MITMECHE

Spring 2010

Vol. 1, No. 1 Published twice a year

Massachusetts Institute of Technology

MechEConnects

News from the MIT
Department of Mechanical Engineering

In This Issue:

Mechanical Engineering
Professor Gang Chen with vacuum chamber

Pushing the boundaries of energy—theoretical, practical, and personal

Professor Gang Chen made headlines last summer when he and his colleagues solved a century-old problem in the physics of heat transfer ...

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Introducing *MechE Connects*

Dear Friends,

I am happy to introduce the first issue of *MechE Connects*. We see this publication as a platform linking more than 5,000 undergraduate and 6,000 graduate program alumni to the department. We also see it as a vehicle for sharing snapshots of the advances emerging from the labs, classrooms, and students of Mechanical Engineering @ MIT. With more than 70 faculty members, 450 undergraduates, 450 graduate students, and 60 postdoctoral associates/fellows pushing the frontiers of mechanical engineering, there is a lot of news to share.

We have maintained our U.S. News and World Report ranking as the number one mechanical engineering department at both the undergraduate and graduate levels. Our research is bringing engineering solutions to a spectrum of global challenges, including clean and renewable energy technologies, next generation technologies for water purification and desalination, and breakthrough instrumentation and controls for medical treatment and biomedical exploration. We are designing systems for underwater exploration and environmental monitoring and materials and technologies for protection of our first responders and soldiers. We also are exploring and decoding optimized designs stemming from the biomimetics of fish swimming, clam burrowing, snail locomotion, and natural armor structures. These projects range from the fundamental engineering science underpinnings to the design and fabrication of new structures, devices, and systems.

This inaugural edition of *MechE Connects* features Professor Gang Chen. Together with colleagues, Gang has just solved a one-hundred-year-old physics challenge. But that is just a small part of his research portfolio. Gang led a multi-department and multi-university team of researchers to win a DOE Engineering Frontier Research Center (EFRC)—the Solid-State Solar-Thermal Energy Conversion Center (S^{3}TEC). S^{3}TEC aims to advance fundamental science and engineering in the development of materials and devices to harness heat—from the sun and terrestrial sources—and convert it into electricity via solid-state thermoelectric and thermophotovoltaic technologies.

MechE Connects will be disseminated twice a year by mail and on the Web, giving everyone with an internet connection the opportunity to stay current. As you read this print edition, we hope you will be inspired to log on and see the extra content in the online version and to strengthen your connection to Mechanical Engineering @ MIT.

Enjoy this first issue of *MechE Connects*, and please drop us a line at mecheconnects@mit.edu with ideas for news or features. I hope this venture opens dynamic new dialogues with our alumni and friends and connects a community engaged in lifelong learning.

Mary C. Boyce,
Gail E. Kendall Professor and Department Head

Massachusetts Institute of Technology

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MechEConnects

News from the MIT
Department of Mechanical Engineering

► http://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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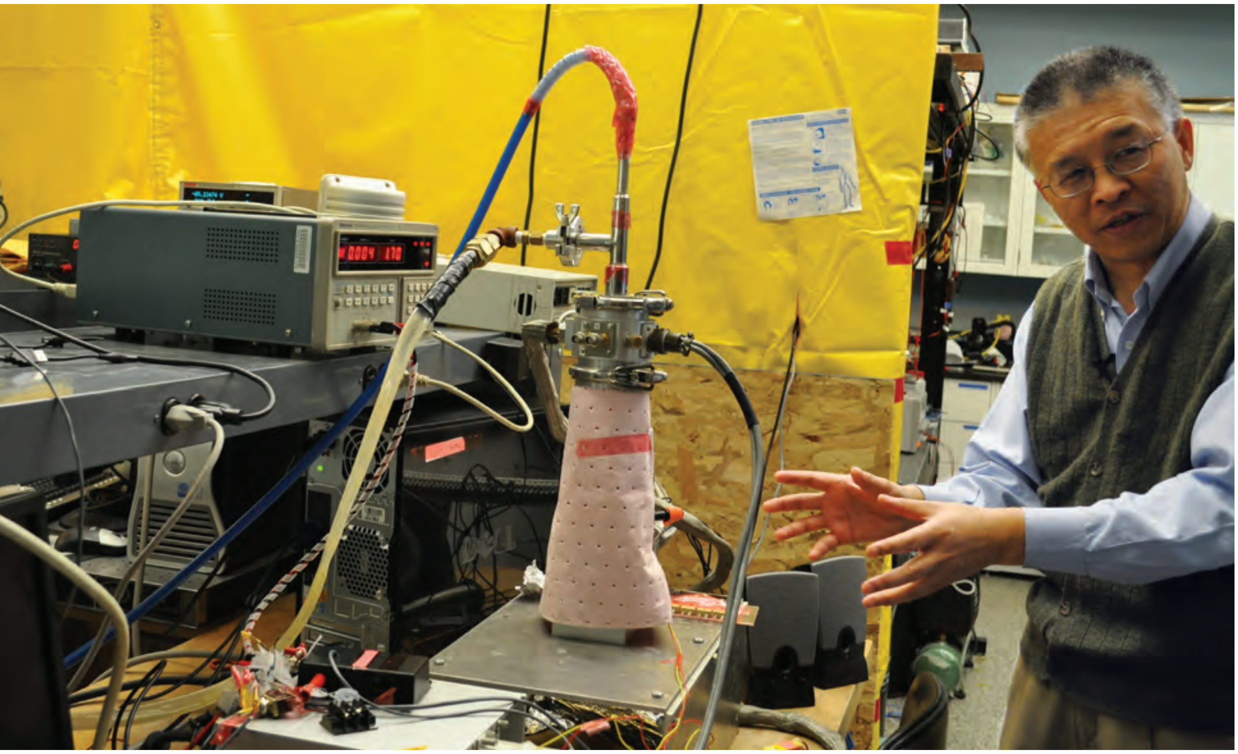
Gang Chen, pushing the boundaries of energy—theoretical, practical, and personal



Mechanical Engineering Professor Gang Chen

Gang Chen—one of the pioneers on the front lines of energy science—is an energy phenomenon himself. The Carl Richard Soderberg Professor of Power Engineering is one of the world's leading researchers in the nanoengineering of energy transfer. He heads the new Solid State Solar Thermal Energy Conversion Center (S^3TEC) with a staff of 50+, serves on the editorial boards of five scientific journals, teaches undergraduate and graduate classes, advises 21 graduate students, 12 postdocs, and two research scientists, and delivers lectures and seminars from one end of the planet to the other. And in whatever time is left at the end of the day, Gang Chen is helping to redefine the laws of physics.

Chen made headlines last summer when he and his colleagues, MIT graduate student Sheng Shen and Columbia University Professor Arvind Narayaswamy (who was also Chen's student), solved a century-old problem in the physics of heat transfer. Since 1900, when German physicist Max Planck formulated his blackbody radiation law, scientists have relied on the fact that the law describes the maximum thermal emission possible from any radiating object. Up to a point, that is.

Beyond Planck's Law

As Planck himself suspected, the theory breaks down when the distance between objects becomes minute. But over the ensuing hundred years, no one has found a way to measure this anomaly precisely. A big part of the challenge has been mechanical—keeping two objects in very close proximity without allowing them to touch.

"We tried for many years using parallel plates," says Chen. The best that he and his colleagues could achieve with this approach, however, was a separation of about one micron (one millionth of a meter).

The ground shifted when the team reconsidered the shape of one of the objects. They replaced one of the flat plates with a small silica glass bead. "Because there is just a single point of near-contact between the bead and the plate, it proved much easier to close the gap to the nanometer scale," explains Chen. Using the bead, they've reduced the distance between the objects to 30 nanometers (30 billionths of a meter)—one-thirtieth of the gap they had accomplished with two flat surfaces.

Once they had transformed the distance parameter, the team then introduced a bimetallic cantilever from an atomic force microscope. This significantly increased the precision of the temperature and heat flow measurements and produced startling results. It turned out that at the nanoscale, heat transfer between two objects can be 1,000 times greater than Planck's Law predicts.

Although the force of Chen's accomplishments is palpable to students and colleagues, the man himself does not betray the extraordinary dynamism that propels his accomplishments. The modest, affable Chen, who is known for his collaborative zeal, will never be the first person in the room to point out that his findings on Planck's Law, published in the August 2009 issue of the journal *Nano Letters*, could well have seismic impact.

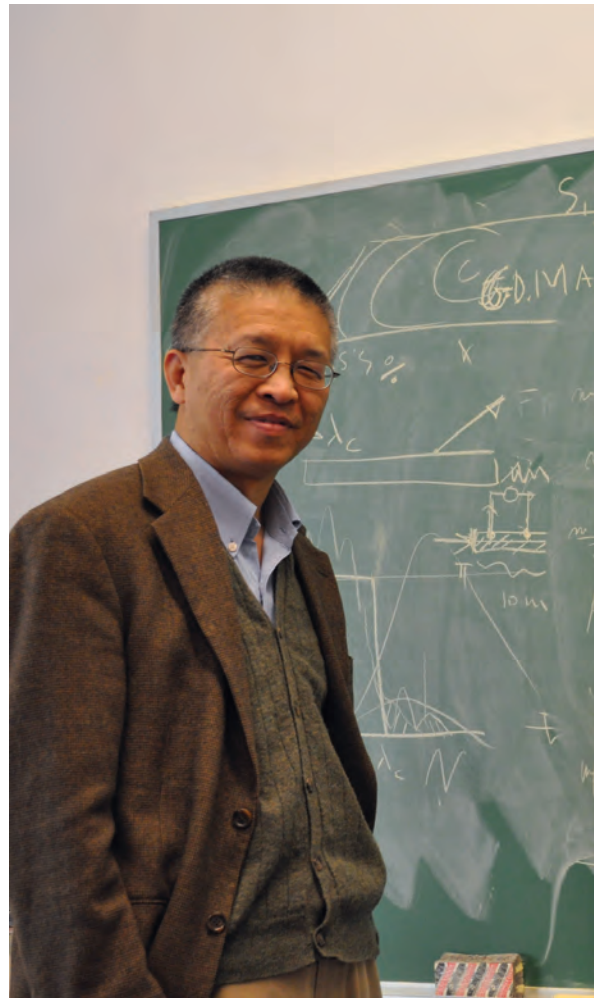
Chen's discovery can have many potential applications. The magnetic data recording systems used in computer hard disks, for example, typically have spacing in the five to six nanometer range. Because the recording heads tend to heat up in these devices, researchers have been looking for ways to manage or even exploit the heat to control the spacing. The fundamental insights revealed by Chen and his colleagues will allow designers to improve the performance of such devices.

Chen also is becoming increasingly excited at possibilities for the development of a new generation of thermophotovoltaics (TPVs)—energy conversion devices that harness the photons emitted by a heat source. "The high photon flux can potentially enable higher efficiency in existing technologies as well as new energy density conversion devices," Chen says. "We don't yet know what the

"**No doubt about it.** The students at MIT are exceptional. I have a very dynamic group of students and postdocs, and I love to challenge them and see them grow. I keep telling them to get their hands dirty. Always be on the lookout for new areas of exploration. My goal: when they are done here, they will be leading researchers."

Professor Gang Chen

Find out more ► Read about Chen's research on Planck's Law in "Surface Phonon Polaritons Mediated Energy Transfer Between Nanoscale Gaps" at http://pubs.acs.org (*Journal of the American Chemical Society*, "Nano Letters," 2009, Vol.9, #8 2909-2913).



limit is on how much heat can be dissipated in closely spaced systems. But current theory won't be valid once we push down to a one nanometer gap."

The birth of S³TEC—and the rebirth of solar

Of course, the plain truth about science in modern times is that discoveries are just a gleam in the eye of the researcher without the funding to move them beyond the theoretical. Gang's leadership in micro- and nanoscale thermal and mechanical phenomena recently helped MIT secure a $17.5 million grant from the U.S. Department of Energy to establish an Energy Frontier Research Center (EFRC). Chen heads the new initiative, called the Solid State Solar-Thermal Energy Conversion Center or S³TEC. He also oversees a staff of 50+, including 12 co-investigators from MIT, Boston College, and Oak Ridge National Laboratory, 32 graduate students, and six postdocs.

S³TEC's mission is to lay the scientific groundwork for transformational solid-state solar-thermal to electric energy conversion technologies. Working at nanoscale, researchers will be developing materials that can harness and convert solar energy and other man-made heat into electricity using thermoelectric and TPV technologies. "At the fundamental level, we'll be advancing our understanding of how electrons and phonons move through materials and interfaces," Chen explains. "This will enable us to engineer materials with significantly improved heat to electricity conversion efficiency." They also are designing surfaces that maximize radiation absorption and minimize thermal loss so that solar radiation can be efficiently converted into electricity via solid-state heat engines.

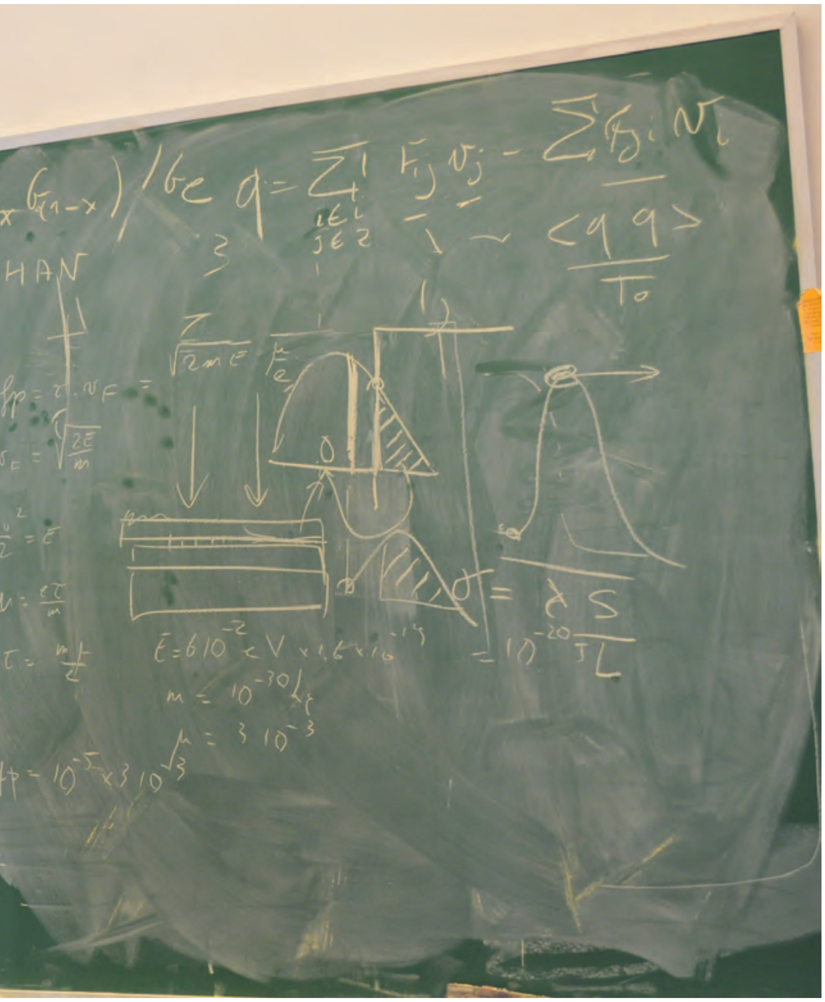
S³TEC researchers may well prove to be game-changers for solar electricity generators. Whereas current silicon-based photovoltaic solar cells produce electricity at $3 to $4 per Watt, the next generation of thermoelectrics could reduce that cost to as low at fifty cents per Watt.

Scaling up to gigawatts

S³TEC scientists also will be pushing the structural design of solar TPVs toward its theoretical limits. The highest recorded efficiency of multiple junction solar cells is slightly more than 40%, but theory indicates that it is possible to nearly double that performance with a nanoengineered single junction TPV cell. "If we can understand the fundamental science at nanoscale," he says, "we'll stand a better chance of successfully scaling up to gigawatts."

Both thermoelectric and TPV technologies can be applied to terrestrial heat sources such as geothermal and waste heat from industrial production, transportation, and buildings. Thermoelectrics, too, can be combined with existing solar technologies and used for

Find out more ► Explore the work of S³TEC at http://s3tec.mit.edu.



Professor Chen in his office at MIT

refrigeration and air-conditioning without producing any greenhouse gases.

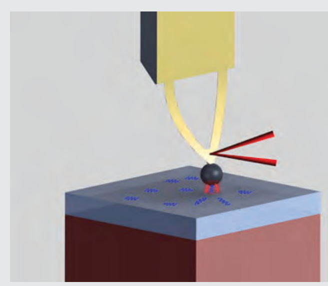
With a characteristic mix of modesty and candor, Chen pays tribute to the *Mens et Manus* credo. "Before I came to MIT in 2001, I was primarily focused on fundamental science," he admits. "I've definitely seen an expansion in my thinking to include the *real-world* impact of research. It's one of the great strengths of the Institute. Everyone is continually asking the question 'What's the potential impact of these findings? How can it be put to work to make life better?'"

Gang Chen has clearly made it his life's work to find out.

Earlier this year, Gang Chen was elected to the National Academy of Engineering for his contributions to heat transfer at the nanoscale and to thermoelectric energy conversion technology.

Planck's Trivia

Contrary to popular myth, Planck did not derive his law in an attempt to resolve the "ultraviolet catastrophe"—the paradoxical result that the total energy of a cavity tends to infinity when the equipartition theorem of classical statistical mechanics is applied to blackbody radiation. Planck did not consider the equipartition theorem to be universally valid, so he never noticed any sort of catastrophe. It was pointed out later and independently by Einstein, Lord Rayleigh, and Sir James Jeans.



A diagram of the setup, including a cantilever from an atomic force microscope, used to measure the heat transfer between objects separated by nanoscale distances.

Image: Sheng Shen

Ain A. Sonin Fellowship

A tribute to the MechE professor's legacy of support to graduate students

Professor Emeritus Ain Sonin retired in 2009

Image: Juhan Sonin

"We'll figure it out," MechE Professor Emeritus Ain A. Sonin would tell his students as he steered them through one challenge after another. Benny Budiman, ScD '04, remembers Professor Sonin, who was a graduate officer for 20 years, helping him to cope with a family crisis without losing his academic momentum. "Professor Sonin was a tremendous resource to graduate students, guiding them through difficulties with grace and dignity. I have adopted 'We'll figure it out,' as my own philosophy in facing challenges, personal and professional."

Born in Tallinn, Estonia in 1937, Sonin fled with his family to Stockholm in 1944. They eventually made their way to Toronto, where Sonin pursued his interest in aerophysics. Shortly after earning his PhD at the University of Toronto, he found his intellectual home at MIT. Sonin retired in 2009 after touching the lives of thousands of students.

In addition to being a top researcher in fluid and thermal sciences, Sonin has a successful line of furniture to his credit. But his greatest passion has always been his students. Sonin was awarded the MIT Graduate Student Council Award for Outstanding Graduate Teaching twice in his MIT career—once in 1973 and again in 1989.

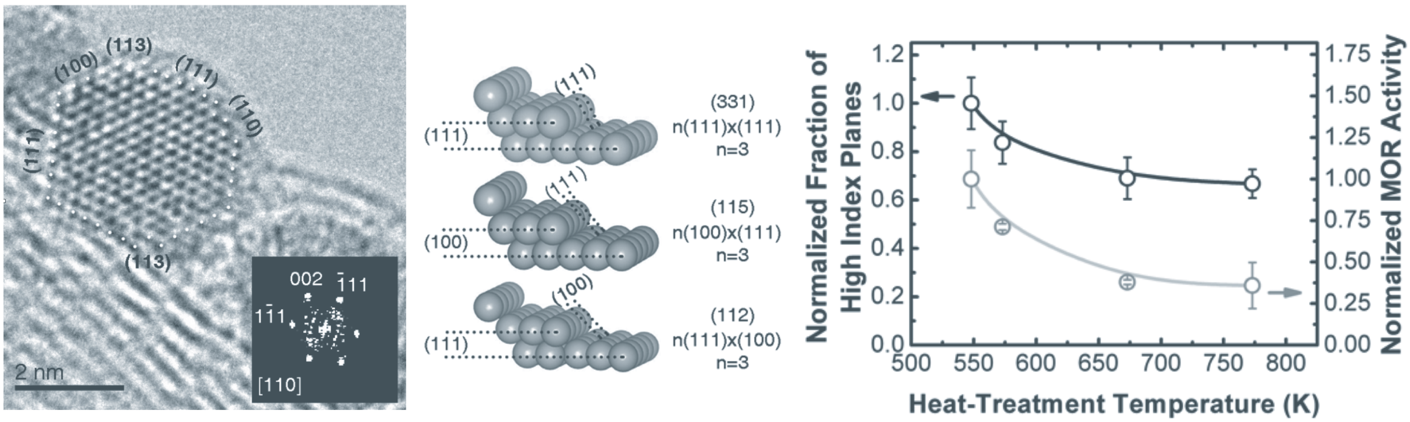
The Ain A. Sonin Fellowship has been established in his name to recognize that extraordinary dedication and impact. "Ain's door was always open," says Epp Sonin, founder of the Lexington Music School and Ain's wife of 39 years. "No matter how difficult the challenge, he always found a way to work through to a solution calmly and rationally."

Mary C. Boyce, Gail E. Kendall Professor and Mechanical Engineering Department Head, says that such fellowship funds are critical to the strength of the department. "The Department of Mechanical Engineering draws much of its international renown from its graduate students, who are widely acknowledged to be the best in the field. First-year fellowships are a key element in continuing to recruit the most talented students to MIT, especially in the face of increasing competition for the best students growing among the world's top universities. Alumni support of funds like the Ain A. Sonin Fellowship has never been more critical."

Find out more ► To make a gift to MechE, visit http://meche.mit.edu/giving.

Fuel cells get a boost

A MechE led team discovers the secret to increasing fuel cell efficiency



A high-resolution Transmission Electron Microscopy (TEM) image of platinum nanoparticles on the electrode of a fuel cell reveals surface steps that researchers say are responsible for dramatically improving efficiency.

Image: *Journal of the American Chemical Society*, 2009, Vol. 131, NO. 43, 15669-15677

One of the most promising new technologies on the energy frontier is the fuel cell. Fuel cells can produce electricity from hydrogen or other fuels without burning them and have the potential to power everything from homes and cars to portable devices like mobile phones and laptop computers. Their big advantage, eliminating emissions of greenhouse gases and other pollutants, has been outweighed by their high cost, and researchers have been trying to find ways to make the devices less expensive.

Now, an MIT team led by Associate Professor Yang Shao-Horn has found a method that promises to dramatically increase the efficiency of the electrodes in a particular type of cell that uses methanol instead of hydrogen as its fuel. These fuel cells are considered promising as a replacement for batteries in portable electronic devices. Because the electrodes are made of platinum, increasing their efficiency means that much less of the expensive metal is needed to produce a given amount of power.

Stepping up the current

The key to boosting efficiency, the team found, was to change the surface texture of the material. Instead of leaving it smooth, the researchers gave it tiny stair steps. This approximately doubled the electrode's ability to catalyze oxidation of the fuel and produce electric current. The researchers believe that further development of these surface structures could end up producing far greater increases, yielding more electric current for a given amount of platinum.

One focus of the research is to develop active and stable catalysts. According to Shao-Horn, the new work is a significant step toward figuring out how the surface atomic structure can enhance the activity of the catalyst in direct methanol fuel cells.

The results of the team's research are reported in the October 13 issue of the *Journal of the American Chemical Society*. The paper's eight authors include chemical engineering

Find out more ► Explore Yang Shao-Horn's Electrochemical Energy Lab at http://web.mit.edu/eel.

Doctoral student Yi-Chun Lu preparing electrolyte for lithium air battery testing

graduate student Seung Woo Lee and mechanical engineering postdoctoral researcher Shuo Chen, along with Shao-Horn and other researchers at MIT, the Japan Institute of Science and Technology, and Brookhaven National Laboratory.

Resolving a controversy

In their experiments, the team used platinum nanoparticles deposited on the surface of multi-wall carbon nanotubes. Lee observes that many researchers have been experimenting with the use of platinum nanoparticles for fuel cells, but the results of the particle size effect on the activity so far have been contradictory and controversial. “Some people see the activity increase, some people see it decrease,” Lee explains. “There has been a controversy about how size affects activity.”

The new work shows that the key factor is not the size of the particles but the details of their surface structure. “We show the details of surface steps presented on nanoparticles and relate the amount of surface steps to the activity,” Chen says. By producing a surface with multiple steps on it, the team doubled the activity of the electrode. Team members are now working on creating surfaces with even more steps to try to increase the activity further. Theoretically, it should be possible to enhance the activity by orders of magnitude.

Shao-Horn suggests that the key factor is the addition of the edges of the steps, which seem to provide a site where it’s easier for atoms to form new bonds. More steps create more of those active sites. In addition, the team has shown that the step structures are stable enough to be maintained over hundreds of cycles. That stability is key to being able to develop practical and effective direct methanol fuel cells.

Excerpted from the article in MIT News *by David Chandler.*

Fuel cells are promising as a replacement for batteries in portable electronic devices. Because the electrodes are made of platinum, increasing their efficiency means that much less of the expensive metal is needed to produce a given amount of power.

Around campus

The MIT Museum, course 2.009, and commencement

MechE at the Museum

Exploring the Arctic Seafloor
Photographs by Chris Linder
Through June 7, 2010
Compton Gallery, 77 Massachusetts Avenue, Cambridge

A new MIT Museum exhibition *Exploring the Arctic Seafloor* chronicles the 2007 voyage of the icebreaker *Oden*, a historic Woods Hole Oceanographic Institution (WHOI) expedition launched in the International Polar Year. MIT/WHOI Joint Program alumni Dr. Hanumant Singh PhD '95, co-leader of the expedition, and photographer Chris Linder SM '96 joined a team of scientists, researchers, and photographers for a 40-day journey to study the 1,800 kilometer-long Gakkel Ridge. Linder created the exhibition in collaboration with Chicago's Field Museum and graphics experts at WHOI.

The Holopod Camera
Installation by Professor George Barbastathis and Cabell Davis
Ongoing
MIT Museum, 265 Massachusetts Avenue, Cambridge

In this interactive exhibit, visitors experiment with a modified version of the state-of-the-art Holopod camera, an innovative oceanographic instrument used to study the tiny life cycles of zooplankton. The imaging system was jointly created by Mechanical Engineering Associate Professor George Barbastathis, graduate students Nick Loomis and Jose Dominguez-Caballero, and Woods Hole Oceanographic Institution scientists.

Learn more about these exhibitions at http://web.mit.edu/museum.

2.009 course highlights

Teams of seniors in David Wallace's 2.009 course pooled their engineering talent and creativity last fall to construct prototype inventions that addressed the theme of "emergency." Final products were graded on ingenuity, performance, and the sustainability of the business plan. The class culminated in an evening of presentations when teams marketed their inventions to fellow students, product designers, entrepreneurs, and alumni. Emergency innovations included:

AquAirius—An adjustable buoyancy backboard for rescuing injured swimmers. The design is easier to maneuver than the classic backboard and allows for greater neck stabilization during rescues.

Ixa Walker—A stable and maneuverable walker engineered to help users rise from a seated position to an upright walking position. The lightweight device incorporates a custom-designed hinge that assists the transition from sitting to standing.

Isis Helmet—A cycling helmet capable of detecting severe crashes. When the helmet senses a significant impact and the rider is unable to signal wellbeing, the device initiates a rescue by sending an emergency message to 911.

Find information and videos of the final presentations at http://web.mit.edu/2.009.

Join us in the tent

The Department of Mechanical Engineering will host a reception immediately following commencement on Friday, June 4, 2010. We hope you'll join us as we celebrate our graduates, reconnect with friends, and showcase our latest research. The MechE tent will be located on Memorial Drive in front of Hayden Memorial Library. See you there!

High-flying alumni

MechE alumni are soaring—in the entrepreneurial realm and in low-Earth orbit

Image: IRobot

Image: NASA

Image: NASA

Helen Greiner SB ’89, SM ’90

With CEO Helen Greiner at the helm, all eyes are on CyPhy Works, a new skunk works for robotics that Greiner launched as a sequel to her celebrated tenure at iRobot. As cofounder, president, and chairman, she and cofounders Colin Angle and Rodney Brooks transformed iRobot from a fledgling MIT spin-off into a $300 million business and the global leader of practical robots. Greiner’s numerous accolades include a place on the prestigious “America’s Best Leaders” list compiled by the Kennedy School and *U.S. News and World Report*. She also has been honored with the Pioneer Award from the Association for Unmanned Vehicle Systems International, recognized as an “Innovator for the Next Century” by *Technology Review*, and selected as one of Ernst & Young’s “New England Entrepreneurs of the Year” for 2003. Greiner was inducted into the Women in Technology International Hall of Fame in 2007.

Christopher Cassidy SM ’00

NASA astronaut Chris Cassidy is the latest MechE alumnus to return from space. Cassidy completed his first orbital flight on board the Space Shuttle *Endeavor* in July 2009. He was part of the NASA mission STS-127 charged with delivering essential components to the International Space Station (ISS). Upon docking, Cassidy was one of 13 astronauts at the ISS—the largest single contingent in the Space Station’s history. He performed three spacewalks and logged more than 18 hours of extravehicular activity during the mission. Before joining NASA, Cassidy served ten years as a member of the U.S. Navy SEALs.

Michael Massimino SM ’88, ME ’90, PhD ’92

NASA astronaut and engineer Michael Massimino has given the Hubble space telescope its final tune-up. Massimino was part of the seven-person crew of the Space Shuttle *Atlantis* mission STS-125 that completed a series of delicate adjustments to the aging telescope in May 2009. Hubble was released into orbit nearly twenty years ago, and these latest fixes are expected to extend the lifespan of the deep space imaging telescope another five to seven years. While in space, Massimino completed more than 15 hours of spacewalks and worked to overcome obstacles like frozen bolts, stripped screws, and stuck handrails.

Filling the skies

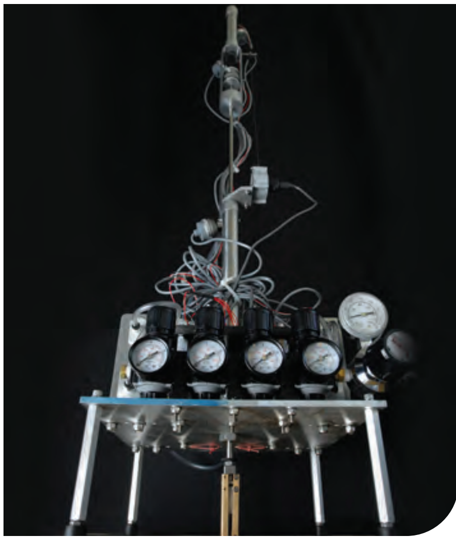
Thirty four NASA astronauts – including nine from MechE – hail from MIT, more than from any other nonmilitary institution in the country. In fact, MIT fliers have traveled on more than a third of U.S. space flights. In addition to Cassidy and Massamino, recent missions placed four MIT alumni in orbit simultaneously: Stephen Bowen ENG ’93, Heidemarie Stefanyshyn-Piper SB ’84, SM ’85, Michael Fincke SB ’89, and Gregory Chamitoff PhD ’92.

Find out more ►

Michael Massamino and Helen Greiner were both on campus last fall. See videos from their visits at http://mitworld.mit.edu.

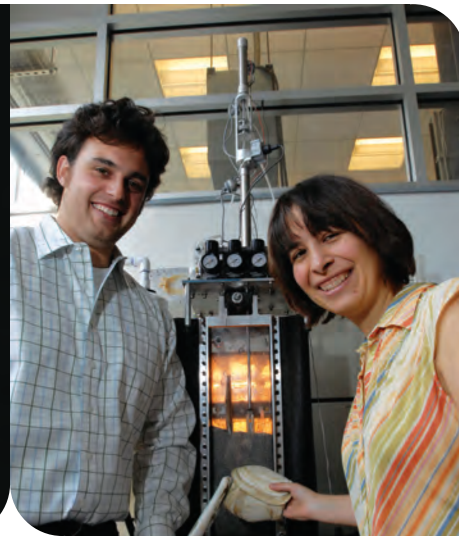
RoboClam

The humble razor clam inspires underwater innovation



The RoboClam anchoring device

Images: Donna Coveney



Mechanical Engineering Professor Anette Hosoi and graduate student Amos Winter developed RoboClam, which could lead to "smart" anchoring technologies

RoboClam, the metal device on the right, next to the inspirational razor clam to the left

Dubbed "the Ferrari of underwater diggers," the tenacious razor clam has inspired the invention of a new MIT robot by a team lead by Anette "Peko" Hosoi, associate professor in the Department of Mechanical Engineering. Hosoi and Amos Winter, a graduate student in her lab, along with engineers at Bluefin Robotics Corp, are collaborating to explore the performance capabilities of clam-inspired digging.

"Our goal was to develop a lightweight anchor that you could set and then easily unset, something that's not possible with conventional devices," Hosoi says. RoboClam may indeed lead to the development of a "smart" anchor that burrows through the ocean floor to reposition itself and even reverse, making it easier to recover.

Such a device could be useful, for example, as a tether for small robotic submarines that are routinely repositioned to monitor variables, such as currents and temperature. Further, a device that can burrow into the seabed and be directed to a specific location could be useful as a detonator for buried underwater mines. Winter presented the team's results at a recent meeting of the American Physical Society.

Novel propulsion mechanisms

For several years, Hosoi's research has focused on propulsion mechanisms inspired by nature. So when faced with the anchor problem, the team thought, "Is there an animal that's well adapted to moving through sediment on the seafloor?" The first stage of the research, Winter says, involved "looking at all the organisms I could find that dig into the ocean bottom, stick to it, or cling to it mechanically." His search uncovered the razor clam. About seven inches long by an inch wide, the razor clam can move at approximately a centimeter a second. "You have to dig fast to catch them," says Winter, who became a licensed clam digger as a result of the research.

Another reason the razor clam makes a good model for novel anchors: it can dig deeply (up to about 70 centimeters). Most important, in a measure of anchoring force—how hard you pull before an anchor rips out of the soil compared to the energy required to embed it—the razor clam reigns supreme. "It beats everything, including the best anchors," Winter explains, "by at least a factor of 10."

Research subject in hand, one of the team's first tests gave perplexing results. They pushed a clam shell cast in epoxy into sand composed of glass beads and compared the amount of force necessary to do so to the razor clam's performance. They found a major discrepancy between the two. "They're much too weak to do what they do," Hosoi says, "so we knew they were doing something tricky."

To test the discrepancy, Winter created a glass-sided box filled with water and beads, added a living clam, and watched the animal burrow. It turns out to be a multistep process. The animal wiggles its tongue-like "foot" down into the sand, then makes a quick up-and-down movement while opening and closing its shell. Together, these movements propel it.

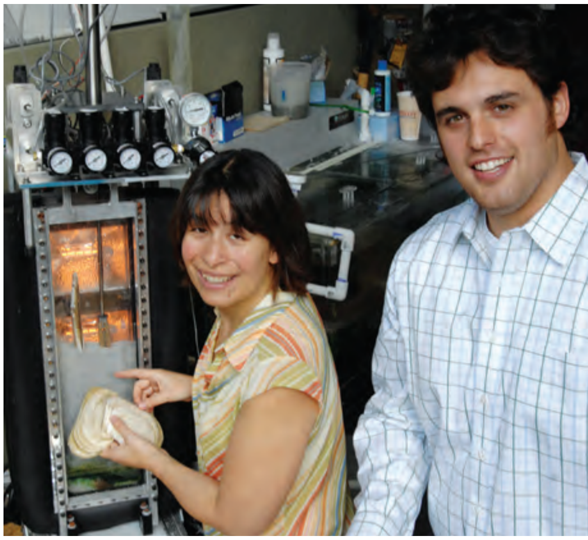
Making quicksand

By filming the movement of the beads, Winter made a startling discovery. The clam's quick up-and-down and opening-and-closing movements turned the waterlogged sand around it into a liquid-like quicksand. Experiments showed that moving through a fluidized substrate (the quicksand) rather than a packed granular medium (ordinary sand) drastically reduces the drag force on the clam's body, bringing it to a point within the animal's strength capabilities.

Over the summer, Winter completed construction of the RoboClam itself. Although only about the size of a lighter, it is supported by a large apparatus of pressure regulators and pistons that control such variables as how hard the robot is pushed in each direction.

This work was sponsored by Bluefin, Battelle, and Chevron.

Excerpted from the MIT Tech Talk *article by Elizabeth Thomson*



Mechanical Engineering Professor Anette Hosoi and graduate student Amos Winter testing the RoboClam

In a measure of anchoring force—how hard you pull before an anchor rips out of the soil compared to the energy required to embed it—the razor clam reigns supreme...

EVT hits the road

Students pursue an all-electric vehicle with rapid recharge

Under the hood after conversion to battery power

EVT students test drive their electric vehicle in Cambridge, MA

Mechanical Engineering sophomore Mike Nawrot trimming the alignment of the 250 horsepower drivetrain

If you take the 2010 Mercury Milan modified by the MIT Electric Vehicle Team (EVT) out for a spin, you might easily mistake it for a typical sedan—minus the engine noise, of course. This battery-powered conversion, dubbed "elEVen," comfortably seats four adults, does 0 to 60 in nine seconds with a top speed of 100 mph, has a range of 65 miles (with the ultimate goal of 200 miles), and recharges in less than 11 minutes.

A conversion of the Ford CD3 platform—the core of the Ford Fusion, Lincoln MKZ, and Mercury Milan—the elEVen demonstrates how an all-electric vehicle can meet the needs of the average driver and perform on a par with conventional cars under real-world operating conditions. "Every component of the drive train conversion was designed, machined, and installed by EVT members," says MechE senior Radu Gogoana. "That includes the quad-chain 12,000 rpm speed reducer."

The lithium-ion battery pack at the heart of the elEVen is a product of A123Systems, a company cofounded by MIT professor Yet-Ming Chiang and MIT Sloan alumnus Ric Fulop SF '06. The battery is ideal for automotive applications because its lithium-ion phosphate cells have extremely low internal resistance, thus can be recharged rapidly. They are also chemically stable, which helps make them safe for consumer use.

"The EVT's primary motivation is to demonstrate the potential of new battery and electric drive technologies," explains Gogoana. "We provide research and educational opportunities for MIT students, present our research at energy, transportation, and technical events, and teach classes for middle school and high school students. We truly believe that by getting the word out we can accelerate the transition to electric vehicles."

The EVT is partially supported by the MIT Department of Mechanical Engineering. The students are actively seeking new sponsors to fund further work on the elEVen project through component donations and financial support.

Find out more ►

Learn more about the EVT's work and its fleet of electric vehicles at http://web.mit.edu/evt.

Student awards

Awards ceremony May 2009

GRADUATE STUDENT AWARDS

American Society for Precision Engineering 2008 R.V. Jones Memorial Scholarship for Best Paper
Vijay Shilpiekandula

Clement F. Burnap Award for Outstanding Masters of Science in the Marine Field
Filippos Chasparis

Department Service Award for Outstanding Service to the ME Department
Barry M. Kudrowitz

Goodwin Medal for Most Outstanding Teaching Assistantship (conferred by the MIT Office of Graduate Education)
Barry M. Kudrowitz

Luis de Florez Award for Scholarly Invention/Innovation Award
Daniel S. Codd, Randy H. Ewoldt

Luis de Florez Award for Technology Invention/Innovation Award
Brian Chan, Amos G. Winter

MIT 50K Arab Business Plan Competition
Husain Al-Mohssen, Ghassan Fayad

Meredith Kamm Memorial Award for the Outstanding ME Woman Graduate Student
Kirki Kofiani, Chen-Rei Wan

National Inventors Hall of Fame Collegiate Inventors Award
Heejin Lee, Timothy Lu

SoE Graduate Student Extraordinary Teaching and Mentoring Award
Gunaranjan Chaudhry

Wunsch Foundation Silent Hoist and Crane Award for Academic Excellence and Outstanding Master's Thesis
Yi (Ellen) Chen, Irene M. Berry

Wunsch Foundation Silent Hoist and Crane Award for Academic Excellence and Outstanding PhD Thesis
Keith V. Durand

Wunsch Foundation Silent Hoist and Crane Award (for outstanding TAs in Course 2.002)
Shawn A. Chester, David L. Henann

Wunsch Foundation Silent Hoist and Crane Award (for outstanding TAs in Course 2.003)
Brendan J. Englot, Brendan P. Epps

UNDERGRADUATE STUDENT AWARDS

AMP Inc. Award for Outstanding Performance in Course 2.002
Maria R. Bageant, John G. Boghossian, Vazrik Chiloyan, Teerawu Wannaphahoon

Alfred A.H. Keil Ocean Engineering Development Fund Award for Excellence in Broad-Based Research in Ocean Engineering
Stephanie J. Chin, Charles D. Field

BJ and Chunghi Park Award for Outstanding Performance in Manufacturing
Mary Beth DiGenova, Ethan A. Huwe

Carl G. Sontheimer Prize for Creativity and Innovation in Design
Justin Y. Lai, Zachary A. Trimble

International Design Competition
Edward M. Grinnell, Pablo J. Bello, Elvine P. Pineda, Arielle G. Fischer (top four individual winners of 2.007 Spring 2009)

James Dyson People's Choice Design Award
Andrew Bishara, Adelaide Calbry-Muzyka, Kwame Hall, Josh Karges, Michelle Lustrino, Nicole O'Keeffe, Sam Phillips, Sarah Shieh, Xiao Wei Chen, Isa Castro, Wenxian Hong, Jennifer Moore, Karina Pikhart, Rachel Tatem, Jodie Wu (2.009 6DOT team)

John C. and Elizabeth J. Chato Award for Excellence in Bioengineering
Julia C. Zimmerman

Lauren Tsai Memorial Award for Academic Excellence by a Graduating Senior
Julia C. Zimmerman

Luis de Florez Award for Invention/ Innovation (team project)
Adelaide S. Calbry-Muzyka, Joshua M. Karges, Karina N. Pikhart, Maria N. Prus, Trevor J. Shannon, Rachel E. Tatem, Tylor J. Hess

Luis de Florez Award for Invention/ Innovation (individual projects)
Adrienne Watral, Mario A. Bollini, Blake A. Sessions

Peter Griffith Prize for Outstanding Undergraduate Thesis
Adam T. Paxson

Society of Naval Architecture and Marine Engineering Award for Outstanding Undergraduate in the Marine Field
Stephanie J. Chin, Charles D. Field

Wallace Prize for Scholarship in Ocean Engineering
Jenna McKown

Whitelaw Prize (for originality in 2.007 design and contest)
John M. Walton, Charles Z. Guan, Blake A. Sessions, David S. Anderson, Benjamin J. Peters

Wunsch Foundation Silent Hoist and Crane Award (for academic excellence and outstanding senior thesis)
Michael L. Stern, Fiona R. Hughes

Wunsch Foundation Silent Hoist and Crane Award (for academic excellence)
Fiona R. Hughes, Adam Paxson, Nathaniel Sharpe, Julia C. Zimmerman

SELECT HONORS 2009

Gates Cambridge Trust Scholarship
Orian Welling

Marshall Scholarship
Nathaniel Sharpe

Harry S. Truman Scholarship
Natasha Scolnik

National Defense Science & Engineering Graduate Fellowships
Matthew Gilbertson
William Hesse

National Science Foundation Graduate Research Fellowships
Michael Barry
Madalyn Berns
Batya Fellman
Maria Luckyanova
Raathai Molian

Faculty awards

Rohan Abeyaratne
Abeyaratne has accepted a three-year appointment in Singapore to serve as codirector of the MIT Singapore SMART program. He recently completed a distinguished seven-year term as Department Head.

Lallit Anand
Anand was named the Warren and Towneley Rohsenow Professor of Mechanical Engineering.

John G. Brisson
Brisson received the Best Paper Award from the *Journal of Cryogenics*.

Cullen R. Buie
Buie received the Best Student Paper award from ASME.

Tonio Buonassisi
Buonassisi was named the SMA Career Development Assistant Professor in Manufacturing.

Gang Chen
Chen was named the Carl Richard Soderberg Professor of Power Engineering. He was elected a fellow of the American Association for the Advancement of Science and a member of the National Academy of Engineering. He also received the ASME Heat Transfer Memorial Award.

Stephen H. Crandall
Crandall received the ASME Applied Mechanics Division Thomas K. Caughey Dynamics Award.

C. Forbes Dewey, Jr.
Dewey was named a fellow of the Royal Academy of Engineering of the United Kingdom.

Daniel D. Frey
Frey received the Joel Spira Teaching Award and the Big Screw Award.

Ahmed F. Ghoniem
Ghoniem received the KAUST Investigator Award.

Leon R. Glicksman
Glicksman received the ASME Heat Transfer Memorial Award. He also received the American Society of Heating, Refrigeration and Air-Conditioning Engineers (ASHRAE) Distinguished Service Award.

Alan J. Grodzinsky
Grodzinsky received the Institute for Advanced Studies Award from University of Western Australia.

David E. Hardt
Hardt was appointed as the Graduate Officer for the MIT Department of Mechanical Engineering.

John B. Heywood
Heywood received the SAE Barry D. McNutt Award for Excellence in Automotive Policy Analysis.

Neville J. Hogan
Hogan was named the Sun Jae Professor of Mechanical Engineering. He also was the ASME Rufus Oldenburger Medalist and received the ASME Henry Paynter Outstanding Investigator Award.

Anette (Peko) Hosoi
Hosoi was promoted to Associate Professor with Tenure. She also was selected to deliver the Batchelor Lecture at Cambridge University.

Roger D. Kamm
Kamm was selected to speak at the Midwest Mechanics Lecture Series. He also was elected a Fellow of the American Association for the Advancement of Science.

Rohit Karnik
Karnik was named an Alex d'Arbeloff Career Development Assistant Professor. He also won a National Science Foundation Career Award with a proposal titled “Cell Separation by Rolling on Asymmetric Receptor Patterns.”

John J. Leonard
Leonard was named Director of the MIT-Ford Alliance.

Pierre Lermusiaux
Lermusiaux was named the Doherty Associate Professor in Ocean Utilization.

John H. Lienhard
Lienhard was named the Samuel C. Collins Professor of Mechanical Engineering. He also was appointed the Associate Head for Education of the MIT Department of Mechanical Engineering.

Henry S. Marcus
Marcus received the William Selkirk Owen Lifetime Achievement Award of the Webb Institute Alumni Association.

Gareth H. McKinley
McKinley was appointed the Associate Head of Research for the MIT Department of Mechanical Engineering.

Sanjay E. Sarma
Sarma was named a MacVicar faculty fellow.

Yang Shao-Horn
Shao-Horn was promoted to Associate Professor with Tenure. She also received the Charles W. Tobias Young Investigator Award of the Electrochemical Society and the Tajima Prize of the International Society of Electrochemistry.

Alexander H. Slocum
Slocum received the ASME Machine Design Award.

Michael S. Triantafyllou
Triantafyllou was named the William I. Koch Professor of Marine Technology.

Nam P. Suh
Suh received the ASME Medal.

Kripa K. Varanasi
Varanasi was named a d'Arbeloff Career Development Assistant Professor. He won a National Science Foundation Career Award with a proposal titled "Fundamental Studies of Condensation Phenomena on Heterogeneous and Hierarchical Nanoengineered Surfaces."
He also received the ASME Nanotechnology Best Poster Award and the Charles E. Reed Award.

David R. Wallace
Wallace received the Jacob P. Den Hartog Distinguished Educator Award.

Evelyn N. Wang
Wang received the DARPA Young Faculty Award. She also was named the Esther and Harold E. Edgerton Career Development Assistant Professor.

Maria C. Yang
Yang was named the Robert N. Noyce Career Development Assistant Professor of Mechanical Engineering and Engineering Systems.

Dick K.-P. Yue
Yue was the Peachman Distinguished Lecturer at the University of Michigan at Ann Arbor.

New MechE faculty


Cullen R. Buie
Assistant Professor


Sangbae Kim
Assistant Professor


Alexander Mitsos
Assistant Professor


Kripa K. Varanasi
d'Arbeloff Assistant Professor of Mechanical Engineering

Images: Tony Pulsone

Cullen R. Buie, Assistant Professor

As director of the MIT Laboratory for Energy and Microsystems Innovation (LEMI), Professor Buie is studying the electrokinetic properties of bacteria used in microbial fuel cells with a grant from the MIT Research Support Committee. He is also using electrokinetics to create nanoporous surfaces for applications in electrochemical systems, biological systems, and surface coatings. Buie received his PhD in mechanical engineering from Stanford in 2009 and joined the MIT faculty in January 2010.

Sangbae Kim, Assistant Professor

Professor Kim's research focuses on the convergence of mechanical engineering, biology, and material science on robotic systems. His design approaches integrate a range of technologies based on biological observations as manifested in his previous research on the directional adhesive and the robotic gecko.

Based on cues from biological systems, Kim is pursuing a new research field called hyperdynamic robotics by establishing a multi-disciplinary research foundation that includes elastomeric compliance design, composite manufacturing, high power density actuator development, and hierarchical control architecture. He received his PhD in mechanical engineering from Stanford in 2008 and joined the MIT faculty in May 2009.

Alexander Mitsos, Assistant Professor

Professor Mitsos' work centers on the optimization of chemical, biological, and energy systems using modeling and simulations. His research interests include the optimal design and operation of microchemical systems, phase equilibrium thermodynamics, combustion with CO_2 sequestration, solar thermal and clean water, and the development of numerical algorithms for global optimization. Mitsos received his PhD in chemical engineering from MIT in 2006 and joined the MIT faculty in January 2009.

Kripa K. Varanasi, d'Arbeloff Assistant Professor of Mechanical Engineering

Professor Varanasi received his PhD in mechanical engineering from MIT in 2004. Since that time, he has been a lead research scientist in the Energy & Propulsion and Nanotechnology programs at the GE Global Research Center, Niskayuna, NY, where he established research programs on nano-engineered materials, was the PI for the DARPA Thermal Ground Plane program, and received several technical and leadership awards. The primary focus of his research at MIT is in the development of nano-engineered surfaces and coating technologies that can result in transformational performance enhancements and avoidance of CO_2 emissions. He has filed more than 25 patents in this area. He joined the MIT faculty as d'Arbeloff Assistant Professor of Mechanical Engineering in January 2009.

Talking shop

Professor Franz Hover

Jordan Lewis asks MechE Professor Franz Hover about ocean-going electrical systems and turning a collection of odds and ends into an intelligent machine.

Tell us about your work with large-scale electrical systems. First, what constitutes "large?"

An oilfield, a naval ship, the power grid of the United States. All these large systems are growing in complexity. Our goal is to incorporate more components—or nodes—without reducing the reliability of the system. If the initial design is not optimized, it will mean challenges in construction, repair, and functionality. To strengthen the design, we use algorithms that select the best configuration for the nodes within a given system. The programming for these algorithms can be refined and calibrated to achieve a balance between efficiency and robust characteristics.

Explain the kind of impact this would have on board a ship.

Think about electricity on a ship for a moment. The vessel might be cruising in very remote stretches of ocean far from shore. As it is cruising, it is generating and serving power to all the onboard electric components. Reliability is important on land, but out here, it must be 100%. And if there's a power outage or electrical failure, it must be resolved immediately. Obviously, if the power is interrupted to the ship's steering, communications, or navigation, it could be very problematic. The design components we are introducing in these algorithms work to reestablish power to every compromised node very quickly—perhaps less than a second.

You teach Design of Electromechanical Robotic Systems – 2.017. Is that as fun as it sounds?

Yes! For this class, we get the coolest sensors, gadgets, and tools we can find, then set a high bar for each team to solve a complex problem found in real working environments. We're asking them to design and build large, integrated projects. Last semester, one team built an autonomous boat that was steered by GPS, then switched over to a sonar guidance system. The other project was a quad-rotor helicopter that incorporated an on-board camera, compass, and GPS, giving it the ability to land in a precise location. Each team combined the instrumentation and customized control algorithms to complete its mission. It was great fun to watch the students test the projects and prove how the designs managed the wind and waves.

Professor Franz Hover joined the Mechanical Engineering faculty in 2007. He received his ScD from the MIT/WHOI Joint Program in 1993 and worked at MIT as a research engineer after graduation. Hover has a broad research focus that includes autonomous underwater vehicles (AUVs), the all-electric ship, and large systems engineering. He recently developed an underwater robot capable of monitoring large ship hulls while they wait at anchor. Guided by sonar and imaging sensors, the robot can map the ship's hull and relay images of foreign objects to the crew for further investigation.

MechE Connects editor Jordan Lewis is a communications specialist in the Department of Mechanical Engineering.

MechE research news

New DOE Research Centers

The White House has announced that MIT will be home to two new multimillion-dollar Energy Frontier Research Centers (EFRCs) being established by the U.S. Department of Energy Office of Science. The Solid State Solar Thermal Energy Conversion Center (S^3TEC) will be directed by Gang Chen, the Carl Richard Soderberg Professor of Power Engineering in the Department of Mechanical Engineering. A second center will be headed by electrical engineering Associate Professor Marc A. Baldo. A total of forty-six EFRCs are being set up at universities, national laboratories, nonprofit organizations, and private firms across the nation.

S^3TEC will receive initial five-year funding of $17.5 million to pursue advanced energy research. The center's objective is to create novel solid-state materials for the conversion of sunlight and heat into electricity. "As global energy demand grows over this century, there is an urgent need to reduce our dependence on fossil fuels and imported oil and curtail greenhouse gas emissions," says U.S. Secretary of Energy Steven Chu. "Meeting this challenge will require significant scientific advances. These centers will mobilize the enormous talents and skills of our nation's scientific workforce in pursuit of the breakthroughs that are essential to make alternative and renewable energy truly viable as large-scale replacements for fossil fuels."

EFRC researchers will take advantage of new capabilities in nanotechnology, high-intensity light sources, neutron scattering sources, supercomputing, and other advanced instrumentation to lay the scientific groundwork for fundamental advances.

MechE Hosts Clean Water & Energy Center

The MIT Department of Mechanical Engineering (MechE) and King Fahd University of Petroleum and Minerals (KFUPM) in Dhahran, Saudi Arabia have launched a seven-year research and education program focused on solar energy, the desalination of seawater, and other technologies related to the production of fresh water and low-carbon energy. The joint effort will lay the groundwork for the creation of the Center for Clean Water and Clean Energy at MIT and KFUPM. The center will be housed within the MIT Department of Mechanical Engineering.

Under the direction of John H. Lienhard, Samuel C. Collins Professor of Mechanical Engineering, and Professor Kamal Youcef-Toumi, the center is expected to conduct 16 joint research projects and eight joint educational projects over seven years. Approximately 20 MIT faculty members will team up with a corresponding number from KFUPM during the center's first year to research topics of mutual interest. The joint projects will be funded by KFUPM.

Faculty and graduate students from KFUPM will have the opportunity to spend one or two semesters at MIT, and faculty from MIT will visit KFUPM for one to two weeks each year. The center will include a groundbreaking outreach program that will bring Saudi women engineers and scientists to MIT for research and educational projects.

SMART Opens BioSystem Group in Singapore

The Singapore-MIT Alliance for Research and Technology (SMART) has established the BioSystem and Micromechanics Interdisciplinary Research Group (BioSyM IRG) with the support of the Singapore National Research Foundation (NRF). The BioSyM IRG brings together a diverse team of faculty members and researchers from MIT and Singapore's universities and research institutes to develop biotechnologies that will produce the next generation of discoveries in biology. Roger D. Kamm, Germeshausen Professor of Mechanical and Biological Engineering, is the lead principal investigator for the group.

The primary focus of BioSyM is to develop technologies that will help answer critical biological and medical questions associated with a variety of diseases. The group also seeks to provide new technological solutions to the healthcare industry and to the broader Singapore research infrastructure. Established in 2007, SMART is MIT's first research center outside Cambridge and its largest international research endeavor. Professor Rohan Abeyaratne, former head of the Department of Mechanical Engineering, serves as the director of SMART. SMART is also the initial center at the Campus for Research Excellence and Technological Enterprise (CREATE) being developed by the NRF.

Chevron-sponsored OE Partnerships

The Center for Ocean Engineering's productive, long-term sponsored research program with Chevron is helping to establish close educational, training, and research links between academia and industry in areas of mutual interest related to oil and gas production. The program's research focus is on remote development and production of oil and gas in ultra-deep waters.

The Chevron program offers two levels of support for sponsored research. The first is for seed-level projects designed to develop promising research ideas and establish collaborative links between MIT and Chevron researchers. Seed projects are awarded $40,000 to $80,000 and are expected to span approximately one year. The second level of support enables successful seed projects to evolve into full research projects. Such projects are funded at $100,000 to $150,000 per year for a period of two to three years.

Battelle Grants for National Security Research

The Department of Mechanical Engineering and Battelle have teamed up to award as many as five one-year seedling challenge grants of approximately $50,000 to $80,000 for one year. The grants, which have the potential for renewal, will support innovative research related to national security and associated commercial applications. Areas of interest include nanoscale heat transfer, advanced cooling, supramolecular chemistry, advanced multifunctional materials, comfortable/stretchable electronics, production of superhydrophobic surfaces, scalable separation methods for single-wall carbon nanotubes, and production of patterns with sub-250 nanometer features over large curved surfaces.

New NSF Center for Integrated Cellular Systems

The Emergent Behaviors of Integrated Cellular Systems Center (EBICS) has been founded at MIT with a $25 million grant from the National Science Foundation (NSF). Roger Kamm, MIT's Germeshausen Professor of Mechanical and Biological Engineering, will be the center's founding director.
Part of the NSF's Science and Technology Centers Integrative Partnerships program, EBICS is a partnership among MIT, the University of Illinois at Urbana-Champaign, and the Georgia Institute of Technology. The center's objectives are to dramatically advance research in complex biological systems, to create new educational programs based on this research, and to demonstrate leadership involving groups traditionally underrepresented in science and engineering.

MITMECHE

Massachusetts Institute of Technology
Department of Mechanical Engineering
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Coming in the next issue:

- The Pappalardo II laboratories complete their renovations
- The KFUPM Center for Clean Water and Energy at MIT
- Course 2.674 introduces undergraduates to micro/nanotechnologies

Alex Slocum, the Neil and Jane Pappalardo Professor of Mechanical Engineering, demonstrates his plan for offshore wind turbines to President Obama, Massachusetts Governor Deval Patrick, MIT President Susan Hockfield, and Senator John Kerry during a visit to campus on Friday, Oct. 23, 2009. "It's clear that he really listens," Slocum says. "He asked some really good questions. He wanted to know what can be done, and what is being done. It was really refreshing."

Image: AP Photo by Gerald Herbert

psb: 09-08-0426