaning surfaces is ion beam sputtering, in which energetic ions (typically Ar or N) are accelerated toward a substrate. Some atoms are displaced and ejected, and this can result in the formation of nanoscale corrugations, as seen in Figure 4. We have been investigating the effects on glass surfaces, and have found that the wavelength of the corrugations can be controlled by temperature and ion-beam energy.

Our investigations have shown that the smoothing of the surface by viscous flow is critical to the self-organization of the surface, even at the nanoscale level.

How does a glassy SiO₂ layer form on a crystalline substrate?

How SiO₂ forms on the surface of Si has been intensively studied because of the importance of SiO₂ as a gate dielectric in the FETs used in random access memories. At relatively large oxide thickness the growth of SiO₂ seems to be well described by an oxygen-diffusion-limited process occurring at the interface. At oxide thicknesses below several nanometers, however, this model is not applicable.

There are several interesting questions: How does the oxygen insert itself into the crystalline Si-Si bonding scheme? At what stage is the regular periodic arrangement of the substrate lost? Does the reaction occur preferentially at atomic steps at the interface?

We have studied the formation of SiO₂ on very special Si(111) and (100) surfaces on which the density of atomic steps is reduced to zero within regularly arrayed areas. (This was done in thesis work by Antonio Oliver.) Both the interface and the oxide surface remained step-free under oxidation conditions similar to those

used in device processing. Also, careful studies of surfaces with widely spaced steps (see Figure 5) showed that there is no evidence for oxide growth by a step-flow process, as previously proposed. On Si(111), oxidation is a layer-by-layer process.

Further studies of the oxygen insertion process and of the structural transition from ordered to disordered are planned using the X-ray facility at the Cornell High Energy Synchrotron Source.

Initial experiments have demonstrated that leakage currents in capacitor structures built on our ultra-flat surfaces—with oxides a few nanometers thick—are smaller than they are with normal wafer surfaces. The improvement is expected to be even greater at a thickness of 1 nm, as used in making extremely small FETs.

In testing the capabilities of our low-current STM, we have obtained images of oxidized layers on vicinal Si surfaces showing clearly visible atomic steps and step bunches. As we learn more about how to control the distribution of charge on such highly insulating surfaces, we aim for images with near-atomic resolution.



Photo by Chris Ober
Jack Blakely (at right) is the H. F. Johnson Professor in the MS&E department. Kit Umbach is a senior research associate in Blakely's group.

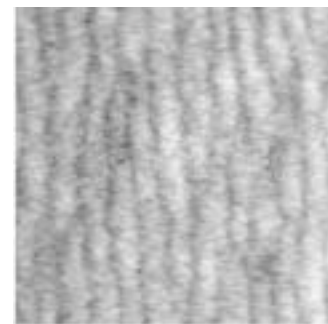


Figure 4. An AFM image, 1 μm x 1 μm , of nanoscale corrugations induced by sputtering of a commercial aluminosilicate glass.

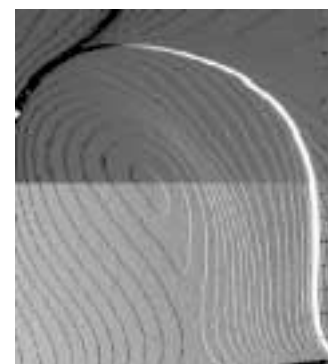


Figure 5. Composite 10 μm x 10 μm AFM image of widely spaced steps on a Si (111) surface before (upper region) and after (lower region) oxidation. The positions of the steps are unchanged by oxidation to within 10 nm. The image was produced by merging two separate AFM images.

Nanocrystalline solar cells go natural with berry juice for dye

In one of Professor Dieter Ast's courses, a laboratory experiment uses berry juice in constructing a solar cell.

The course is MSE 574, Solar Cells, and the kind of cell under study is a nanocrystalline dye-sensitized solar cell in which the processes resemble photosynthesis by plants. The dye of choice is an anthocyanen—a pigment responsible for the red or blue coloring in flowers and fruits.

The experiment demonstrates the operating principles of the nanocrystalline solar cell, Ast explained. Light is absorbed by dye that is chemically attached to a thin layer of nanocrystalline particles of titanium oxide. These tiny particles have properties that differ from those of bulk TiO₂; for example, the coordination of the Ti surface atoms changes as the particles are reduced from 50 nm to 3 nm in diameter.

The dye transfers electrons to the semiconducting TiO₂ layer, and from there the electrons move to an underlying conductive layer. Meanwhile, the positive charge on the dye is transferred to a mediator such as

an iodide solution that fills the cell, and from there to a counter electrode. When the circuit is closed, electricity is produced. An operative cell comprises a stack of the basic units.

This novel cell was invented by Michael Graetzel, a German scientist working in Switzerland, and has reached efficiencies of over 10 percent. A big advantage of the dye-sensitized cell, Ast said, is that production costs are less than they are for the more conventional solar cells based on single-crystal silicon.

Current research includes efforts to replace the mediator solution with a solid-state electrolyte. In the MS&E department at Cornell, Professor Emmanuel Giannelis' group is investigating the use of nanocomposites for this purpose.

Another aim is to synthesize more efficient dyes than nature provides, Ast pointed out. Still, what could be more environmentally appealing than electricity generated by a photosynthetic process using sunlight and berry juice?

Alumnus works worldwide as IBM vice president

It's like trying to sail into a gale-force wind. That is how William LaFontaine, IBM's vice president for worldwide semiconductor sales, describes his job during the current downturn, the worst in the history of the semiconductor industry.

LaFontaine, a 1990 Cornell Ph.D. in MS&E, nevertheless found time—mostly on flights to distant cities—to discuss, via e-mail and telephone, his experiences at Cornell and how they have influenced his career.

The most important thing he got out of his doctoral studies, he said, was learning how to think—to look at all aspects of a problem, stay objective, and come to a realistic solution—and then to actually complete a project. The hurdles in completing a Ph.D. program, he said, are the same kind encountered in the business world.

In fact, quite a few of the people who earned doctorates in MS&E around the time he did have become corporate executives or leaders in research development, he commented. Some have founded start-up companies—ventures in which a solid technological background is very important.

"I use my MS&E education on a regular basis," he said. "In many cases, customers are pushing the technology envelope and developing leading-edge products. The problems they face are fundamental technological ones—Can I cool this electronic assembly? Can I get this chip to run faster?—that my background helps me understand."

LaFontaine began graduate study in MS&E after earning a B.S. degree at California Polytechnic State University in San Luis Obispo. At Cornell he earned M.S. and Ph.D. degrees.

For his doctoral research project, he worked with Professor Che-Yu Li in the area of micro-mechanics of thin films and interconnects. In particular, he worked on stresses in thin films and their effect on the behavior of metallizations.

He joined IBM in 1990 as an engineer in an advanced technology group at the Endicott, NY facility. Soon he became a manager of an experi-



LaFontaine

mental mechanics group and then assumed responsibility for all of the process development.

After four years at Endicott, he switched to International Marketing and Sales at Fishkill, NY. "This was about the time that IBM decided to get into the merchant marketplace and sell semiconductors and packaging to customers outside of IBM," he said. His activities included setting up and supervising operations in Japan and in Singapore for the Pacific Asian markets.

After several other assignments, he was appointed last July as vice president, Worldwide Sales and Services. In this role, he leads the North American team as well as overseeing activities in Asia and Europe. He is responsible for semiconductor sales to major producers in the areas of information technology, communications, and consumer goods.

Of course, spending time with his family—his wife, Laura, and two young sons—has high priority. He and Laura, a Cornell graduate, met when she came back to campus for Homecoming in 1988. Their wedding took place in Sage Chapel.

LaFontaine's most recent return to campus was in May for a meeting of the MS&E department's Advisory Council. Cornell, it appears, remains a home base for alumni, including those who work worldwide.

Attention Alumni!

☞ We would like to update our database of your e-mail addresses and make them available—to other alumni—on the MS&E website. We will protect this list of addresses with a password so that it cannot be used by non-alumni. The password will be posted in the next newsletter.

We ask you to please send an e-mail message with your name, degree, and year of graduation to: matsci-web

@ccmr.cornell.edu

To help us quickly recognize these messages, please specify the subject as "Alumni News."

And while you're at it, do send us news about yourself for inclusion in MS&E News.

☞ Mark your calendars for the Cornell reunion June 7–9. We're planning a Saturday breakfast for MS&E alumni. Sometime before then, please make reservations with Carol Armstrong (607/255-9617; ca20@cornell.edu).

Showing off the department

As the newly formed MS&E Advisory Council entered Bard Hall for the group's initial meeting last May, they encountered posters showing off the state-of-art research in the department. At least, that was the purpose of the Second Great Bard Poster Contest, according to the publicity for the competition.

Postdoctoral Associate Young Bae won the \$150 first prize. Graduate student Gina Weibel won the \$100 second prize and Katherine Tyner, also a graduate student, won the third prize of \$75.

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