Letter From the Deans

Quick! What’s the first word you think of when we say, “Engineering and the Sciences at UCSB”?

Was it “collaboration”? If so…you’re in good company.

More and more people are finding that one of our distinctive features is a quality that you don't necessarily consider when you picture academia.

We’re very collaborative. Our ability to work effectively with people in industry is contributing significantly to the quality of learning and research at UCSB and to our reputation as a leader in a wide range of fields.

So much in engineering and the sciences depends on having the opportunity to put good research to use, test our ability to execute a design or a concept, evaluate demand in a global market, and work well with colleagues outside the university.

It isn’t always easy for professors and students to step outside the ivory tower and into a variety of corporate cultures, or to work with varied teams representing a broad spectrum of disciplines. And frankly, we suspect it isn’t always comfortable for people from industry to work within the university culture, which typically has a style different from that of many corporations.

Yet we’re having great success at bridging the academic-corporate gap and the world is noticing. We drew global media attention this September when we announced that John Bowers, a UCSB professor of electrical and computer engineering, had collaborated with Intel Corporation to develop the first electrically-powered hybrid silicon laser. This device has the potential for revolutionizing the computer industry. Our Technology Management Program (TMP) produces scores of new product ideas and a significant number of start-ups every year. Mitsubishi Chemical Corporation of Tokyo recently extended its research and education alliance with us, investing between $8.5 million to $10 million over the next few years. And we have many, many other examples of professors and students in engineering and the sciences working directly with industry both to advance the science and to improve the quality of life for people now and far into the future.

Some say the highest compliment students can get in kindergarten is that they “play well with others.” That probably holds true in adulthood, and especially in business, where effective teamwork is highly valued.
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The university, long known for its work in computer security, is also gaining notice for teaching students how to attack and defend computer systems and thus stay ahead of the bad guys. Instruction includes both theory and practice, with a stress on the latter for the advanced students. “The only way to teach security is to break security,” says Associate Professor Giovanni Vigna, a noted hacker himself who teaches a hands-on class to graduate students in computer sciences. The course aims to show students how to exploit the weaknesses of networks without crossing ethical or legal lines.

Vigna, 37, defines hackers in positive terms, as people “who know how things are broken and could be repaired.” He is a leader in efforts to bring security-breaching skills into the academic mainstream. His hacking course started in 2001 and, he says, it is still “unique in this country.” Also in 2001, he started a hacking contest that has grown into a global event. The latest “International Capture the Flag”, as it’s now called, was held in December 2005 and drew 22 student teams representing 18 schools from North and South America, Australia and Europe. (See “Software Slugfests” for more on hacking competitions and UCSB’s record in them.)

On the more theoretical side, Professor Richard Kemmerer teaches a course that introduces undergraduates to the basic concepts of computer security while giving them exercises such as writing password-cracking programs. The 63-year-old Kemmerer is a pioneer in computer science – he had an email account on one of the Internet’s first four nodes (at UCLA). He also was one of the first academics to take computer security seriously as a field of study. “He has been around for 30 years doing this kind of work,” says Vigna, who came from Italy to UCSB in 1997 in order to do post-doctoral work with him. “He’s super-respected within the community.”

Kemmerer says his undergrad class aims to give students the intellectual tools they need to deal with unforeseen security challenges. “The purpose of the class is to teach security basics, and if someone leaves it, there are certain things they should know,” he says. “More importantly, when they are put in a novel situation, they should know how to make this particular site more secure.”

Hacking For Credit

They’re out there -- cyber-criminals from around the globe, trying to steal your identity, your privacy, your money. They’re working 24/7 to get into your computer.

So who is going to protect you? Hackers, including some trained at UC Santa Barbara.

A homework assignment might be to take a harmless program, such as finding a keyword in a file, and tweak it so that the computer interprets the keyword as a malicious command, such as “delete this file.”

Class Notes from Underground

So how does one teach hacking, a set of skills long identified with social outcasts (or outlaws) too bright for their own good? First of all, Vigna creates a space where hackers-in-training can hone their skills without doing any damage or breaking any laws. In the Capture the Flag contest, for instance, he sets up a virtual private network for the competing teams that is “sort of real world” but at the same time protected. (The real real world is protected, too). Also, he writes unique software for his competitions and classes, never allowing students to hack programs that already are in use somewhere.

As for the course content, he says it comes down to the teaching of specific skills and a more general “hacker mindset.” On the skill side, students learn how to trigger events such as buffer overflows, a type of data overload that can disrupt a system and enable hackers to gain control of it. On the mindset side, they are encouraged to think outside the programmer’s box and come up with unforeseen threats. “The task of the attacker is to identify what is the unexpected input and how to generate unexpected behavior,” says Vigna. A homework assignment might be to take a harmless program, such as finding a keyword in a file, and tweak it so that the computer interprets the keyword as a malicious command, such as “delete this file.”

Some might find it unnerving to learn that graduate students are learning the methods of cyber-crime and getting course credit to boot. But it’s all in a good cause – that of protecting computer users. “I don’t teach this way to create the next generation of criminals. I want to create the next generation of cops,” Vigna says. Those cops are much in demand for tasks such as security audits of software. Vigna says graduates of his class have gone to work for Apple Computer, Microsoft Corp. and companies that specialize in intrusion detection: “They definitely don’t have a problem getting jobs with those skills.”
Kemmerer says the university has been holding cryptology conferences since 1981. Back then, the public sharing of such information was new and, to some, highly risky. “When we started it, we didn’t know if the government would shut us down or not,” says Kemmerer.

Software Slugfests

UC Santa Barbara has made a name for itself in hacking competitions, both as host and participant. Its own event, International Capture the Flag (iCTF), has grown to include nearly two dozen teams with some 400 participants. And it has won a similar competition at Defcon, the hacker convention held each summer in Las Vegas.

Its specialty, Capture the Flag, is a contest in which multiple teams try to attack one another’s services while protecting their own. Final scores are based on the number of services that each team has been able to maintain and the number of services on other teams that they have managed to compromise.

The iCTF at UCSB is exclusively for college and university teams. It grew out of a contest between two UCSB teams in 2001 and was expanded to include other U.S. schools in 2003. It went international in 2004 and takes place on a virtual private network. In the most recent iCTF, an eight-hour bout in December 2005 that drew contestants from four continents, a German team (“0ld Eur0pe” -- the zeroes are not misprints) took first place among 22 teams. Two UCSB teams, “Alfa” and “Omega,” placed ninth and 16th.

At Defcon, eight teams slug it out in a Capture the Flag match that takes place over 36 straight hours. UCSB professor and hacking master Giovanni Vigna says this is a “tougher, rougher” counterpart to iCTF, with corporate and military security pros in the mix. In the past three Defcons, UCSB’s team has racked up an impressive CTF record -- second place in 2004, first in 2005 and third in 2006.

A Longtime Security Leader

Well before Vigna started his hacking class and competitions, UC Santa Barbara was a leading center for studying computer security and finding threats. In 1997, one of Kemmerer’s graduate students, Andre L.M. dos Santos, found that a hacker could use a flaw in Netscape’s Web browser to track users and steal information such as credit card numbers and passwords. Netscape fixed the problem, but not before it got a name: the “Santa Barbara Privacy Bug.”

UCSB is also known worldwide for its work in cryptography, the science of protecting privacy and controlling access to information through means such as codes and encryption keys. Kemmerer says the university has been holding cryptology conferences since 1981. Back then, the public sharing of such information was new and, to some, highly risky. “When we started it, we didn’t know if the government would shut us down or not,” says Kemmerer.
Much has changed since the early days of computer-security studies, when Kemmerer says “you could count on your hand” the number of academics in the field. Now he says the subject is a standard part of computer-science resume presentations: “Almost anyone who comes here looking for a job says, on their last slide, that they do security.” Awareness of security issues and threats has risen with the public’s use of the Web (and its personal encounters with viruses and other ills once known mainly to system operators). Kemmerer says laws are getting tougher and people are getting smarter about computer crime. At the same time, the need for security is growing as more commerce moves to the Internet and more people send it private data as they buy, sell, bank, invest or just surf. Can science keep up? Time will tell, but it’s safe to say that UCSB will continue on the front lines with the latest knowledge, not to mention world-class hacking.

Tips for Safe Computing

Feeling insecure when you log on? UCSB security experts Richard Kemmerer and Giovanni Vigna have some tips for making your online experience safer from identity theft and other attacks:

- Use strong passwords. These are combinations of letters and numbers (or special characters such as pound signs) that cannot easily be guessed. Avoid basing a password on something that might be known to others, like a family name, license plate or car model. But a password can be based on an easy-to-remember sentence, as in this example from Vigna: “I always use strong passwords for important stuff” converted to “Iausp4is.”
- It’s “also a good idea to change passwords from time to time,” says Kemmerer. To keep track of his passwords, he writes them down in scrambled form.
- Use anti-virus and firewall programs, and keep your system security up-to-date.
- “Be aware of where you’re going on the Web,” says Kemmerer. Understand that, when you go to any site, you give that site permission to download to your computer.
- Don’t believe all the email you get. Identity thieves often use email that mimics legitimate web sites in order to extract personal information.
- Be aware of browser risk. Both Kemmerer and Vigna say Firefox is currently more secure than Internet Explorer.
few stories of human ingenuity are more dramatic than that of the shrinking circuitry and expanding power of computers. Since the mid-20th century, the cost of a transistor has been cut by a factor of one billion, and the size of this basic computing device has been reduced by roughly the same amount. Reliably following the trend dubbed Moore's Law (after Intel Corp. co-founder Gordon Moore), the speed of processing has doubled every 18 months or so as inventors and manufacturers have pushed the scale of circuits on computer chips down to once unimaginable scales.

But do all good things, even Moore's Law, have to come to an end? That question bedevils the semiconductor business these days as it tries to compress microcircuits to the nano-scale, where transistors and other features are produced at sizes below 100 nanometers (one ten-millionth of a meter). Engineering problems that so far have been manageable now threaten to become show-stoppers.

One of the most serious hurdles looms in the production process. Chip makers now print circuits by shining lasers through a patterned mask and focusing them onto light-sensitive thin polymer films, called photoresists, which are then used in etching the underlying silicon wafer. This technique, called optical lithography or photolithography, is now hitting technical and economic limits. Craig Hawker, a UCSB professor of materials and chemistry, says, “The state of the art is now 193-nanometer lithography,” which can print features down to about 45 nm. For sizes smaller than this, the wavelength of light becomes a critical issue and decreasing the wavelength below 193 nm becomes prohibitively expensive. Current lithography machines cost about $20 million. Semiconductor plants have to have many of these, so the price tag now runs to more than $1 billion for a typical fabrication facility. “You need perfection at such a small size. That’s why the expense,” says Hawker.

Dance of the Polymers

Hawker has been working with two UCSB materials and chemical engineering professors, Ed Kramer and Glenn Fredrickson, on new technology to break the nano-scale barrier. Called block copolymer lithography, it’s a hybrid of top-down and bottom-up methods. From the top down, it uses polymer chemistry as well as current lithography techniques to create large patterns such as lattices. From the bottom up, it uses polymers to create so-called “microdomains,” about 10 nanometers in size, that are integrated into the larger patterns.

At the core of this process are molecular structures called block copolymers, which assemble into nanometer-scale features through a natural process. They are made up of two or more different polymer sections — familiar molecules such as polystyrene or poly(methyl methacrylate) — in a somewhat tense relationship. Each polymer is joined to the other by a covalent (electron-sharing) bond on one end. Like oil and water, however, they don’t mix. It’s as if reluctant dancers were forced to hold hands while avoiding other bodily contact as much as possible. Just as those dancers might end up creating an interesting pattern on the floor, block copolymers create distinctive shapes from the interplay between bond and repulsion. In simple cases, they can organize themselves into spheres or cylinders. They also can interact with other block copolymers to form more complex geometric patterns.

The trick is to guide this self-assembly process so that it produces patterns on a silicon chip that can be used for circuits. “The patterns that people have achieved so far are basically cylinders or spheres,” says Fredrickson.
It’s as if reluctant dancers were forced to hold hands while avoiding other bodily contact as much as possible.
QUESTION & ANSWER: Jean-Pierre Fouque

What’s it worth?

That simple-sounding question is one of the most difficult to answer, especially in a financial world that constantly invents new vehicles for building wealth and managing risk.

UC Santa Barbara’s new Center for Research in Financial Mathematics and Statistics brings together scholars and financial practitioners to tackle this question and others with the latest tools of theory and practice. The center includes researchers from the departments of Statistics and Applied Probability, Economics, Mathematics, Computer Science and others. Its agenda includes subjects such as derivatives pricing, risk management, hedging and portfolio optimization.

The center, which started activities earlier this year followed by its formal launch in October, is headed by Jean-Pierre Fouque, professor of statistics and applied probability. Fouque, 52, was born in France, earned his PhD in mathematics in Paris and most recently taught at North Carolina State University before coming to UCSB in 2006. His research has long been focused on two distinct areas—the behavior of waves and the workings of volatility in financial markets. Fouque recently talked with Convergence about the center, its work and his own research. Here is an edited version of that interview:

How did the Center for Research in Financial Mathematics and Statistics get its start?

UCSB has been trying to do this for some time. It was already awarding degrees such as bachelor of actuarial science, bachelor of financial mathematics, and a PhD in statistics with the major in mathematical and empirical finance. The idea was to do something bigger along these lines, with more research. It had been trying to hire someone to lead this initiative.

So when I came here in January 2006, my main goal was to start the center. I put together a proposal, working very closely with the chair of the Statistics and Applied Probability Department [Raya Feldman], and started a seminar in May. We had a very nice program of seminars in May and June, and we have succeeded in hiring four post-doctoral fellows for the 2006-07 year -- two from Cornell, one from Georgia Tech and one from the University of Bristol in the U.K.

What makes this program timely right now?

Financial markets are changing quickly and new problems are emerging. One of the big problems is the fast growth of the markets surrounding credit risk. A lot of money — more than a trillion dollars — has been invested in credit-related products such as CDOs [collateralized debt obligations] and credit default swaps. These are products that we try to understand and put prices on, but it is not clear that we understand them. My own research is in this area, and we are also drawing on ideas from insurance, such as how one measures risk.

How can non-academic experts be involved?

I have a lot of colleagues working on Wall Street, and some have ideas for writing a book. The center might give them the chance to go to Santa Barbara to spend a couple of months to do some thinking and get away from Wall Street.

One highly regarded derivatives expert from the financial community, Bruno Dupire of Bloomberg LP, has been selected as a Regent’s Lecturer for next spring. He will give a public lecture during his time here, and he will interact with our students, faculty, and the local community. Also, among the three speakers at the October formal opening there are two practitioners. That should tell you something.

What do you think of the old idea that academic theorists had little in common with the people actually working in financial markets?

That idea is out of date. When you look at trading floors, you see people with PhDs in mathematics or physics in their research teams. It is different from a university, but you will find a level of knowledge that is very remarkable. I recently gave a talk at one of the big financial...
Have you ever been a professional trader?

No. What I have been doing for the past five or six years is consulting. With my own money I am a passive investor. I don’t have time for trading. I trust the people who do it for the University of California. I trust that they will do a good job.

Do you have any idea where the stock market is heading?

I am not claiming to be a financial analyst. I am a mathematician. I try to do modeling, things that are compatible with the market, but I am not a forecaster.

But I can tell you that derivatives have been smoothing out the stock market. On the other hand, the market for credit instruments such as default swaps and CDOs is quite new and needs to be better understood. It has been booming for the last five or six years. The money is there, and people are investing there, but they are having trouble getting returns. Bringing a little logic and consistency to it would be a good thing.

institutions, and the audience was what you would get for a seminar at a university. There were around 20 PhDs who knew very well what I was talking about.

Do you plan any educational outreach at the center - for instance, trying to improve the public’s level of financial sophistication?

This is one of the things I would like to propose to the local community, maybe having a seminar once a month, bringing in an expert to talk to the public about the new ideas, the new problems, the new strategies.

Another project that I am working on with a group of friends and colleagues from industry and universities is called REDPI, for Research, Education and Development in the Public Interest. The idea is to collect research and ideas on new trading strategies, to develop them in a hedge fund and to make this hedge fund work for charity.

Tell us something about your own background. Did you start out in financial mathematics?

Not exactly. I earned my PhD in 1979 in Paris with a dissertation on probability. What was interesting, though, is that my advisor Nicole El Karoui had just made the front page of the Wall Street Journal in March. She had been extremely successful in putting together a program in quantitative finance in Paris. During the 80s and 90s I worked more in the application of mathematics to physics, specifically to waves propagating in random media. But I followed the development of quantitative finance because students were demanding to know about it at the time.

I became more involved in finance when I spent a sabbatical at Stanford in 1996. I worked there with George Papanicolaou [on the Stanford faculty] and K. Ronnie Sircar [then a student, now at Princeton], and in 2000 we wrote a book together - Derivatives in Financial Markets with Stochastic Volatility. Since then, finance has been a very active area for me.

Most of your research has focused on two seeming different areas, volatility in financial markets and the behavior of physical waves. How are these related?

The relation between the two is simply a way to look at randomness. The common ground is that you have a random phenomenon and various time or space scales, and you have mathematical tools to say something about them. There is no relation between the waves and markets, though I wish there were.
What is this?

See solution on inside back cover.
The researchers were able to combine the light-emitting properties of Indium Phosphide with the light-routing capabilities of silicon into a single hybrid chip. When voltage is applied, light generated in the Indium Phosphide enters the silicon waveguide to create a continuous laser beam that can be used to drive other silicon photonic devices. A laser based on silicon could drive wider use of photonics in computers because the cost can be greatly reduced by using high-volume silicon manufacturing techniques.

The research was published in the October 2 issue of Optics Express. The news generated more than 250 print, television and radio reports in major media worldwide.

Bowers has worked with Indium Phosphide-based materials and lasers for more than 25 years. Currently his research is focused on developing novel optoelectronic devices with data rates as high as 160Gb/s and techniques to bond dissimilar materials together to create new devices with improved performance. The UCSB work was funded by the Microelectronics Technology Office of the Defense Advanced Research Projects Agency (DARPA) and Intel Corporation.

UC Santa Barbara and Intel Corporation have developed the world’s first electrically-powered hybrid silicon laser using standard silicon manufacturing processes. This breakthrough addresses one of the last major barriers to producing low-cost, high-bandwidth silicon photonics devices for use inside and around future computers and data centers, said John Bowers, a professor of electrical and computer engineering here.

“By combining UCSB’s expertise with indium phosphide and Intel’s silicon photonics expertise, we have demonstrated a novel laser structure based on a bonding method that can be used at the wafer-, partial-wafer or die-level, and could be a solution for large-scale optical integration onto a silicon platform,” said Bowers. “This marks the beginning of highly integrated silicon photonic chips that can be mass produced at low cost.”

Researchers at UC Santa Barbara have discovered what limits our ability to reduce the size of capacitors, often the largest components in integrated circuits, down to the nanoscale. They have answered a 45-year old question: why is the capacitance in thin-film capacitors so much smaller than expected?

Because there is great interest in increased portability in consumer electronics, researchers are continually searching for ways to reduce the size of electronic devices, but capacitors have proved particularly problematic. Researchers have tried to use high-permittivity materials to achieve more capacitance in a smaller area, but nanoscale devices have yielded lower-than-expected capacitance values. These low values have limited the performance of thin-film capacitors and prevented further device miniaturization.

A predatory protozoan has yielded the secrets of its genome. The results were published in the September 2006 issue of Public Library of Science Biology. The publication of this project caps over a decade of work by Eduardo Orias’ research group. Orias is a professor of molecular, cellular, and developmental biology, and his team has mapped hundreds of genetic and physical landmarks in the Tetrahymena genome.

The newly-published genome sequence reveals that thousands of genes are common to both the protozoan and humans, thus confirming Tetrahymena as an important model organism for biomedical research. Surprisingly, the genome sequence shows the Tetrahymena genome contains over 27,000 genes, a number remarkably similar to the number of genes found in the human genome.

Orias has long been a strong supporter of undergraduate research. The systematic mapping of the Tetrahymena genome was started by UC Santa Barbara undergraduate student Jason Brickner (now an assistant professor at Northwestern), and continued by scores of other undergraduate researchers in Orias’ lab. Altogether, more than 60 UCSB undergraduates have worked on the genetic and physical mapping project since 1994.

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Nicola Spaldin, a professor in the Materials Department of the College of Engineering, and her collaborator, post-doctoral researcher Massimiliano Stengel, used quantum mechanical calculations to prove that a so-called "dielectric dead layer" at the metal-insulator interface is responsible for the observed capacitance reduction. Their work was published in the October 12 issue of Nature. "Our results provide practical guidelines for minimizing the deleterious effects of the dielectric dead layer in nanoscale devices," they say.

Gas escaping from the ocean floor may help us understand historical global warming cycles and provide information on current climate changes, according to a team of scientists here. The findings were reported in Global Biogeochemical Cycles in August.

Support for this idea occurred when divers and scientists from UC Santa Barbara observed and videotaped a massive blowout of methane from the ocean floor. It happened in an area of gas and oil seepage coming out of small volcanoes on the floor of the Santa Barbara channel — called Shane Seep. The blowout sounded like a freight train, according to the divers.

Atmospheric methane is at least 20 times more potent than carbon dioxide and is the most abundant organic compound in the atmosphere, according to the study's authors, all from UC Santa Barbara.

"Other people have reported this type of methane blowout, but no one has ever checked the numbers until now," said Ira Leifer, lead author and an associate researcher with UCSB’s Marine Science Institute. Leifer explained that when this type of blowout occurs, virtually all the gas from the seeps escapes into the atmosphere, unlike the emission of small bubbles from the ocean floor, which partially, or mostly, dissolve in the ocean water. Transporting this methane to the atmosphere affects climate.

Co-author Bruce Luyendyk, professor of marine geophysics and geological sciences, explained that, to understand the significance of this event (which occurred in 2002), the UCSB research team turned to a numerical, bubble-propagation model. With the model, they estimated methane loss to the ocean during the upward travel of the bubble plume.

The authors explain that these results show that an important piece of the global climate puzzle may be explained by understanding bubble-plume processes during blowout events. The next important step is to measure the frequency and magnitude of these events. The UCSB seep group is working toward this goal through the development of a long-term, seep observatory in active seep areas.

Scientists have discovered that parasites are surprisingly important in food webs. Their findings appear in a report published in July in the Proceedings of the National Academy of Sciences. Scientists with the University of California, Santa Barbara, the U.S. Geological Survey, and Princeton University contributed.

The report describes a study performed in Santa Barbara County at the Carpinteria Salt Marsh, one of several natural reserves set aside by the University of California for research and teaching.

Food webs trace the flow of energy through an ecosystem. They extend the concept of food chains — those who-eats-whom sequences — to biological communities. Food webs rarely include parasites because of the difficulty in quantifying them by standard ecological methods. Parasites are small and invisible, hidden inside their hosts. However, parasites strongly affect food web structure and parasite links are necessary for measuring ecosystem stability, according to the study.

"Food web theory is the framework for modern ecology," said Kevin Lafferty, a scientist with the USGS Western Ecological Research Center who is based at UC Santa Barbara and is lead author of the study. Using data from four relatively comprehensive food webs that contain parasites, Lafferty and his coauthors examined if and how parasites affected the food webs. They found that parasites dominated the food web links between species; on average, a food web contained more links between parasites and their hosts than between predators and their prey.

"Parasites may well be the thread that holds the structure of ecological communities together," said study coauthor Andrew Dobson of Princeton University.

"The work illustrates that 'the pyramid of life' we learn about in kindergarten is wrong," said Dobson. "When you add parasites to food webs, the pyramid contains a second inverted pyramid of parasites that are as abundant as all the other species."
Two young scientists here were featured among 35 of the top innovators in science and technology under the age of 35 in the 2006 edition of the "TR35" list, published in the Massachusetts Institute of Technology's Technology Review.

Jeffrey W. Bode, 32, assistant professor of chemistry, has developed a more versatile way to connect small protein snippets called peptides. The result could lead to a surge in the creation of protein-based drug therapies. Ben Zhao, 30, assistant professor of computer science, is working to make structured overlay information technology networks more secure by piggy-backing new networks on top of the Internet. His efforts could lead to practical networks that manage and heal themselves. The honorees are selected by the editors of the magazine in collaboration with a panel of judges from major institutions and corporations including Hewlett-Packard Labs, the Lawrence Livermore Laboratory, Caltech, and Applied Materials.

Tony Evans, a professor of Materials and Mechanical Engineering, was elected a Fellow of the Royal Academy of Engineering in recognition of his internationally-renowned research leadership in the micro-mechanics of advanced materials for aerospace and ship structures, including composites, multi-layers, sandwich panels, lattice solids, ceramics and interfaces.

Evans is recognized as a leader in advanced structural materials, a field with critical implications to the performance and reliability of systems in a broad range of technologies, including energy, transportation, information, communications and health. His interests include not only materials for structural systems, where their primary function is to support loads, but also those with other functionality (electronic, magnetic, optical and thermal) whose survivability depends on their ability to withstand stress without failing. He has made major contributions to the mechanics of interfaces and thin films, with applications as diverse as electronic packaging and high temperature coatings for metallic components in gas turbines.

Election to the Royal Academy of Engineering is by invitation only; up to 60 Fellows are elected each year from nominations made by existing Fellows. Based in London, its priorities are to enhance the UK's engineering capabilities; celebrate excellence and inspire the next generation; and lead debate by guiding informed thinking and influencing public policy.

Tony Evans and his colleagues choose the geometry of a multimaterial lattice structure. Geometric changes due to heating and cooling can be minimized so that the lattices can be used for the hot surfaces of hypersonic aircraft.

A UC Santa Barbara Physicist Shares the $250,000 Gruber Cosmology Prize for 2006. Philip M. Lubin, a professor of physics here, was recognized in August with the 2006 Gruber Cosmology Prize for his team’s groundbreaking studies confirming the “Big Bang” theory of how the universe was born.

Lubin is one of 19 members of what is called the Cosmic Background Explorer team, formed by NASA in 1979. The Cosmic Background Explorer was built at NASA’s Goddard Space Flight Center and launched in 1989. The instruments on board the explorer made possible groundbreaking studies of the spectrum and spatial structure of the relic radiation from the Big Bang and enabled the scientific team to look back over 13 billion years to the early universe.

An astrophysicist who joined the UC Santa Barbara faculty in 1987, Lubin is an authority on early-universe studies and has participated in many balloon-borne and South Pole-based studies of the remnant radiation from the early universe.

The Gruber Cosmology Prize is awarded in partnership with the International Astronomical Union. According to the award’s sponsors, the prize recognizes extraordinary scientific advances in our perception and understanding of the universe.
Glenn Fredrickson, professor of chemical engineering and materials here, has won the American Physical Society’s 2007 Polymer Prize. The prize, which recognizes outstanding accomplishment and excellence in polymer physics research, includes a $10,000 award.

In announcing the prize, the American Physical Society cited Fredrickson’s “insightful and predictive theories regarding the thermodynamics and dynamics of macromolecular systems.” The prize was established in 1960 and is now supported by the General Electric Company.

Guillermo C. Bazan, a professor in the Department of Chemistry and Biochemistry here, is a winner of the 2007 Cope Scholar Award, given by the American Chemical Society (ACS) to recognize and encourage excellence in organic chemistry. The citation for the award reads, “For his creative design of catalysts for the synthesis of commodity polyolefins and for the synthesis, study, and applications of organic molecules with delocalized electronic structures.”

Bazan and his team have demonstrated creative new designs for catalysts that convert cheap monomers derived from petrochemical products into valuable everyday materials, such as polyethylene or polypropylene. His group has also tackled several important questions concerning organic molecules with delocalized electronic structures. These are the building blocks for organic semiconductors, which can be used in emerging optoelectronic devices and highly specific biological sensors.

The award consists of $5,000 and a $40,000 unrestricted research grant to be assigned by the recipient to any university or nonprofit institution. The Arthur C. Cope Scholar Awards were established in 1984.

Joseph G. Polchinski, professor of physics at the Kavli Institute for Theoretical Physics here, has been named one of two winners of the 2007 Dannie Heineman Prize for Mathematical Physics given by the American Institute of Physics and the American Physical Society (APS).

The citation for Polchinski’s award reads, “For profound developments in mathematical physics that have illuminated interconnections and launched major research areas in quantum field theory, string theory and gravity.” The award was established to encourage further research in the field of mathematical physics. Since 1959, the prize has been administered jointly by the American Physical Society and the American Institute of Physics.

UCSB received a $2.75 Million NSF Grant for Research and Education in Materials. The College of Engineering has received a $2.75 million Partnerships for Research and Education in Materials (PREM) award from the National Science Foundation to partner with Jackson State University (JSU), in Jackson, Mississippi. The five-year grant is designed to accomplish two distinct but related goals: to develop and apply new materials research in organic semiconductors and optical nanosystems; and to focus on the education, training and mentoring of minority students and postdoctoral fellows, including developing a master’s program in materials at JSU.

This grant is one of six awards given to university partnerships designed to enhance minority participation in materials research, representing total funding of $15.4 million. The UC Santa Barbara partnership with JSU will focus specifically on 1) organic semiconductors based on small molecules or conjugated polymers which have potential applications ranging from electronic circuitry to flexible displays, and from solar cells to biological and chemical sensors; and 2) optical nanosystems that use laser-induced fluorescence techniques to detect DNA damage, RNA interaction and modification of nucleic acids.

An essential part of the grant includes developing hands-on undergraduate and graduate courses at JSU to prepare minority students to pursue careers in science; establishing an undergraduate Materials Science Interns program, and creating a two-year materials-focused master’s program at JSU which bridges to the UCSB doctoral programs in materials.

Written and reported by staff writers and editors, and by staff from the Office of Public Affairs.
Brain Food?

Scientists probe the connections between growth hormone, learning and memory.
It makes you taller, but can it also make you smarter?

That’s one of the questions raised by recent research on the brain and growth hormone (GH), the substance that stimulates cell reproduction and bulks up bone, muscle and other tissues. GH may not have the same direct impact on mental function as it does, say, on children’s height. It’s too soon to say when, if ever, it would be put to use in treating neurological disease.

But researchers have found links between the learning process and the production of GH in the hippocampus, a region of the brain crucial to learning and memory. GH levels also are affected by age, stress and the presence of estrogen. What’s clear is that the relation of growth hormone to the brain is more complex and intriguing than once believed.

It has only been a few years since scientists confirmed that any GH came from within the brain (rather than from its main source, the pituitary gland). A study published in 2002 showed that the production of GH in the hippocampus was stimulated when rats were put through a common learning experiment called eye-blink conditioning. “Before this paper, no one had actually reported that growth hormone is expressed in the brain at all,” says Kenneth Kosik, who co-authored the paper while on the Harvard Medical School faculty and who now heads the Neuroscience Research Institute at UC Santa Barbara. (He is also the Harriman Professor of Neuroscience Research).

Using new techniques to track gene activity, the 2002 study showed not only that the gene for GH was being turned on in the hippocampus but that this process coincided with successful learning. The rats that learned the conditioned response (blinking after a bell or a small electric shock) were the ones with heightened activity in GH genes. “We saw that the learning process leads to the production of growth hormone,” Kosik says.

Yet to be answered is the question of exactly how GH affects learning or learning affects GH. A second paper, authored by Kosik along with Christine P. Donohue of Harvard and Tracey J. Shors of Rutgers, offers an intriguing clue. Published in March in the Proceedings of the National Academy of Sciences, it shows how GH in the hippocampus rises and falls with estrogen levels during the estrous (reproductive) cycle in female rats. Estrogen also is associated with the growth of dendritic spines, the structures on neurons that transmit signals to and from other cells by way of synapses.

“No one knows the relationship between estrogens and the spines in a biochemical way. It’s just a correlation,” says Kosik. But it is known that the spine synapses play a key role in learning. In other words, estrogen or another factor, such as a growth-hormone receptor, may boost GH, which then enhances learning by stimulating the growth of spines and neurons.

If such a scenario holds true in further research, it would open up exciting possibilities for treatment of neurological diseases or injuries. Kosik’s research has started to stir up interest in the medical community -- after the 2006 paper appeared, he got an invitation to present it at an endocrinology conference, though he had to decline.

He cautions against raising hopes for usable drugs anytime soon, especially for Alzheimer’s disease. “In Alzheimer’s,” he says, “neurons are dying for reasons we don’t understand. It’s not clear if just plumping up these neurons with growth hormone would help.” But he sees more potential for GH treatment of congenital conditions such as autism, where the brain seems unable to process information properly and use it to interact with the rest of the world. “If growth hormone really has a role in learning and memory,” he says, “we can think about ways of delivering a growth-hormone agonist -- a drug that mimics GH -- to various parts of the brain to increase learning and memory.”

“Before this paper, no one had actually reported that growth hormone is expressed in the brain at all,” says Kenneth Kosik.
In an energy-hungry world, it may come as a surprise how much methane -- natural gas -- is flared off, burned off or re-injected each year because there's no market for it. Much of it is so-called "stranded gas" that is found in oil fields not linked to gas pipelines or in quantities too small to make conversion or storage economically feasible. In addition to gas that is truly stranded, there is coal bed methane and bio-methane from sources not large enough to justify a billion-dollar chemical complex. The volume of this neglected gas is huge, estimated at 20 trillion cubic feet per year. That's the energy equivalent of about two billion barrels of oil, roughly what the U.S. consumes from both domestic sources and imports in three months.

There is money in that methane if it can be turned into liquid fuels and useful chemicals. And no one needs reminding that petroleum products, gas and liquid fuels included, are in high demand. The trick is to come up with methods of turning the gas into salable products at a cost that makes economic sense.

That is the mission of Goleta-based GRT (Gas Reaction Technologies) Inc. Initially working through a sponsored research agreement with UCSB, GRT has developed a process that can convert methane to fuels such as gasoline or jet fuel and chemicals such as benzene, ethylene, acetone and various alcohols. It has formed strategic partnerships with major energy firms and will soon be building a pilot plant to give its technology a real-world test.

Specializing in Start-Ups

The company's CEO is Eric McFarland, a UCSB professor of chemical engineering who is on his third start-up. He earned a PhD in nuclear engineering at MIT and later joined the faculty. While a graduate student he was involved in a start-up company that designed and built the first permanent magnet based magnetic resonance imaging (MRI) unit. After joining the UCSB faculty in the mid-1990s, he and then-colleague Henry Weinberg helped start Symyx Technologies, a firm providing research services in combinatorial chemistry (Symyx eventually went public and now books over $100 million in annual revenue). McFarland also has an M.D. from Harvard. Up until recently he continued to practice medicine part-time in the emergency room, but now only has time to volunteer in a clinic in Mexico once a month.

So how did an MIT-trained nuclear engineer, Harvard-educated ER doctor get involved in methane conversion? His start-up experience was one reason. Another was the salesmanship of chemist and business executive Dr. Jeff Sherman, who founded GRT and put the initial UCSB research team together. "I was content to be a professor and didn't want to do another start-up," McFarland said. "But Jeff is very persuasive."

Sherman had already started GRT in 1999, as a spin-off from a Houston-based firm specializing in the re-refining of waste oil. His first UCSB contact was Galen Stucky, a professor of chemistry and biochemistry who had come up with a new way of making porous materials used for converting crude oil into lighter-weight products. He and Sherman got to talking, and Sherman said he was looking for an alternative to the syngas process -- the expensive conventional method for converting methane to gasoline and other liquids. "That's what started the project," Stucky says. The two worked out an agreement through which GRT would fund R&D work by UCSB as well as GRT employees, and the enterprise took off from there. UCSB Chemistry Professor Peter Ford came on board, along with post-doctoral researcher Xiao-Ping Zhau and, later, Engineering Professor Michael Doherty. McFarland started out consulting to the team and eventually took over top management duties.
Catalytic Magic

In 2001, the researchers had a breakthrough. They found that they could produce organic compounds (methanol and dimethyl ether) from methane by first activating the gas with bromine. This method proved capable of converting methane to a wide range of fuels and chemicals through the use of compounds (called “cataloreactants”) that can be reconstituted. This was crucial to the economic viability of the process, as Ford explains. The bromines and metal oxides used by GRT are expensive, and their cost would wipe out margins on a finished product if they could not be reused. “You can afford to use very expensive reagents that are not recoverable if you’re making Viagra or some other expensive drug that you can sell to a lot of people,” he says. “But you can’t do that with a bulk product like gasoline.”

Over the next three years, GRT continued its research, garnered eight U.S. patents and signed its first R&D agreement with a Fortune 500 company (unnamed here for business reasons) to commercialize its process. In 2004, it moved its laboratories and offices to Goleta, where it set up a 9,000 square-foot laboratory facility and built a 1 gallon-per-day reactor unit to produce test batches of liquid fuels. By 2005, its revenue from joint development programs was over $3 million. Over the next two years GRT will be working with strategic partners to build a pilot plant designed to produce approximately 10 barrels (420 gallons) of liquid fuel per day.

Start-ups are nothing new at UCSB. College of Engineering Dean Matt Tirrell estimates that 25 to 30 percent of his school’s faculty have been involved in them at some level, such as management, research or consulting. Several firms started by UCSB professors are going strong as subsidiaries of major companies. Alan Heeger, a materials professor and Nobel Prize winner, started Uniax to pursue the development of organic semiconductors and eventually sold it to DuPont, where it continues as DuPont Display. Nitres, Inc., started by Umesh Mishra and Steven Denbaars to develop gallium nitride for solid-state lighting, was bought in 2001 by the semiconductor company Cree, Inc. It now operates as Cree Lighting and is still based in Santa Barbara. Experticity, Inc., a developer of Web-based remote-access software started by computer science Professor Klaus Schauser, has been acquired by Citrix, Inc. and operates as Citrix Online.

The New Paradigm: Do It Yourself

“The activity is plenty here,” says Tirrell. “I can’t quantify it compared to other universities, but it really does reflect a change in the nature of engineering research in relation to industry.” In earlier times, such as when he was starting his research as a chemical engineer in the 1970s, Tirrell says professors could get their ideas into development by consulting to large companies such as DuPont and Dow Chemical. A professor would pitch an idea, and the company “would work on it for a month or two” to see if it showed promise. If it did, the professor would get another lucrative consulting contract. Academic researchers are much more on their own these days. Unless they have a “major, broad, good fit-in connection with a big company,” Tirrell says, “they have to take it a lot farther than they used to for commercial development.” They “start companies not for the idea of growing the company, but for developing the technology to the point where, a) somebody, usually a big company can see its potential and b) it’s packaged in such a way where the company can see what it is getting.”

As it moves forward on that track from idea to commercialization, GRT is maintaining its strong UCSB ties. “Something on the order of 75 percent of our employees are UCSB graduates,” says McFarland (the company has 21 employees in all). For his part, he is officially on leave from the university until next spring, but he continues to teach and do research at UCSB with his salary paid 100% by GRT. Meanwhile, the company is widening its horizons and its strategic partnerships. McFarland says it’s looking beyond stranded gas to biological materials, such as methane-producing plant matter and animal waste. GRT has entered into a joint technology development agreement with Cargill Inc. for the conversion of renewable feedstocks to higher value specialty chemicals.

McFarland doesn’t see GRT getting much larger that it is now. Rather, its role will be to develop new technology, participate with partners in commercializing it, and then license it. That suits his start-up style: “I’m much happier in companies as they grow from 1 to just over 20 people,” he says. “Then I’m done.”
Will Martinez moves in two different worlds. One is in Santa Barbara, where this UCSB-trained engineer works with a startup company on the development of micro-machines. The other is in the Peruvian village of Araypalpa, where Martinez’ father was born. Here the work is decidedly lower-tech – to produce electricity and clean water.

This mission and many others are being undertaken under the banner of Engineers Without Borders (EWB), a fast-growing network of students and professionals who volunteer in the developing world. “EWB projects are very different” from those in grad school, says Martinez, who earned his master’s in materials science at UCSB in 2005 and was founding president of the university’s EWB chapter. “You have to add the human factor, with a language barrier and a cultural barrier in between,” he says. But the effort pays off in benefits for both sides: A better life for the villagers and, for the engineers, the sort of practical knowledge that they would never have acquired in the classroom or lab.

UCSBB’s EWB chapter has been working in Araypalpa, a settlement of about 300 in the Andean highlands, for the past three years. It started in July 2004 when six students installed solar panels to provide lighting for two classrooms and performed water and sanitation assessments. The next summer, the chapter set up a pilot slow sand filtration system for the village’s water supply. Members returned to the village this year to make sure the system was working and to start a community library with solar-powered lighting.

The chapter has also done work in Thailand, where five of its members last year installed a septic system for a rural elementary school dormitory being built by another EWB chapter. Recently it designed a press that villagers in the African nation of Mali can use to extract oil from the jatropha nut for biodiesel fuel.

Above: Community and team members carry the filter tank up to the concrete pad behind the main water reservoir. Right: Community members review the slow sand filter they saw in another village with the town plumber.
Designing for Sustainability

All these projects share a common theme. They are designed not just to work when trained engineers are around, but to continue working long after the engineers have gone home. “What we're trying to do is build their capacity,” says Vared Doctori, a doctoral student in environmental science who manages the Peru project. “We don't want them to be dependent on us.” EWB focus on projects that can be operated and maintained by the local community without having to rely on imported spare parts or outside expertise. Also, she says, starting small has enabled EWB not just to hold down costs but also to train the villagers and test their ability to keep the system functional in the long term: “We only did a pilot” at Araypallpa “and made it very clear to the community that if you don't take care of it, we won't take care of it. Nobody will do it for you.”

The Mali project is a collaboration between the UCSB chapter and an EWB chapter of professional engineers in Minnesota. As in Peru, the challenge is to design something that can be made in Mali and maintained by local craftsmen. As is typical with EWB project, this one was first proposed to the national organization – in this case by Mali-Folkecenter, a non-profit group promoting renewable energy development – with local EWB chapters submitting proposals to complete the work.

Chapter co-advisor Dave Bothman, a lecturer and staff engineer in UCSB’s Mechanical Engineering department, says the project caught his eye because of its mechanical focus. “Most [EWB] projects focus on water, sanitation or energy, and none of these is particularly well-suited to mechanical engineering students,” he says. But this project was just right for that group, and a team of ME students started design work last year. “They looked at existing technologies in Mali and elsewhere for pressing Jatropha, and made improvements to what they thought was a promising design,” Bothman says. The Minnesota chapter is doing the final design of the press, and the UCSB students will be designing a machine that turns the Jatropha oil into a usable fuel. As with the press, the processing equipment must be appropriate for use in rural villages.
Learning Low-Tech Ways

For the students, the project is an education unlike anything they would get in a country like the U.S., where high technology and ultra-precise machine tools are taken for granted. “To us in the West, creating biodiesel seems like a very low-tech process,” Bothman says. “But in Mali, they don’t have the materials.” He adds, “We find that that the students really have to work hard to really understand what life in Mali is like” and to understand how the technology they’re designing “would work in a place that is so different.”

The UCSB team is planning a trip to Mali over the coming winter break to get a first-hand look at the manufacturing potential there.

The UCSB work in Peru was different from the typical EWB project. Instead of starting with a request from an outside group such as Mali-Folkecenter, it was the brainchild of an individual EWB member. The idea for it goes back to 2000, when Martinez was an undergraduate engineering student at Colorado School of Mines and the nation’s first EWB chapter was just getting started at the University of Colorado in Boulder. In that year he saw Araypallpa for the first time. His father was born in the village but left it for the city in his early teens. “He was always talking about it, but I didn’t visit it until 2000,” Martinez says. What he found there were wonderful people – “incredibly warm, very nice, and very welcoming” – with little wealth and some basic needs. Back in the U.S. he heard about the fledgling EWB, and he became involved with the University of Colorado chapter. In 2003, he worked with that group on a water and sanitation project for another Peruvian village. Arriving at UCSB that fall to start graduate work, he wanted to do something similar for Araypallpa.

As luck would have it, the idea of starting an EWB chapter had already caught on at UCSB. Mary Dinh, a staff engineer who serves as co-advisor with Bothman, says Bothman one day in October 2003 “was just wondering, if there’s a Doctors Without Borders, why can’t there be an Engineers Without Borders?” So he searched the Web and found that there indeed was such a group – and it was about to hold a conference, which Dinh proceeded to attend. Then along came Martinez, already active in EWB and eager to help the people of Araypallpa. “It was almost magically timely,” Dinh says.

Engineers Without Borders

Engineers Without Borders is a worldwide network of organizations working with disadvantaged communities to improve their quality of life through sustainable engineering projects and education, as well as broadening the experience of engineers, students and non-engineers. It currently has 14 national members, with another 30 provisional members being trained in overseas development work. The American organization, EWB-USA, was founded in Colorado in the fall of 2000. It now has 109 student chapters, 39 professional chapters and two regional organizations, one of which is EWB-UCSB. In October 2006, the UCSB chapter hosted the EWB West Coast Region Workshop.

Juan de Dios Castro, the multi-skilled town plumber, puts the finishing touches on the concrete pad.

UCSB staff engineer Mary Dinh hanging out with the kids.

Clockwise from top: Luke Bawazer, Yoram Doctor and Mary Dinh navigate their way through Lima.
Non-Engineers Pitch In

Since then, the chapter has drawn participants not only from the ranks of engineering staff and students but from other disciplines such as cultural anthropology and geography. Bothman says some non-engineers are interested in the new Mali project because they “want to make sure this isn’t another dead-end technology that gets exported to Africa,” while others “want to see the effect of this technology on local culture.”

The Peru project likewise has attracted an interdisciplinary team. Along with the engineering students, geography graduate student Lisa Murawski went to Araypallpa in 2005 to gather health data as a baseline for assessing the impact of the water filter being installed that year. With her was a cultural anthropology student making sure the project “was culturally OK” with the villagers. Another student trained the villagers how to monitor the water quality. These non-engineering tasks are integral to EWB work because they help ensure that projects are sustainable and produce measurable results. “If we can quantify changes, then we can actually say we have changed their life,” Murawski says.

One early chapter member, Vanni Lughi, recently graduated with a PhD in materials science. He managed the Thailand project as well one closer to home, designing a solar power system at a bath and shower building for workers on a farm near Santa Barbara. Now he helps the chapter with public relations and fund-raising—a key concern, since the chapter has to rely heavily on private donations to fund its projects and its members’ travel. “So far we’ve targeted small fund-raising sources,” Lughi says. Professors and other individuals connected to UCSB have come forward with contributions, as have local companies and Santa Barbara Sunrise Rotary Club, which contributes $1,000 a year. Chapter members hold tostada sales, and UCSB’s International Center for Materials Research (ICMR) has covered most of the chapter’s travel expenses so far (Lughi says students are expected to pay for 50% of their own travel costs up to $500).

The chapter wants to expand its horizons, and it sees the need for a wider range of funding sources. Chapter members can live cheaply once they get to their project sites—the Araypallpa team uses a room at the schoolhouse as lodgings, for instance—but getting there and back can be expensive. The annual Peru trips have each cost about $15,000, including materials, equipment and travel costs. Doctori, the Peru project manager, says travel to Mali could cost up to $2,500 per person; and projects typically involve between six and 12 chapter members. The chapter also would like to expand the water filter system at Araypallpa so that it serves the whole village. Doctori says that would cost $20,000 in materials alone. But the chapter’s record so far bodes well for its future. In just three years, it has gone from an idea to an organization that’s changing hundreds of lives for the better, thousands of miles away.
the blocks arrayed in hexagonal lattices. “The electronics people generally like square lattices because they tend to wire at right angles.” Another challenge is to maintain what Fredrickson calls “long-range order,” with a consistent lattice pattern over wide areas and every microdomain in its proper place. “The problem with self-assembly is that it’s easy to get imperfections,” he says, and that won’t do for nano-scale production. “If you’re trying to make a magnetic storage device, you want to know where your little magnetic dots are.”

“Wells” for Wayward Molecules

The control problem stems from the two-dimensional nature of the self-assembly process. Self-assembly in three dimensions – as in the formation of crystals – is stable and predictable. The geometry linking molecules is repeated faithfully throughout the finished product. But in two dimensions, as when self-assembling copolymers are deployed in a single-layer film, waves generated by the vibration of atoms introduce uncertainty into the process. As the self-assembly proceeds farther from its starting point, the more likely one will find deviations from the expected pattern.

This is where the top-down side of the new nanolithography comes into play. Kramer says the uncertainty can be reduced by keeping the self-assembly in a tiny space. “If I can divide the plane into small regions, I can improve the order,” he says. Using traditional lithography methods, the UCSB team divides a surface into “wells” about 12 microns across – a diameter equal to that of about 500 microdomains. Each of these regions functions as a self-contained factory and as a corral, with its potential for error limited by tight boundaries. “What we’re doing is using optical lithography to guide the formation of our two-dimensional crystal,” Kramer says.

Kramer’s role in the block copolymer project grows out of his specialty, polymer physics. It’s also part of an interdisciplinary division of labor. Though all the researchers play a part in various stages of the project, each

has a definite focus. Fredrickson and his group of students are the designers, trying to predict what shapes will emerge from particular types of block copolymers. “I am a physicist who does the paper and pencil work,” he says. Hawker is the working chemist. He and his group make the copolymers. Along the way, they are refining what once was a difficult and expensive process. “Reactions take place over hours, so you have to have control over the chemistry for this period of time,” says Fredrickson. “That’s proved to be a challenge in the past.” Kramer’s focus is on the physical properties of the compounds that come out of Hawker’s lab based on Fredrickson’s designs. “On our side, we’re trying to see if those block copolymers behave as predicted,” he says.

Catching on at Toshiba and IBM

Is the new method ready for market? In limited ways, it may be. In 2002, Toshiba scientists published a paper describing block copolymer self-assembly could be confined in spiral-shaped grooves to make high-density magnetic recording discs. IBM researchers have used a similar approach, called “templated self-assembly,” to build flash memory devices. Block copolymer lithography has yet to advance beyond these applications into high-speed and high-density uses such as content-addressable memory. It is also competing with other methods (such as imprint lithography, in which a pattern surface is stamped on a wafer) and with engineers’ efforts to squeeze more performance out of optical lithography.

But Hawker says the self-assembly model potentially has a huge economic edge. Instead of trying to push $20 million-plus photolithography machines to new levels of performance, he says chip makers could etch nano-scale circuits with nothing fancier than $5,000 ovens. Most of the hard work will have been done by the copolymers – and, of course, by researchers such as Hawker, Fredrickson and Kramer, striving to harness the science of self-assembly.
This is a conceptual illustration of a mixed micelle of lipid-conjugated peptides, being explored in the Tirrell group as possible artificial proteins.