MITMECHE

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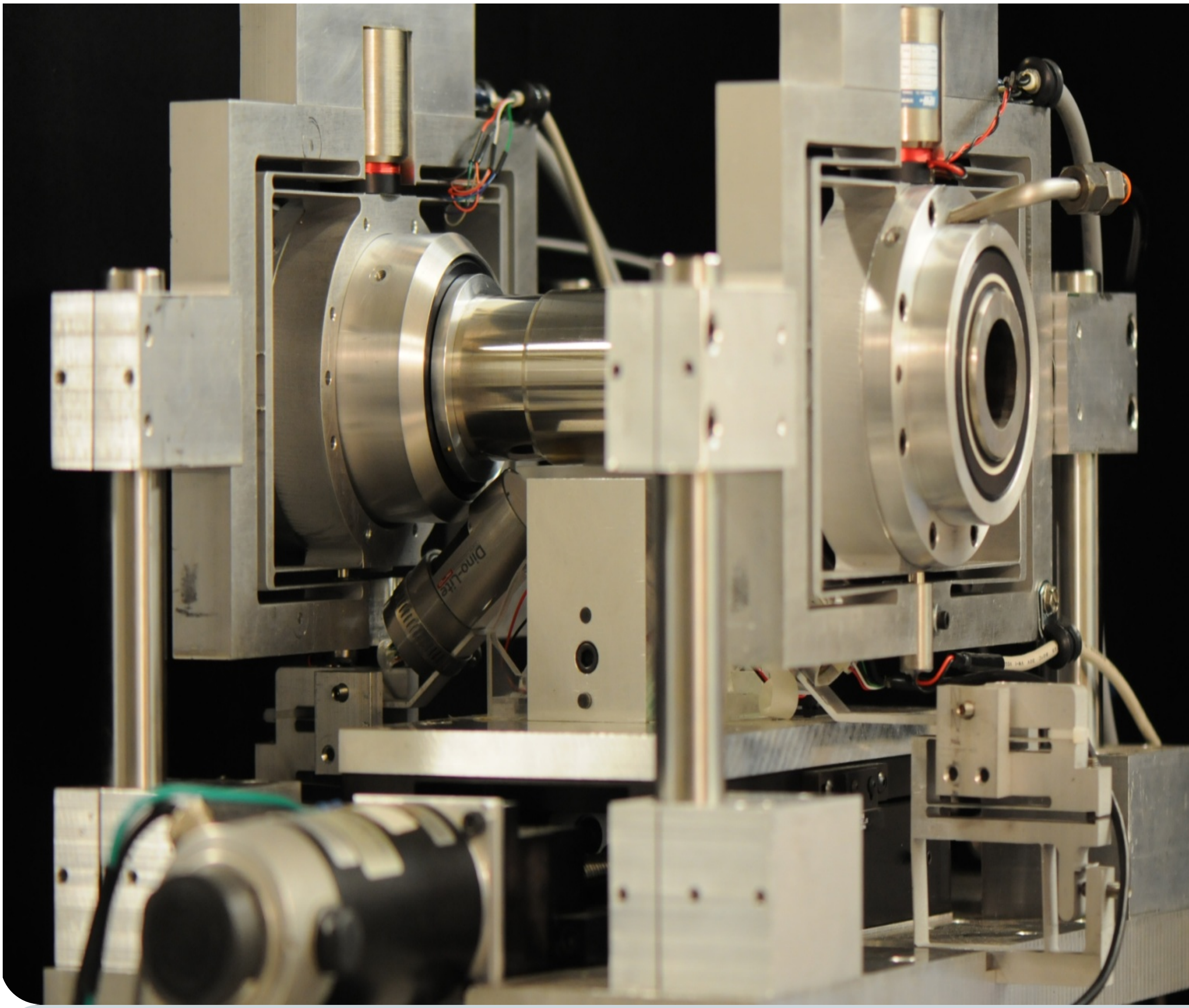
MechEConnects

News from the MIT
Department of Mechanical Engineering

In This Issue:



This is Not Your Grandfather's Manufacturing: A Renaissance in US Manufacturing

Despite claims that US manufacturing is on the decline, MechE faculty and students continue to prove otherwise...
| ► p. 4 |

A Manufacturing Renaissance

Dear Friends,

Manufacturing has consistently been an integral part of the Department of Mechanical Engineering. From the innovative research into metal cutting and machine tool design by professors Milton Shaw and Nathan Cook in the 1950s and '60s, through Nam Suh's establishment of the MIT- Industry Polymer Processing Program in the 1970s and the foundation of the Laboratory for Manufacturing and Productivity (LMP) in 1977, the department has long been devoted to exploring new frontiers in manufacturing research. Today, we continue this tradition by offering a Masters of Engineering in Manufacturing (MEngM), a degree that produces technically exceptional leaders for industry, and by offering an unparalleled number of hands-on learning and research opportunities for all our students.

Manufacturing stands at the crossroads of innovation, design, and commerce. Core engineering principles can be brought to bear to invent and improve manufacturing processes, but the ever-changing commercial demands of manufacturing also create opportunities to expand fundamental knowledge in engineering. This mutually beneficial relationship between research and commerce propels both industry and academia forward.

As a department, we teach product design and manufacturing in the spirit of MIT's motto, *mens et manus*. Students are asked to fabricate tools and products in a variety of courses, such as Toy Product Design (2.00b), Design and Manufacturing I and II (2.007 and 2.008), Product Design and Development (2.739 and 2.009), Precision Machine Design (2.75), Elements of Mechanical Design (2.72), Engineering Systems Development (2.014), and Manufacturing Processes and Systems (2.810). The products they produce in these classes are effective solutions to real markets and problems, and in many cases go on to be produced commercially. This focus on building our tools and designs is a hallmark of mechanical engineering education.

Our commitment to improving manufacturing extends beyond the department. On the Institute level, MIT President Susan Hockfield has created an interdisciplinary commission called Production in the Innovation Economy (PIE) to evaluate production capabilities in domestic manufacturing. Professors David Hardt, Sanjay Sarma and I serve on this commission. On a national level, when President Barack Obama called for the creation of a partnership between universities and industry to spark a "renaissance in American manufacturing," he recognized MIT's leadership in this field by appointing Susan Hockfield as the co-chair.

In this issue, we highlight the reciprocal relationship between manufacturing research and commerce. You will read about the challenges posed by manufacturing on the nano-scale and the innovative solutions that allow for the fabrication of increasingly smaller devices and tools. We also present novel approaches to making existing manufacturing "better"—lowering defect rates, designing more efficient tools, improving automation and controls, identifying new and better-suited materials from which to build, and determining how to increase energy efficiency and reduce emissions through the entire lifecycle of a product.

For more information on our faculty's areas of research focus, I invite you to visit our new interactive faculty grid at http://meche.mit.edu/people/cloud.

Sincerely,

Mary C. Boyce, Ford Professor of Engineering and Department Head

Massachusetts Institute of Technology

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► mecheconnects.mit.edu

About MechE

Mechanical engineering was one of the original courses of study offered when classes began at the Massachusetts Institute of Technology in 1865. Today, the Department of Mechanical Engineering (MechE) comprises seven principal research areas:

- **Mechanics: modeling, experimentation, and computation**
- **Design, manufacturing, and product development**
- **Controls, instrumentation, and robotics**
- **Energy science and engineering**
- **Ocean science and engineering**
- **Bioengineering**
- **Nano/micro science and technology**

Each of these disciplines encompasses several laboratories and academic programs that foster modeling, analysis, computation, and experimentation. MechE educational programs remain leading-edge by providing in-depth instruction in engineering principles and unparalleled opportunities for students to apply their knowledge.

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US Manufacturing: A Modern-Day Renaissance

by Alissa Mallinson

PhD candidate Adam Paxson (left) points to a live display of a condensing surface to Professor Kripa Varanasi (center) and postdoctoral researcher Sushant Anand (right).

On the surface, it would seem like manufacturing in the US is all but dead and gone.

But take a closer look—at the approximately 11% US gross domestic product (GDP) from manufacturing, or the US's sustained lead in global manufacturing (20% of global manufacturing value added [MVA]), for example —and you just might have a change of heart.

In the Department of Mechanical Engineering, manufacturing has been a part of our DNA since the creation of our first lab in 1874 with the donation of a steam engine—all the way to 1977, when MechE Professor Nam Suh created the interdepartmental Lab for Manufacturing and Productivity (LMP), to which many MechE professors currently belong, including Assistant Professor Tonio Buonassisi; Professor Jung-Hoon Chun, director of LMP; Associate Professor Martin Culpepper; Professor Timothy Gutowski; Professor David E. Hardt; Professor Sanjay E. Sarma; Professor David Trumper; and Associate Professor Kripa Varanasi.

Today, MIT continues to lead in manufacturing, spearheading in-depth research and analysis on the subject just as it did with 1989's industrial productivity report *Made in America*. When President Obama recently expressed his commitment to spark a "renaissance in [US] manufacturing," he called on MIT President Susan Hockfield to co-lead a government program called the Advanced Manufacturing Partnership (AMP) (see page 13), tasked with the goal of sparking such a resurgence. Here on campus, President Hockfield has commissioned a group of faculty to assess the state of US manufacturing, initiating the Production in the Innovation Economy (PIE) project (see page 10). PIE is a cross-disciplinary look at how to optimize production capabilities in the US for competition

Professor Kripa Varanasi

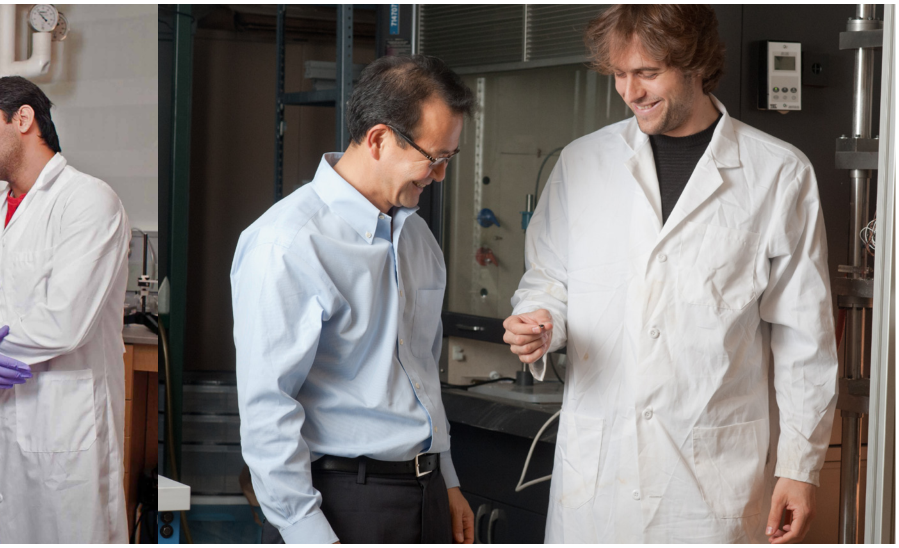
Most people do not give surfaces a second thought, but for Professor Varanasi, they form the basis of everything. His days working at General Electric taught him how crucial a surface can be.

"One of the areas where I saw significant challenges was interfaces," says Varanasi. "Every phenomena happens on a surface. Whether it be energy transport or mass transport, everything happens at an interface between two materials."

When Varanasi came to MIT, one of the first things he did was address the classic 100-year-old problem of moisture-induced efficiency losses in steam turbines. To solve it, Varanasi developed a completely new class of highly non-wetting super slippery multi-structured liquid coatings that repel water droplets that impact or condense on the surface, thus preventing moisture from forming on blades. He says that the coating can be applied using the existing coating equipment by simply modifying the processes and materials, thus opening up retrofitting opportunities at every level of the value chain.

Conversely, Varanasi's super wetting coatings combat the opposite problem of surfaces so hot that vapor forms over them and repels any water, such as that used for

Graduate student Aron Blaesi shows a coated pharmaceutical pill produced by his experimental apparatus to Professor Jung-Hoon Chun.



in the global marketplace, with a focus on innovation, incubation, technological advancement, education, and partnerships. Professor Hardt, Professor Sarma, and Ford Professor and Department Head Mary C. Boyce sit on the commission. These two programs posit that not only is manufacturing still alive and well in the US, but it is imperative to a healthy economy, national security, innovation, and sustainability. PIE in particular is looking at such trends as mass customization, distributed manufacturing, and global supply chains, and analyzing the production capability opportunities that could arise from scaling up.

"The one who is manufacturing the great ideas is the one making the money," says Professor Hardt. "So I look at it and wonder, how could you ever have an economy without manufacturing?

"Several popular startup companies with innovative products had to

►

cooling purposes. It's precisely the situation that can cause such power plant disasters as the one that occurred in Fukushima, Japan in 2010. Varanasi and his group have developed new nano-engineered, multi-structured highly wetting coatings to solve this problem. At temperatures greater than 400 degrees Fahrenheit, he is able to get the water droplets to anchor to the surface.

◄

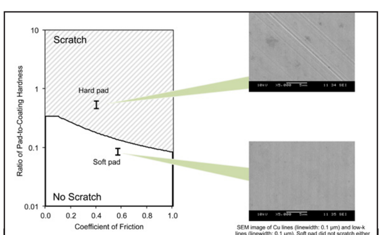
Professor Jung-Hoon Chun

Professor Jung-Hoon Chun, the director of MIT's Lab for Manufacturing and Productivity, began his work with the invention of uniform metal spheres, called solder balls, used for electronics packaging. Now he works with faculty from the Department of Chemical Engineering in the Novartis-MIT Center for Continuous Manufacturing. His research focuses on the continuous downstream manufacturing processes (blending, forming, and coating) of solid pharmaceutical dosage forms. He and his interdepartmental team have developed a patent-pending continuous process to lower the cost of manufacturing pharmaceutical pills.

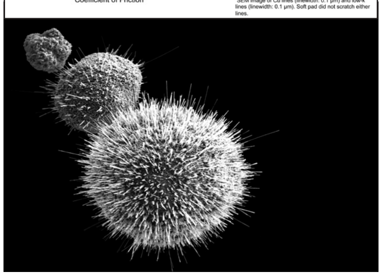
At the same time, Chun is also focused on solving yet another electronics manufacturing problem: semiconductor chip defects. These chips are made layer by layer, each requiring planarization in order to accommodate the next layer.

"As the critical dimension in semiconductor chips becomes smaller and smaller to the nano-scale, the need for accuracy becomes greater," he says. "And at the same time, the materials are changing too. But the new materials used in the semiconductors are more easily scratched as they are being planarized by the chemical-mechanical polishing process. This causes defects in the chips."

Chun is conducting fundamental research to understand how scratches are formed as the oft-used copper and low-*k* dielectric materials are polished for planarization. He is also designing a new process to eliminate scratch defects, with the hope of significantly decreasing the cost of production.



SEM image of Cu lines (linewidth: 0.1 μm) and low-k lines (linewidth: 0.1 μm). Soft pad did not scratch either lines.



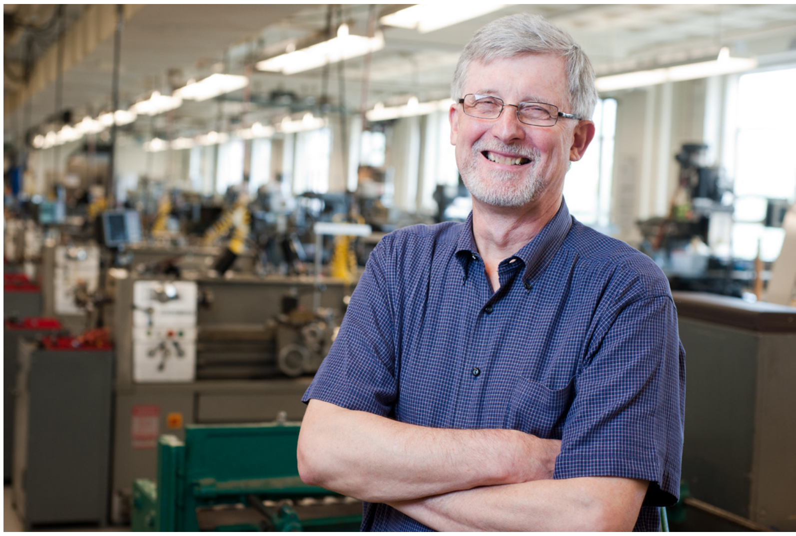
Professor Timothy Gutowski

While many engineers are looking for ways to increase cost efficiency in manufacturing, Professor Timothy Gutowski focuses on an oft-overlooked type of manufacturing efficiency: energy. He looks for ways to reduce emissions by taking a product's complete lifecycle into account.

Sometimes, the most obvious way of reducing energy by remanufacturing does not work as well as people expect. For example, in studies published recently in his new book *Thermodynamics and the Destruction of Resources*, Gutowski found that when the entirety of a product's lifespan is calculated in energy cost—instead of looking only at the manufacturing phase—creating a new, greener product from scratch is sometimes more energy efficient than remanufacturing an older, less-efficient one. The older one is less energy efficient overall, thus canceling out any energy advantage gained during manufacturing. This does not make him the most popular guy on the block, he says—and yet his group's research is critical to our long-term sustainability.

Gutowski has created a systematic process for determining the total energy cost of various manufacturing practices based on thermodynamics. He measures mass, energy interaction, heat interaction, and fuels, among other things, using a lifecycle energy analysis he developed based on the Second Law of Thermodynamics. As a result, he is able to get a full, comprehensive view of the energy use by looking at individual pieces of the lifecycle.

"When I first started out doing these types of analyses," he says, "I was trying to understand the smallest pieces. But little bit by little bit, we worked our way up to the bigger picture. Of the many moving pieces in manufacturing, it turns out that there are only a few that dominate energy use and carbon emissions—and they can be used to gain insight into the challenges we face."



Professor Gutowski stands in the Lab for Manufacturing and Productivity's machine shop.

immediately relocate offshore to manufacture their products—not because of cost or taxes, but because we did not have the capacity or capability to do it here in the US," he continues. "Those companies had no choice but to go offshore for their production."

"Without manufacturing," adds Professor Chun, "we would have service with little value. You need both together for success."

Economics is not the only concern. Many academics have also noted a crucial link between manufacturing and innovation. PIE is interested in analyzing the relationship between innovation and production in countries with strong export performance and manufacturing sectors. They believe that those who are manufacturing a particular product are also the ones inventing new and better ways to make it.

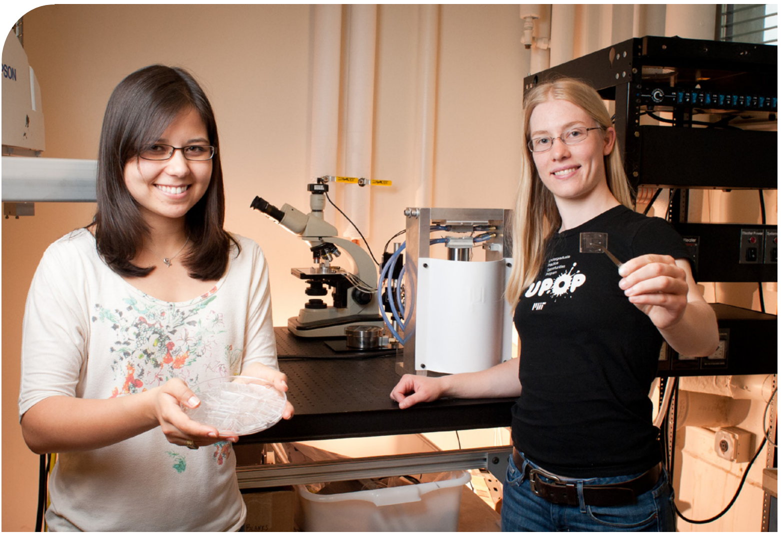
"A lot of innovation in the US happens as a result of manufacturing," says Professor Varanasi. "Many new ideas come from talking with engineers on the field and the folks on the shop floor. That is why it is so important for the US to continue manufacturing. If we lose it, we will lose research and ultimately innovation. Then we will no longer be a high-tech country. Manufacturing is important from every perspective—new jobs and national security, as well as maintaining our way of life."

"The fear is that if you lose manufacturing, you lose the ability to invent," adds Professor Sarma.

Manufacturing in the 21st Century

Of course, US manufacturing has progressed rapidly in the past 30 to 40 years, in large part due to game-changing inventions such as computers, automation, and micro manufacturing that have led to a more agile industry.

New information-sharing and automation technologies such as three-dimensional scanning (read more on pages 24 and 26) and nano-scale reliability testing (see sidebar) allow hyper efficiency and precision we could not achieve previously. The PIE project is currently studying the potential of advanced materials



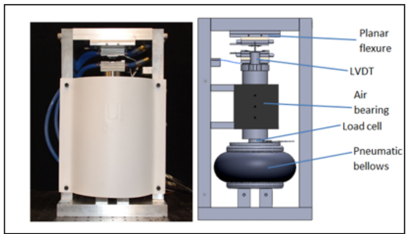
Master of Science students Caitlin Reyda and Maia Bageant show off microfluidic devices produced and tested by equipment of their design and construction.

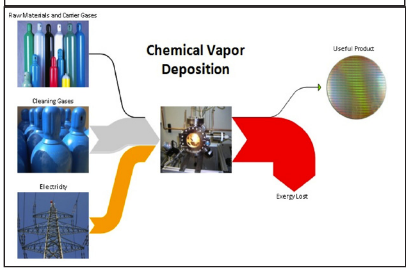
and new production technologies to "achieve radical increases in distribution efficiency, energy efficiency, flexibility, and overall productivity."

In response to these advances, consumers are demanding ever-increasing speed and accuracy. Such progress has also created considerable global competition. There is no longer room for experimental approaches of the past. In order to compete in today's marketplace, production processes require speed, accuracy, and consistency. And the workforce needs to be able to meet the demand—both the workers on the shop floor as well as the engineers behind it.

"One of the biggest changes I have seen is the way people understand the whole system of manufacturing," says Hardt. "It is important to know how it all fits together: what parts to make, how to design them properly, how to make them the same continuously, how to deliver them to the right place, and how to change things quickly if need be. It is exciting because it is very real and fast-paced, but by the same token, it is very unforgiving if you mess up. Mass production still exists, but it is much more agile than it used to be."

We have started to answer the question of "how?" but the question of "what?" still remains. What should the US manufacture in 2012? To answer that question, we will look to critical forthcoming data from AMP and PIE that are expected to identify advanced manufacturing as a potential option.





Professor David E. Hardt

For Professor David E. Hardt, it is all about the perfection of every piece. Taking production processes— specifically for hot micro embossing and large-scale production of microfluidic devices—from good to great using automation and process control is the focus of his current research.

"The cost and productivity of making microfluidic devices were not issues until it became a product that could have mass distribution," he says. "Now you have companies that want to make millions of these a year at low cost and high quality, taking it from a laboratory curiosity to a true manufacturing challenge.

"The method for creating a few prototypes is completely different from mass production—the materials are different, everything is different," he adds.

This means looking at embossing amorphous polymers such as PMMA instead of the typical casting of PDMS or conventional injection molding. It also means looking at fundamental issues of precision machine design, and even micro-scale tooling manufacture.

In all cases, Hardt and his group are focused on modeling and control to produce a superior automated process that can identify errors and fix them automatically in real time.

"Our recent work has been on design and control of low-cost, high-quality embossing machines. We have a mini factory in our lab to do real-volume production testing, to measure quality and to determine which factors in the machines and materials will influence the process for maximum performance."

Masters of Engineering in Manufacturing:

An Engineering Mind and A Business Savvy

by Alissa Mallinson

With technological advances pervading almost every aspect of business, we all know by now how important it is for business people to understand technology. But what about the other way around?

People often overlook that it is just as important for manufacturing engineers to understand the business context of their technological advances, whether they be process-, design-, material-, or operations-based.

This is not the case in MechE. Not only does the Department of Mechanical Engineering offer individual hands-on undergraduate courses such as Design and Manufacturing I and II, Product Engineering Processes, Toy Product Design, and Precision Machine Design (with a focus on biomedical devices design), we also offer graduate students the opportunity to focus specifically on professional manufacturing practice with the Masters of Engineering in Manufacturing (MEngM).

Ralph E. and Eloise F. Cross Professor of Mechanical Engineering David E. Hardt explains, "To do manufacturing properly requires much more than any one discipline or area of mechanical engineering, and it is not even limited to this one department. So it is really hard to do effectively at an undergraduate level, and in fact we have never had an undergraduate degree in manufacturing at MIT. As a result, most companies hire mechanical engineers and then through on-the-job training teach them to be manufacturing engineers, and that is in essence what we are doing with the MEngM. We are condensing and formalizing that experience."

The MEngM, which first began in 2001 as a master's degree in the Singapore-MIT Alliance program, has graduated approximately 400 students since its inception. The 12-month professional degree program is specifically designed to teach a broad systems-based understanding and a level of technical excellence for manufacturing leadership in any industry, as well as business communications, conflict resolution, and project scoping. It emphasizes math- and science-based methods for analysis, design, and operation of manufacturing enterprises while developing an understanding of global manufacturing business strategies. Each student takes eight required classes with a cohort of 12 to 25 fellow students over two semesters.

"With this program, we are attracting a different type of student than is normally attracted to other master's degree programs in mechanical engineering," says MEngM Director and Research Scientist Dr. Brian Anthony. "These students love engineering, but they are more interested in product realization than research—understanding how to design a product, manufacture it, and deliver it." ►

"These students love engineering, but they are more interested in product realization than research."

-Dr. Brian Anthony

"I get really excited about the MEngM program because it is so desperately needed in manufacturing. It fills a tremendous void."

-Professor David Hardt

There are five important pillars of the program's degree curriculum: 1) manufacturing physics, including processes, machines, assembly, and process control; 2) manufacturing systems, including factory design and control, and supply chain design and control; 3) design and manufacturing, including design for manufacturing and product development process; 4) management and global manufacturing, including management for engineers and global manufacturing. And the fifth and arguably most crucial—and unique—element of the program is the company-based on-site group project. For eight of the 12 months of the program (full time in January, part time in the spring, and full time all summer), groups of three to four students work at a partner company to solve an immediate problem.

"These students are trained engineers that go into these partner companies as outside experts with enthusiastic and fresh perspectives," says Anthony. "Companies don't work with us out of the goodness of their hearts; to appropriately educate our students, we require real problems that are going to impact the bottom line, so that the students will be in the critical path of problem evaluation and solution implementation.

"This project is the hallmark of the degree," he continues. "It forms the basis for their thesis but also provides the context to immediately apply classroom learning."

There are other programs at MIT addressing the intersection of business and engineering, such as the Leaders for Global Operations (LGO) program—a joint program between Sloan School of Management and the School of Engineering. But unlike those programs, which approach the issue from the business side, the basis for the MEngM is engineering, with a focus on manufacturing.

"I get really excited about this program because it is so desperately needed in manufacturing," says Hardt. "It fills a tremendous void for MIT and for industry."

Production in the Innovation Economy

MIT Faculty See Promise in American Manufacturing

by Peter Dizikes, MIT News Office

Not long ago, MIT political scientist and faculty member Suzanne Berger was visiting a factory in western Massachusetts, a place that produces the plastic jugs you find in grocery stores. As she saw on the factory floor, the company has developed an innovative automation system that has increased its business: Between 2004 and 2008, its revenues doubled, and its workforce did, too. Moreover, the firm has found a logical niche: plastic jugs produced stateside. Since these jugs are both bulky and inexpensive, it is not economical to produce them overseas and ship them to the United States, simply to fill them with, say, milk or syrup.

"Is this just an odd little story?" Berger asks. "Actually, no." While the decline of American manufacturing has been widely trumpeted—manufacturing jobs in the United States have dropped from 20 million in 1979 to about 12 million today—conglomerates such as Procter & Gamble and high-tech firms such as Dow Corning have kept significant amounts of manufacturing in the country. Moreover, 3,500 manufacturing companies across the United States—not just the jug-making firm in Massachusetts—doubled their revenues between 2004 and 2008.

With that in mind, Berger asks, "How can we imagine enabling these firms to branch out into more innovative activities as well?"

That is the kind of problem Berger and 19 of her faculty colleagues at MIT, including Department Head and Professor Mary C. Boyce, Professor David E. Hardt, and Professor Sanjay E. Sarma, are now studying as part of a two-year Institute-wide research project called Production in the Innovation Economy (PIE), which is focused on renewing American manufacturing. The guiding premise of PIE is that the United States still produces a great deal of promising basic research and technological innovation; what is needed is a better sense of how to translate those advances into economic growth and new jobs.

That question is currently at the forefront of MIT's concerns as well. Institute President Susan Hockfield is serving as a co-chair of the steering committee of President Barack Obama's Advanced Manufacturing Partnership (AMP), which in June will give policy recommendations to the White House about renewing American manufacturing. PIE is not a subset of AMP, but arises from similar concerns about applying technology in the national interest. ►

Find out more ►

Read the full MIT News article:
http://web.mit.edu/newsoffice/2012/manufacturing-pie-overview-0125.html

In the course of conducting its research, PIE will issue an interim report later this spring; publish a final report in 2013; create a film on manufacturing; host a lecture series; and issue a working-paper series of research findings from the professors on the team.

PIE focuses on specific questions that may cut across a multitude of industrial sectors, and has organized its work into eight distinct "modules" that cover a diverse set of issues, ranging from the challenges of scaling up small startups to the problems of training workers.

Like IT or not?

In so doing, PIE is also broadly scrutinizing a common assumption of the last quarter-century: that the information technology industry is the basic paradigm for innovation-based manufacturing in the United States. "Some people think we can just do the innovation, and then license and sell and outsource it," Berger notes. By contrast, she says, "those of us in the PIE study think it is an open question whether a similar model works elsewhere, particularly in the new emerging-technology areas."

Information technology companies often have low startup costs covered by venture capital, and their production tasks lend themselves to being handled overseas. But in other areas with advanced-manufacturing potential, such as energy, advanced materials or biotechnology, "you are going to need far heavier capital investment," Berger says. It is not obvious how such companies can best finance the development and commercialization of their products.

One of the PIE modules will also examine the effects of manufacturing —and the loss of manufacturing jobs —on other industries. Manufacturing is widely viewed as an industry that creates additional jobs besides those on the production lines; factories create a need for additional service-industry workers. Additionally, the income earned by manufacturing workers creates demand for still more goods and services.

The factory visits that Berger and her colleagues have been making for PIE underscore that point. On a recent visit to a company that makes equipment pipes and tanks for biotechnology companies, she found that a quarter of the company's revenue comes from repairing and servicing the equipment. "What we are discovering is that this connection between manufacturing and services is an integral one," Berger says. "A set of capabilities is gained in making products that then get redeployed in the service part of a business."

Ultimately, the PIE researchers may have many more such discoveries ahead of them—and may need them, to help chart the possible paths for new success in manufacturing.

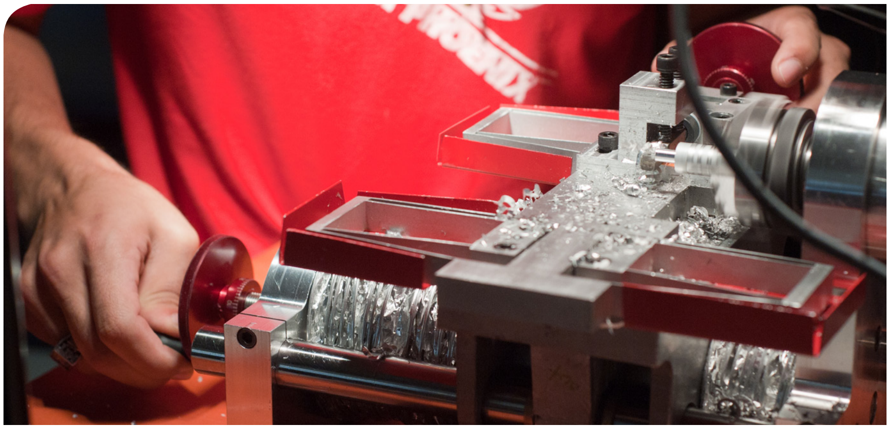
From top to bottom: De Florez Awards Competition, 2.007 Robot Competition, 2.72 final lathe presentations, classroom.

Student Snapshots

Course 2.72 Elements of Mechanical Design

“Mens et Manus” At Work

by Alissa Mallinson



Most courses don’t end in a death test, but Course 2.72 Elements of Mechanical Deisgn isn’t a typical course, even for mechanical engineering.

One of the last undergraduate courses mechanical engineering students can opt to take at MIT, “this class integrates all the other studying they’ve done up until now,” says the course’s instructor, Professor Martin L. Culpepper, who radically updated the class when he took it over several years ago. Now, in the place of problem sets is considerably more hands-on building, most notably of a working lathe, the main project of the semester.

“The students need to apply all the theoretical and mathematical knowledge they’ve acquired along the way,” he says. “Success only comes with a judicious combination of theory, simulation, and experimentation.”

The students know it will be a difficult final course, and yet many say it is one of their favorites.

Graduating senior Marcel Thomas says, “For me, 2.72 was such a great class because the instructors [Professor Culpepper, Bill Buckley, and Dave Brancazio] provide a balance of freedom and guidance. They will always point you in the right direction if you get lost or start falling behind, but they will not hold your hand.”

Upcoming senior Laura Matloff adds, “2.72 is the class that has best prepared me for work in the ‘real world.’ It brought together the principles from the other mechanical engineering courses that I have previously taken at MIT and showed me how to apply the theory to design something that functions not only well but consistently.”

The course is a combination of lecture and lab, geared toward helping the students hone their ability to create new machines, take them apart, and put them back together again, including a cordless screwdriver, a lawn mower engine, and a lawn tractor transmission. It requires a different approach than in some of the other hands-on mechanical engineering courses—such as 2.007 Design and Manufacturing I, 2.009 Product Engineering Processes, or 2.00b Toy Design Lab—because it focuses more on utility than design.

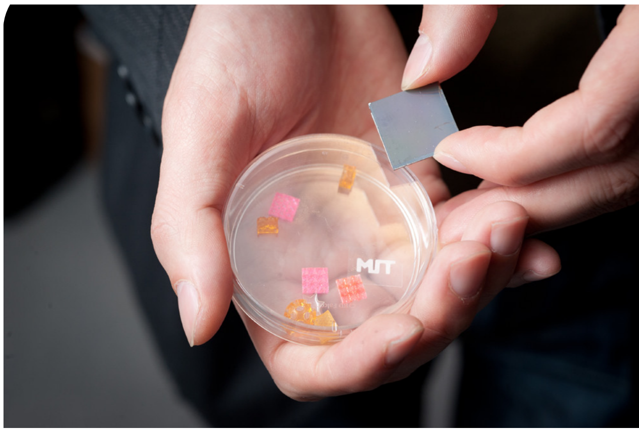
Students’ final grade hinges on their team designing and building a functional, fast, and practically indestructible lathe that works again and again. To help teach the students how important it is to make machines that *last*, Professor Culpepper performs a death test on the student-built lathes as part of the final challenge, which also includes a competition to see whose lathe can work down a steel rod the fastest.

“It’s one thing to build a machine that only has to work once, but it’s yet another to build a machine that can handle multiple uses. That’s why we do the death test. I drop the lathes on the ground, deliver impact with a hammer, and so on. The best lathes are the ones that are strong, work well, and don’t waste time with bells and whistles.”

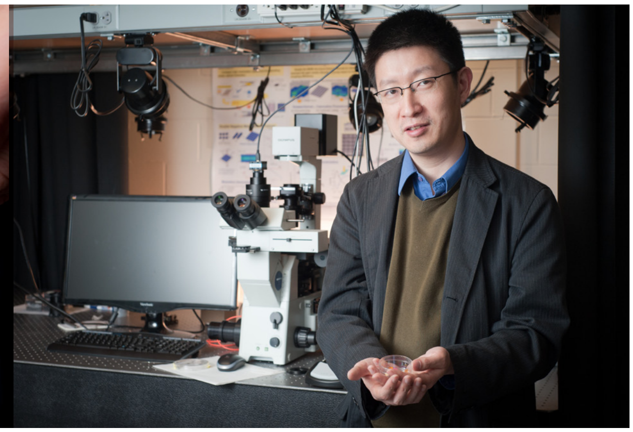
Printing in Reverse

Professor Nick Fang Explores Etching at the Nanoscale

by Alissa Mallinson



Using electrochemical and optical processes, programmable meta-materials, composed of functional micro- and nanostructures, are prototyped at Fang's lab for applications such as reducing thermal expansion, trapping, and steering waves.



Fang's group studies manufacturable components and devices for concentrating light at the nanoscale. Their applications span from imaging to energy conversion.

Have you ever wondered how your favorite DVD was created?

Nanostructure printing on plastics and polymers is nothing new. But what about on metal or glass—for electronic circuit boards, for example?

"Electrochemical machining works on the micro scale," says Nicholas X. Fang, the d'Arbeloff Career Development Associate Professor, "but not yet on the nano scale. The requirement is 100 times off, because if you try to apply a voltage across liquid and metal, it spreads out and smears small features."

Fang and his group searched for harder materials to print on for use in electronics, photonics, and fiber optics (his expertise is in nanophotonics and nanomanufacturing), but in the process they discovered something entirely new. Instead of creating an impression on polymer, as happens with pressing, the group developed a process of etching that allows for nanoscale-level precision on hard materials. It is also a speedy, low-voltage process.

Etching occurs when a solid stamp is covered with an electrode that connects to the positive pole of a battery, while the material to be etched is connected to the negative pole. When the circuit is switched on, the electrons are repelled from the material, leaving active ions on the surface. These ions are then pulled toward the positive electrode in the stamp, leaving an empty space where they used to be in the pattern of the stamp.

The materials for both the stamp and the material are of the utmost importance, requiring specific electrochemical and mechanical properties to allow the etching to occur. The group's favorite is Nafion (an ion-conducting polymer commonly used in batteries and fuel cells), because it can incorporate several types of ions and chemical species.

Fang says, "We have to select the stamp materials based on particular electrochemical and mechanical properties, since we want to shape the stamps with fine nanostructures and maintain their geometry against wear and tear from extended use. That limits the type of materials suited for the stamps, but we are fortunate to have found several that meet our needs. We are still learning tricks from chemistry to expand the list."

According to Fang, they can print down to 20 nanometers, about 1,000 times smaller than the width of a hair, on curved surfaces (including fibers) ►

as well as flat surfaces, at a rate of up to tens of nanometers per second. That means films of several microns thick can be etched in a few minutes.

"It turns out that this process does not rely on hardness of the materials being etched, unlike the counterpart, chemical-mechanical polishing, which does not work well for copper in particular," he says. "So we have reduced a process that can take up to 8 hours to a couple minutes."

A major result of Fang's discovery is the ability to print metal circuit boards at the nanoscale, which previously could only be accomplished on the microscale. Another application is in the area of photonics. "One thing we could now do is selectively enhance the reflection of an infrared wavelength, which we can use to create a smart window that rejects heat in summertime and absorbs more heat from the sun in winter time."

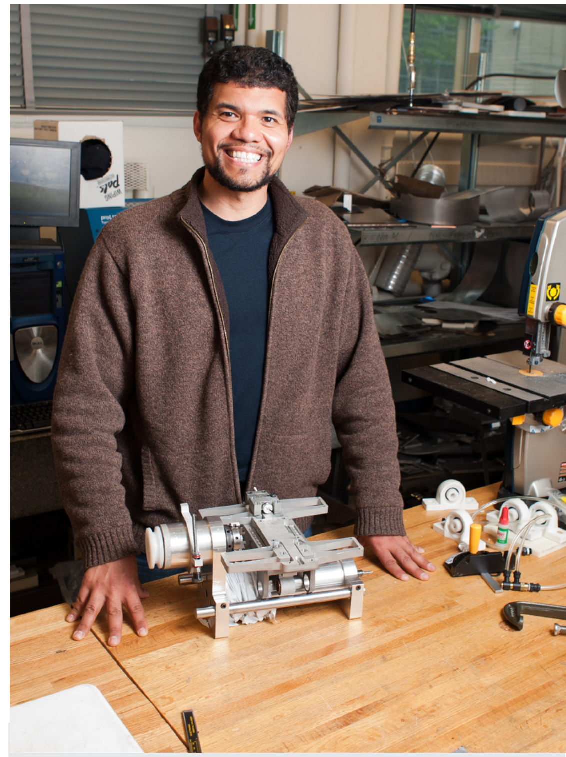
So far Fang and his team have demonstrated the ability to print on an area of 2 inches, but they anticipate being able to increase that to the size of a window.

"We are also trying to build a tool that is compatible with the contact aligners that are used in many semiconductor fabrication designs. In particular, we want to make something as portable and modular as a laptop so you can essentially print the same module and turn it into a nanofabrication system."

Fang's new process has important applications as a catalyst for other nano materials as well; for example, etching into silicon to create silicon nano wires or nano patterns. In other words, printing a catalyst that can generate other nano materials.

"We are interested in silicon because silicon nanowires, when properly shaped, can absorb 98% of light over the complete visible range. We are working with a company now to help create a space telescope whose material composition will not fail in space. Since we can now print nanoscale structures on flexible materials like silicon, we are able to help them."

Other applications include sensors to enhance florescence, thermal imaging, and possible early detection of some dangerous species.



Associate Professor Martin L. Culpepper received his PhD in mechanical engineering from MIT, then became a professor here in 2001. He has received several awards since then, including the R&D 100 Award for his HexFlex—a structure used for very fine positioning—the Ruth and Joel Spira Award for Distinguished Teaching, and the TR100 award for top young innovators. He is a member of ASME, the American Society for Precision Engineering, and the European Society for Precision Engineering and Nanotechnology.

Faculty Spotlight:

Associate Professor Martin L. Culpepper

Why is manufacturing still important?

Manufacturing is an easy way to maintain an advantage over the rest of the world. It is the way we create wealth, because it creates jobs, meaning more people have more money to buy things. As a result, people demand higher-tech products and want them sooner. So manufacturing has to be even faster and more agile in terms of how to service that increased customer base. Innovation in manufacturing is going to be critical because that is what is going to allow a faster, better implementation of the engineering and science that enable these new technologies.

How important is it to understand the business side?

Manufacturing encompasses two very tightly integrated components: business and science. If you walk into a machine shop, you see materials being converted into products. What governs how they get converted and how well it all works afterward is the physics of those materials—the science. But after you have a tangible object, it still has to be sold. You always have to ask yourself not only if something is scientifically possible but also questions about production, demand, cost, and supply chains.

Describe your current research.

We are currently looking at ways to manufacture at the micro and nano scale to aid scientists experimenting and implementing at this level. They are naturally separated from what they are doing simply by scale, so they have to rely on machines. We started to develop technologies that could do both displacement and force measurement down at the small scale to give scientists the instruments and equipment they needed to get a good characterization of what is happening and really understand it.

The instruments we are building for them need to transition into the manufacturing phase as well. We are working on designing and building low-cost sensors that can do force and displacement sensing quickly as well as measure what is happening down to the atoms, characterizing them in ways you never could before. Scientists can fabricate with them, moving things where they want to at the nano scale. I cannot emphasize how important that is. With macro scale objects, if I want to move it, I just move it. But at the nano scale, there are a lot of different forces at play. Imagine that everything in this room sticks to everything else, so when you start grabbing for something and trying to move it, you have to be careful not to break it, but the “stickiness” can make it hard to “let go.” There are very similar problems at the nano scale. DNA or biological specimens are a good example; being able to pick and place them accurately isn’t easy, and you have to be careful how hard you push on them.

We have been able to get the equipment to do nanometers easily and inexpensively, and the force measure can do 10 pica-Newtons, but we still need to integrate them. When we are done, you will actually be able to build molecular objects and measure forces on them while the material itself is undergoing a chemical transformation.

What do you like best about being a MechE professor at MIT?

Once you leave the walls of MIT, you often lose the hands-on experience that MIT does so well. You walk into a machine shop here, and there is a faculty member running a lathe or a mill. Same with students: Unless there is a good reason it cannot be made here at MIT, my students make everything. As a result, they have a really good intuition for how things work, enabling them to make decisions fast and save future employers both time and money. You can learn about manufacturing from books, and you will know manufacturing to some extent, but you don’t really understand it unless you do it yourself. That is what manufacturing is all about.

Alumni Profile

RJ Scaringe, CEO, Rivian

When most people first hear that alum RJ Scaringe (SM '07, PhD '09) has started a new car company, they are stunned. Why focus on a mature industry with a bad reputation? For those precise reasons exactly, says a determined Scaringe. *MechE Connects* had a chance to speak with Scaringe about his innovative new car design and reasons for taking on such a challenge.

With the auto industry at such a low and mature state, why did you decide to start a new car company now? What gaps did you see in the market?

The launch of a new automotive company right now is indeed a considerable challenge. But at the same time, there have been a number of market and industry shifts that make this a realistic objective. The recent downturn and need to diversify has made the supply chain hungry for new opportunities. The same is true for the distribution network, which has excess capacity and is hunting for unique, differentiated products. Furthermore, the capability of computer simulations has reduced engineering and development expenses by enabling deep design on the front end of the process.

Beyond these lowered operational barriers, the focus on mass volume segments by the established manufacturers has created a number of white space opportunities.

What makes your car different?

Rivian's first vehicles will be an unmatched portfolio of efficient performance cars targeted at enthusiast buyers. Additionally, our manufacturing and platform technology has led to a range of strategic partnership opportunities both domestic and international.

We have developed a new approach to vehicle design and production that transforms the operations and economics of automotive manufacturing. This transformation shifts from conventional design and manufacturing to processes that are lean in every aspect, starting with a fully integrated team of designers and engineers focused on common, vehicle-based goals and carrying through to the actual vehicle production process.

Rivian's modular platform system provides unmatched flexibility for the rapid design and production of new vehicles. It enables greatly reduced capital requirements, while providing the flexibility to tailor vehicle designs for specific market opportunities.

This platform and manufacturing technology has applications well beyond Rivian's North American vehicles.

Your car will handle like a Porsche and achieve gas efficiency like an economy vehicle. How?

Rivian's quick acceleration, outstanding handling, and distinctive styling provide the excitement and exhilaration of the world's top enthusiast vehicles but with much higher fuel efficiency and a far more affordable price. Rivian's lightweight platform enables the dramatic efficiency improvements. The US launch vehicle utilizes a mid-engine layout, rear-wheel drive, and double wishbone suspension, all of which provide a superb driving experience.

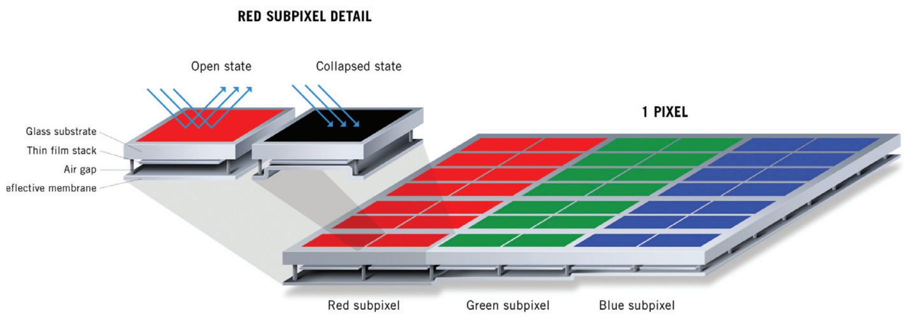
How did your time at MIT as a master's and PhD student prepare you for this role?

The hard work and problem-solving techniques I used while completing my graduate work have proven to be extremely useful with starting Rivian. The process-oriented thinking and persistence required to solve complex problems carries over to both the technical and non-technical areas of Rivian.

Rivian's US launch is targeted for 2014.

Iridescent Displays

MechE Alum Leads a Revolution in Displays



Clarence Chui (PhD '98), senior vice president and general manager of Qualcomm's MEMS Technologies, producer of a radical new display that boasts full color in sunlight and low power usage, describes some of the technology behind his team's discovery and his role in helping to shape it.

How did the team come up with the idea to simulate the mechanism for iridescent color in butterfly wings?

The mechanism responsible for the iridescent color in butterfly wings has been known for some time, and is also responsible for the naturally produced colors one sees in a soap bubble or in an oil slick. Two French scientists (Fabry and Pérot) discovered how optical interference (etalons) can alter wavelengths of light way back in the early 20th century.

Your displays are able to achieve full color even in direct sunlight and consume less energy than most displays. How?

At the most basic level, a mirasol display is an optically resonant cavity. The device consists of a self-supporting deformable reflective membrane and a thin-film stack (each of which acts as one mirror of an optically resonant cavity), both residing on a transparent substrate.

When ambient light hits the structure, it is reflected both off the top of the thin-film stack and off the reflective membrane. Depending on the height of the optical cavity, light of certain wavelengths reflecting off the membrane will be slightly out of phase with the light reflecting off the thin-film structure. Based on the phase difference, some wavelengths will constructively interfere, while others will destructively interfere.

The human eye will perceive a color as certain wavelengths will be amplified with respect to others. The image on a mirasol display can switch between the selected color and black by changing the membrane state. This is accomplished by applying a voltage to the thin-film stack, which is electrically conducting and is protected by an insulating layer. When a voltage is applied, electrostatic forces cause the membrane to collapse.

The change in the optical cavity now results in constructive interference at ultraviolet wavelengths, which are not visible to the human eye. Hence, the image on the screen appears black.

A full-color display is assembled by spatially ordering IMOD elements reflecting in the red, green and blue wavelengths.

What do you consider to be the most revolutionary about your displays?

Mirasol displays are a technology breakthrough that delivers substantial performance benefits over competing display technologies. Never before has a single display technology supported color and interactive content while also offering crisp visibility inside and outdoors with energy efficiency to provide weeks of battery life. Our displays use microscopic mirrors to reflect ambient light. This means ►

Find out more ►

Read the *Technology Review* article:
http://www.technologyreview.com/demo/427641/iridescent-displays/

they do not use a backlight, one of the largest consumers of power in today's backlit displays.

Mirasol displays are also bi-stable, which allows for near-zero power usage in situations where the display image is unchanged. This means that mirasol displays benefit from considerable power savings, especially compared to displays that continually refresh, such as LCDs.

If it's lit by the sunlight, how does the display work in the dark?

Qualcomm has developed a front light solution that is integrated into mirasol devices. The front light can be switched on when needed and consumes only a small amount of energy compared to a LCD's back light. Our goal is to provide a consistent viewing experience regardless of ambient light conditions.

How is your manufacturing affected by this new process of creating displays?

While the technology behind mirasol displays is unique, the manufacturing processes (and tools and materials) share many similarities with other mainstream display technologies, including LCD. MEMS are unusual in the display world but have a broad application in other industries.

What was your role in the R&D and production of these new displays?

I met the founders of Iridigm, the startup that came up with the technical concept behind mirasol displays, while I was working at a consulting firm, Exponent, in the Boston area. The inventor and his co-founder were both MIT alums and we were introduced by another alum, who happened to be my supervisor at the firm. Even though some of the still image optical demonstrations of the technology were fantastic at the time, there was very little understanding of how the relationships between mechanical stress, device geometry, material thicknesses, and environmental conditions were interconnected and could be optimized to create a properly functioning full display. After all, the basic device is mechanical in nature and so the mechanical properties are really critical to understand.

I started out as a consultant to Iridigm and my first task was to put together an analytical framework within which the relationships amongst these key attributes could be understood so device designs and fabrication efforts could be guided by criteria that gave us the best chance to create a good-looking, active display. That initial analysis was fruitful enough that when the company moved from Boston to the Bay Area they asked me to join full time, which I happily did toward the end of 1999. The analytical model become the basis for a lot of the early decisions we made in adjusting the material choices, design parameters, and fabrication methods. Versions of that analysis were used for quite a few years afterward as a tool to help

Chui (Photo credit: Ken Hansen)

subsequent engineers understand how all the basic parameters were interrelated. We didn't have enough funding during the early stages of the company to afford sophisticated simulation tools so having a set of simple scaling relationships was really important for getting a good "feel" for how devices ought to be designed.

Over time, I also made contributions to areas beyond the basic device like display systems and drive scheme methods, especially the techniques for defining, sequencing, and delivering voltage waveforms that would help produce good-looking images. I especially liked working on this part of the technology because it was a lot like trying to solve a puzzle by figuring out what combinations of waveforms, voltage levels, timing, and image processing could coax the best performance out of the display. The resulting solutions were definitely not obvious at the outset, since the displays and system typically had a significant amount of uncharacterized behavior to them in the beginning. So it's very satisfying at the end when you see what combinations of things end up in the product. I think the biggest lesson I've learned so far is that it takes very long to make changes in the materials and manufacturing processes involved in making MEMS, so getting performance improvements by other means has to be an essential part of this type of commercialization effort.

As the organization has grown, my contribution has primarily been helping to build and mentor the teams involved in the day-to-day development activity, with the intermittent direct contribution of ideas. Many of the initial concepts have made their way into the commercial products, so that part of my role has been very satisfying. I'm also extremely pleased that many of the ideas that have made it into our products or are being planned into our roadmap have come by unexpected means or sources From a technology and product development point of view, one of the best contributions I can make at this point is to try to get out of the way of our highly capable teams.

How did your studies at MIT help prepare you for this role?

I suppose I could say a bunch of the normal general things like how the training helped encourage my natural curiosity, or that my exposure to the analytical methods involved in the coursework and thesis work provided me with a broad skillset that helped make professional opportunities including Iridigm and Qualcomm available, or that the great people and learning environment shaped my views of technology during a critical period in my life and probably shaped my perspective within my current role, or many other similar things. Of course, all of those things are true. However, I will point out a specific example where the training helped me.

Because of the group I worked in (The Mechanics group within the Department of Mechanical Engineering), I picked up a habit of always trying to redefine complex mechanical or materials problems into a framework that could be solved with reasonable accuracy in an analytical form, say within 15%-25% of the actual solution, or a solution that could be achieved by more sophisticated means, like computational simulation. The habit also lead me to get involved in other classmates' problems (even those outside of our group or department), especially if they had something mechanical or materials related to them. It allowed me to see that the same kind of methods could be applied to problems outside of the context that I was used to, and probably helped me generalize my problem-solving approach so I could look at problems in other fields and feel confident that I could contribute.

It was probably that tendency that lead me to choose engineering consulting as a starting point in my career rather than continue focusing on my specific field of study. I'm sure things would probably have worked out fine either way, but overall I'm grateful that the curriculum and the expectations of my thesis advisor were flexible enough to accommodate my natural tendencies to want to look at many different types of problems. It was this basic skill that eventually allowed me to contribute meaningfully to the fundamental analysis that supports the mirasol-related technologies. The mirasol work just happened to be really amenable to the tools and methods I had practice using as a student and early in my career. It was just coincidentally a very good match.

How do you see this new technology affecting the display market in both the short and long term?

We believe that mirasol displays are a revolutionary advance in display technology, unlike any we have seen previously. The application of this display offers disruptive performance advantages for any device into which mirasol displays are built: delivering color and interactive content, best-in-class energy efficiency and visibility even in the brightest of outdoor conditions. Because mirasol displays address the inevitable market demand for a color and outdoor visible display technology that is extremely low power, they enable a wide range of new consumer experiences and new use models.

Undergraduate Spotlight:

Katy Olesnavage Lays Groundwork for Locating Fresh Water Sources

by Nancy Adams

Katy Olesnavage

Submarine groundwater discharge, or SGD, describes water flowing underground from coastal aquifers into the ocean.

Though SGD may contain recirculated seawater, it is most often associated with fresh water discharge, water that can be tapped for the benefit of local needs, both domestic and agricultural. And in Cyprus, or any region where part of the demand for fresh water is being met by energy- and cost-intensive desalination, proper management of fresh water resources is a high priority.

"The environmental aspect is what initially drew me to it," says Katy Olesnavage, a graduating senior in MechE whose senior thesis on the subject earned her the 2012 Horn Award. "The fact that it had components of electrical engineering, programming, and aeronautical engineering were just added benefits. I have gotten a lot more out of working on this interdisciplinary project than I could have if I had worked on something that fell strictly within the bounds of mechanical engineering, where I am most comfortable."

Indeed, locating SGD, which has been described as akin to looking for a needle in a haystack, is outside most students' comfort zones. But a review of the literature and consultation with researchers working with SGD pointed Olesnavage toward a promising approach. Because the temperature of groundwater is constant year round while the temperature of the ocean changes with the seasons, one way to locate groundwater flow into the ocean is by identifying temperature anomalies on the ocean's surface using aerial thermal imaging. These images can then be used to locate favorable areas for further in situ salinity testing to verify the presence of fresh water SGD.

Before traveling to the eastern Mediterranean in search of SGD, Olesnavage field-tested her procedures and equipment closer to home at Quonochontaug Pond, on the Rhode Island coast. Using existing thermal images of the pond provided by Dr. Matthew Charette of the Woods Hole Oceanographic Institution (Charette is a currently funded MIT Sea Grant investigator), Olesnavage selected sites for further investigation. At the locations where thermal imaging indicated the possible presence of SGD, she successfully measured salinity levels with a conductivity, temperature, and depth sensor, and used the results to analyze the relationship of anomalous temperatures to the presence of fresh groundwater discharge.

Armed with confidence in her method, Olesnavage was ready for Cyprus. The Cyprus Institute organized the team and equipment Olesnavage needed and provided expertise on the issues of SGD in the eastern Mediterranean. And, perhaps equally important, staff at The Cyprus Institute had connections in the local fishing community, which, using less high-tech methods such as observation of surface bubbles and sightings of farm animals drinking at certain locations along the ocean's edge, was able to help her pinpoint a likely spot to begin the investigation. Using an infrared camera attached to a piloted aircraft, Olesnavage and her Cypriot colleagues then captured the thermographic images of coastal waters needed to confirm likely outflows of SGD.

These images were not always easy to come by—both nature and airport security managed to slow them down on occasion. Some days, takeoff had to be postponed due to morning fog or airport security procedures, which ate up the few hours during which data could be collected before ►

the sun's heat eliminated any sea-surface temperature differences. Through patience and perseverance, they got enough thermal images to identify areas for in situ salinity measurements. The methodology and findings of Olesnavage's thesis have set the stage for testing along the island's coast.

The Cyprus Institute could not be happier with Olesnavage's work. Dr. Costas Papanicolas, president of the Cyprus Institute, comments, "The findings reported by Katy pave the way for the next phase of this important research project, which is to identify, quantify, and actually harvest some of the fresh water that is flowing or seeping into the sea." In this next phase, they have plans to use unmanned aerial vehicles (UAVs) that can more efficiently and accurately collect the needed thermal imaging. The Cyprus Institute has several UAVs, a unique resource in the area, which it hopes will be functional and ready for implementation in this project by late spring 2012 when rainfall, and thus SGD, is highest.

Papanicolas goes on to praise Olesnavage's work: "Katy's superb work exemplifies some of the best aspects of the collaboration between MIT and The Cyprus Institute: young, promising scientists performing cutting-edge research to address one of the world's most acute problems."

New Faculty

We are pleased to introduce two new faculty members, Mark Thomas and Amos Winter.

Mechanical Engineering is in an exciting period of faculty renewal, with four faculty searches this year in Manufacturing, Bioengineering, Ocean Engineering, and one search broadly across all mechanical engineering disciplines. We look forward to introducing new hires for these positions next year.

Captain Mark Thomas, Professor of the Practice

Professor of the Practice in Naval Architecture and Engineering Captain Mark Thomas earned his BS in electrical engineering from Oklahoma State University, his SM in electrical engineering from MIT, his NE in naval engineering from MIT, and his PhD in hydrodynamics from MIT. He is the US Navy's senior uniformed Naval Architect. His technical contributions encompass a wide range of naval engineering challenges, from keeping today's ships at sea and designing ships for the future to evaluating technology advancements for both today and tomorrow's Navy.

Amos Winter, Assistant Professor

Amos Winter earned a BS in mechanical engineering from Tufts University in 2003 and an MS and PhD in 2005 and 2010, respectively, in mechanical engineering from MIT. His research interests include design for emerging markets, biomimetic design, fluid/solid/granular mechanics, biomechanics, and the design of ocean systems. He is the founder and director of the MIT Mobility Lab and the principal inventor of the Leveraged Freedom Chair (LFC), an all-terrain wheelchair designed for developing countries and winner of a 2010 R&D 100 award. He received the 2010 MIT School of Engineering Graduate Student Extraordinary Teaching and Mentoring Award and the 2010 Tufts University Young Alumni Distinguished Achievement Award. He was also recently awarded the 2012 ASME Pi Tau Sigma Gold Medal.

Student Awards

American Bureau of Shipping Department Service Award (Outstanding Service to M.E. Department)
Guangtao Zhang, Yazan Z. AlNahhas

Lockheed Martin Prize (Outstanding Sophomore in Mechanical & Systems Engineering)
Sean M. Cockey

Meredith Kamm Memorial Award (Excellence in a Woman Graduate Student)
Melinda Rae Hale

Lauren Tsai Memorial Award (Academic Excellence by a Graduating Senior)
Latifah Hamzah

AMP Inc. Award (Outstanding Performance in Course 2.002)
Jack Wanderman, Ragheb El Khaja

Society of Naval Architecture and Marine Engineering Award (Outstanding Student in the Marine Field)
Abhimanyu Belani, Christian Welch, Leah Hokanson

Robert Bruce Wallace Academic Prize (Academic Excellence in Ocean Engineering)
Grace Young

Alfred A.H. Keil Ocean Engineering Development Fund Award (Excellence in Broad-Based Research in Ocean Engineering)
Leah Hokanson

Clement F. Burnap Award (For Outstanding Masters of Science in the Marine Field)
Timothy Emge II

Louis N. Tuomala Award (Outstanding Performance in Thermal Fluids Engineering)
Lauren Kuntz

Ernest Cravalho Award (Outstanding Performance in Thermal Fluids Engineering)
Ken Lopez

Luis de Florez Award (Undergraduate Award)
Andrew Yang
(Graduate Design Award)
Nikolai Begg
(Graduate Science Award)
Christopher Love

Peter Griffith Prize (Outstanding Experimental Project)
Shen Huang

Thomas Sheridan Prize (Creativity in Man-Machine Integration)
Brooks Reed

International Design Competition (2.007 Contest)
Angela Chu, Kawin Surakitbovorn
Michael Farid, Sarah Southerland

Whitelaw Prize (Originality in 2.007 Design and Contest)
Joseph Church, Samuel Whittemore

John C. and Elizabeth J. Chato Award (Excellence in Bioengineering)
Ashley Brown

Park Award (Outstanding Performance in Manufacturing)
Cecilia Cantu
Wesley McDougal

Rabinowicz Tribology Award (Outstanding Research in Tribology)
Robert Panas, Sean Vaskov

Link Foundation Fellowship in Ocean Engineering (For Study of Ocean Engineering Instrumentation)
Audrey Maertens

Carl G. Sontheimer Prize (Creativity and Innovation in Design)
Erich Brandeau, Ian McKay, Julian Merrick, Latifah Hamzah, Richard Larson, Ruaridh Macdonald

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Wunsch Foundation Silent Hoist and Crane Award (Outstanding TA)
Paul Ragaller, Joseph Sullivan, Nevan Hanumara, Shane Colton

(Exceptional Performance in Dynamics)
Wai Hong Chan

(Leadership)
Daniel Dorsch

(Academic Excellence)
Ashley Brown, David Parell, Evan Schneider, Ian McKay, Luke Mooney, Kathryn Olesnavage, Nigel Kojimoto, Omar Abudayyeh, Reuben Aronson, Richard Larson

Faculty Awards

Mary Cunningham Boyce

Department Head Professor Boyce was elected to the National Academy of Engineering (NAE) this past winter for her outstanding contributions to the understanding of the mechanics of deformation in engineered and natural polymeric solids.

Cullen Buie

Professor Buie was awarded a National Science Foundation CAREER Award for his proposal titled, "Dielectric Phenotyping of Bacteria for Energy and Medicine."

Tonio Buonassisi

Professor Buonassisi was recently awarded a National Science Foundation (NSF) CAREER Award for his proposal titled, "Toward Robust, Scalable, and Non-Intermittent Solar Power: Silicon-Based Multi-Junction Devices with Integrated Photocatalysis."

Nicolas Hadjiconstantinou

Professor Hadjiconstantinou recently won the prestigious ASME Gustus L. Larson Memorial Award for his international leadership in modeling and simulation of micro/nano. The award recognizes outstanding achievement in mechanical engineering 10 to 20 years post-graduation.

Anette "Peko" Hosoi

Professor Hosoi was awarded the JP Den Hartog Distinguished Educator Award for excellence in teaching mechanical engineering, for serving as an inspiration for students, and for fostering the development of physical insight and engineering judgment.

Rohit Karnik

Professor Karnik was recently awarded a Department of Energy Early Career Award by the Office of Basic Energy Science for his research on "Graphene Membranes with Tunable Nanometer-Scale Pores."

John Lienhard

Professor Lienhard was recently awarded the ASME Technical Communities Globalization Medal, which was recently established in 2011 for an ASME member who demonstrated a sustained level of outstanding achievement in the promotion of international mechanical engineering-related activities.

Derek Rowell

Professor Rowell was recently recognized with the Spira Award for Teaching Excellence in Mechanical Engineering for his history of excellence in teaching and his introduction of the new course Electronics for Mechanical Engineers two years ago.

Sanjay E. Sarma

Professor Sarma has been recognized for his exceptional achievements and contributions in research, education, and service with an appointment to the Daniel Fort Flowers and Fred Fort Flowers Professor of Mechanical Engineering.

Evelyn Wang

Professor Wang recently received the 2012 Young Investigator Award from the Office of Naval Research for her development of advanced thin film evaporation and condensation surfaces for high-performance thermal management devices.

Professor Wang was also the recipient of the 2012 ASME Bergles-Rohsenow Young Investigator Award in Heat Transfer, given to a heat transfer engineer under the age of 36 who has a PhD or equivalent and has demonstrated the potential to make significant contributions to the field.

David E. Wallace

Professor Wallace was recently selected to receive the 2012 ASME Joel and Ruth Spira Outstanding Design Educator Award in recognition of his leadership in product development education.

Maria C. Yang

Professor Yang has been recognized for her exceptional advising and mentoring of students with the Earll Murman Award for Excellence in Advising by the Office of Undergraduate Education.

2012 Phi Beta Kappa Inductees

- Omar Abudayyeh
- Reuben Aronson
- Ashley Brown
- Latifah Hamzah
- Nigel Kojimoto
- David Parell
- Theresa Saxton-Fox

LiquiGlide

Professor Varanasi's Condiment-Bottle Coating Gives Waste the Slip

by Alissa Mallinson

The Varanasi Research Group, led by Associate Professor Kripa Varanasi, took a break from researching super slippery and super non-wetting coatings for equipment such as steam turbines and airplanes to present their newest invention at this year's $100K Competition: LiquiGlide, a nontoxic, nonstick, super slippery coating for condiment bottles. Made from food materials, LiquiGlide is easy to apply to food packaging and prevents stubborn condiments from sticking to the inside of the bottle.

For food sauce companies—and their customers—easy removal of condiments is a constant challenge. Most people have experienced the frustration that comes with struggling to expel a condiment like ketchup, mustard or mayonnaise with furious shaking, messy rummaging, or pure brute force. Now, a simple tilt of the hand sends condiments sliding out.

"Our research group is mainly focused on big issues in energy, water, and transportation," says Varanasi, "but we found that bottles are no small thing, with the worldwide condiment market comprising about 17 billion bottles."

With a market that big, small additional costs such as the 20-cent charge customers pay for the special cap on upside-down bottles can add up to billions of dollars. Just as important, eliminating those special caps can reduce the need for plastic by about 25,000 tons. LiquiGlide can save food by ensuring that none is wasted and increase recycling rates by removing all food remnants.

The group was named runner-up in the competition for LiquiGlide and easily took home the Audience Choice Award, along with the $2,000 that went with it, but it's the media frenzy that followed that garnered them so much attention. The coating was featured in NPR, ABC News, the Chicago Tribune, The Wall Street Journal, and CNN, among many others, in the week leading up to Memorial Day.

Along with Professor Kripa Varanasi, the LiquiGlide team is J. David Smith, Christopher J. Love, Adam Paxson, Brian Solomon, and Rajeev Dhiman.

For more information, visit liquiglide.com

Find out more ►

Read more about the $100K Competition and the LiquiGlide team:
http://web.mit.edu/newsoffice/2012/cloud-top-wins-mit-100k-0517.html
http://mit100k.org/bpc/bpc-semi-finalists/liquiglide/

Department News

Recent Alum Wins First Place for 3D Modeling Tools

This past March at the South by Southwest Festival's Accelerator-Innovative Web Track competition, two MIT students—Tom Milnes, MechE PhD candidate working with Professor Douglas Hart, and Sloan School alum Ash Martin—won first place for one of their company's products, Hypr3D. This web-based tool brings photo-realistic 3D modeling to the masses with user-uploaded photos or videos. The models can then be used for product visualization, gaming, reverse engineering, and even 3D printing.

Viztu, the company Martin and Milnes started after meeting in an iTeams class at the Sloan School, has developed several 3D-focused tools since forming in 2010. In addition to Hypr3D, they also offer Zeebl, which allows users to upload photos or videos to Hypr3D via their mobile phones; VizScan, a 360-degree laser scanner that works with any digital camera (including the iPhone); and Drink My Face, another web-based program that uses scans of people's profiles to create customized coffee mugs.

Annual Manufacturing Summit Focused on Innovation

MIT's sixth annual manufacturing summit, hosted by the Lab for Manufacturing and Productivity (LMP), was held this past October 27 and 28, in Cambridge, Mass. This year's theme, "Revitalizing US Manufacturing to Capitalize on Innovation" featured renowned speakers on the topic of manufacturing from academia, government, and industry, including the VP of Strategy Operational Services at Siemens Healthcare Diagnostics, the Executive Director of Production in the Innovation Economy (PIE, see page 11 for more) and MIT Professor Olivier de Weck, and the Industry Co-Director of the Sloan School Leaders for Global Operations (LGO) program Vahran Erdekian, just to name a few. This convergence of manufacturing leaders addressed everything from the current perception of manufacturing to educational needs and models of collaboration.

World-Class Renovations of Educational Research Space Continue in MechE

In continued support of the Department's world-class education and research environment, we have undertaken several major space renovations this past year. We have completed upgrades to the Experimental Marine Hydrodynamics Laboratory for ►

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naval engineering education and research, home to both a propeller laboratory and state-of-the-art three-dimensional imaging of complex fluid dynamics phenomenon. Significant enhancements to the d'Arbeloff Lab have been undertaken by installing chemical and biological hoods for the study of feedback and control of cellular networks and systems of biological cells, and ongoing upgrades continue in the Department's Center for Energy and Propulsion Research in Building 31 to support research in oxy-combustion and clean fuel technologies. At the center of this year's space improvements, a major renovation of the third floor of Building 3 has been completed to develop the Energy, Controls & Mechanics (ECM) Research Nexus. We are grateful for the support of the Department's Center for Clean Water and Clean Energy at MIT and KFUPM together with a very major donation from MIT alum Neil Pappalardo '64 in making this transformation possible. This gut-level renovation encompasses more than 10,000 square feet and creates a contiguous and dynamic space for more than 75 graduate students and postdoctoral staff. The space also includes a new state-of-the-art classroom, a microscopy facility for graduate and undergraduate research, an optics research lab, an experimental fluid mechanics lab, and a new conference room overlooking Killian Court.






Department Head Mary C. Boyce Elected to NAE

Professor Mary Cunningham Boyce, Mechanical Engineering Department Head and Ford Professor of Engineering, was recently elected to the National Academy of Engineering (NAE).

Professor Boyce was elected for her outstanding contributions to the understanding of the mechanics of deformation in engineered and natural polymeric solids. According to the NAE web site, "Election to the National Academy of Engineering is among the highest professional distinctions accorded to an engineer. Academy membership honors those who have made outstanding contributions to engineering research, practice, or education and to the pioneering of new and developing fields of technology, making major advancements in traditional fields of engineering or developing/ implementing innovative approaches to engineering education."

Talking Shop: Professor Sanjay E. Sarma

The Small Shop Becomes a Virtual Factory

Can you tell us about the current research you've been working on?

I am working on the development of a virtual factory. The idea is to enable small shops to present a united front and act as one big shop. It is like an ant farm. Every ant does one thing, but the ant colony is one big, breathing, living entity. In order to do that, you need to seize web-based technologies to bring the shops together and enable them to coalesce on the fly. We also need a better supply chain.

What are your ideas about how to connect these small shops and make them one?

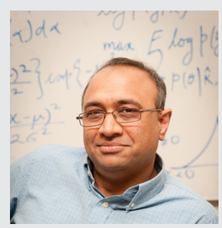
There are three steps: distributed manufacturing, distributed quality control, and distributed shipping, all of which my team and I are looking at now. Distributed manufacturing is about getting independent machine shops to all do their part for the benefit of the whole. For example, if I have a small shop and would not normally be able to bid on a big project, I could work together with a couple other small shops to contribute a part of a bigger order. That is one piece of it, and I have worked on it for a long time. I am trying to make that more common.

The second piece of it is quality control. Wouldn't it be great if a machine shop owner could do a CAT scan on the parts I made? The reason companies like to do something in a single big factory is because "they only have one throat to choke," meaning they can control quality and have accountability. But if the work is distributed, quality control is more difficult. But what if we used 3D scanning? Before a machine shop sends the part, it could send a complex and detailed photo of the part that far exceeds the awareness you would have in a factory.

The third piece is now that I have made the part and it weighs 30 pounds, how do I ship it? UPS? At $100, that is way too expensive. You could put everything on a big truck to ship it off, but not if I'm only making 10 parts. So we are trying to evolve a new approach to supply chain planning in which small shops can rent unused space in someone else's truck. It is called fractional ownership. RFID and other technologies will enable a new world in which the supply chain works as if it were a packet-switched computer network. The irony is that computer networks were inspired by the supply chain—or how it was thought to work!

How would this kind of setup affect factory employment?

I think education is huge. The United States is very computer savvy, so I have few concerns that we will innovate, but I do think we need to change our game. A lot of the unskilled jobs available will decline, but the great thing about America is how adaptive we are. And education is the key to all of this. I think there will be some job retraining, but I also think there will be some self-driven people learning new skills. A lot of people are quick to declare that America is in decline, but you see more spark of entrepreneurship in an average person here than you sometimes do in business leaders in other countries. It is an amazing thing, and you have got to trust that. But you have also got to facilitate that creativity. Distributed manufacturing may be one such facilitator.



Professor Sanjay Sarma has been a professor in the Department of Mechanical Engineering since 1996, after earning his PhD from University of California at Berkeley. Renowned for his co-development of standards-based radio frequency identification (RFID) technology use in commercial supply chain management, Sarma's research focus is on efficient manufacturing and automatic identification, including barcodes and RFID, supply chain management, transportation, and sensors. A member of the Laboratory for Manufacturing and Productivity (LMP), he is also the chairman of EPCglobal and is currently the director of the MIT/Singapore University of Technology and Design (SUTD) Collaboration.

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Coming in the next issue:

► Bioinstrumentation and Biomedical Device Design

Course 2.00b, more popularly known as Toy Product Design, is an undergraduate course students really get excited about. Named one of "30 Awesome College Labs" by *Popular Science* magazine, Toy Lab is another shining example of MechE's commitment to hands-on learning, challenging students to design, build, and present a toy prototype in one semester. Moderated by Professor David Wallace, the final event was chock full of laughter as a crowd of hundreds watched each team's "PLAYsentation" of their toy. Here, the "Soundy" team presents their portable motion-sensor speaker.