MITMECHE

Fall 2011

Vol. 2, No. 2 Published twice a year

Massachusetts Institute of Technology

MechEConnects

News from the MIT
Department of Mechanical Engineering

In This Issue:

In MechE, Viable Clean Energy Isn't Just Wishful Thinking

Mechanical Engineering faculty members are solving the world's energy crisis in their own creative ways.

| ► p. 4 |

MITMECHE

Addressing the World's Energy Challenges

Dear Friends,

Research in Mechanical Engineering has long focused on societal needs, using the depth and breadth of our capabilities to bring innovative technical solutions to a range of pressing issues facing the world. The complexity of the world's energy challenges has drawn Mechanical Engineering faculty from across the department into energy research. In this issue, we present a portfolio of research activities that are tackling the challenges of developing the next generation of solutions for clean and renewable energy. Our faculty, their students and their postdocs cover a wide spectrum of solutions. You will read about advances in renewable energy sources—process optimization of photovoltaic materials and the design and use of thermoelectric materials for harnessing solar energy, storage of solar energy, new technologies for wind energy, electrochemical energy conversion and storage— as well as the development of technologies for cleaner conversion and use of fossil fuels.

Our focus on societal needs also permeates our project-based classes. This issue features a story on our popular Course 2.75, Precision Machine Design. In recent years, Professor Alex Slocum has teamed students with medical professionals to address a need presented by the medical team. In the MIT spirit of mens et manus, the students learn the complete design cycle all the way up to full prototype development and testing through active engagement. These students work directly with real clients on real problems, and after graduation they often go on to create successful startups based on their inventions. In fact, a team of students from last year's course has recently secured investment funding for their Sombus Sleep Shirt, which allows doctors to monitor their patients' sleep from the comfort of their own home.

Finally, I would like to thank you for your support which is instrumental in our leadership of our discipline and pivotal to our ability to continue to attract top student and faculty talent to MIT. We are pleased once again to have our undergraduate and graduate programs ranked #1 by US News & World Report as well as all other national and international rankings.

MechE Connects is one small mechanism for keeping our community connected. In an effort to improve and expand our web presence, I would like to request your participation in an on-line usability survey (https://www.surveymonkey.com/s/YDFJYRJ). As MIT Mechanical Engineering alumni, your input is valuable in helping build our community and keep you linked to the department.

Sincerely,

Mary C. Boyce

Mary C. Boyce
Ford Professor of Engineering and Department Head

Massachusetts Institute of Technology

Fall 2011 | Vol. 2, No. 2 Published twice a year

MechEConnects

News from the MIT
Department of Mechanical Engineering

► 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.

Table of Contents

Contact MechE

Department of Mechanical Engineering
Massachusetts Institute of Technology
77 Massachusetts Avenue, Room 3-174
Cambridge, MA 02139

E-mail: mecheconnects@mit.edu

mecheconnects.mit.edu

Newsletter Staff:

Alissa Mallinson
Editor/Writer

Sucharita Berger Ghosh
Administrative Officer

B. Harris Crist
Webmaster

Wing Ngan
Designer

Photo credits
Tonio Buonassisi, Stuart Darsch, Patrick Gilooly, Jonathon Harding, Istock.com, Alexander Mitsos, Tony Pulsone, Len Rubenstein, Susumu Sigitani, Department of Mechanical Engineering Archives

This newsletter was printed on Green Seal certified Mohawk Options which contains 100% postconsumer waste fiber and manufactured with Green-e certified renewable wind energy credits that match 100% of the electricity used in the operations.

In MechE, Viable Clean Energy Isn't Just Wishful Thinking

MechE Professors Find Creative Solutions to the Problems of Clean Energy

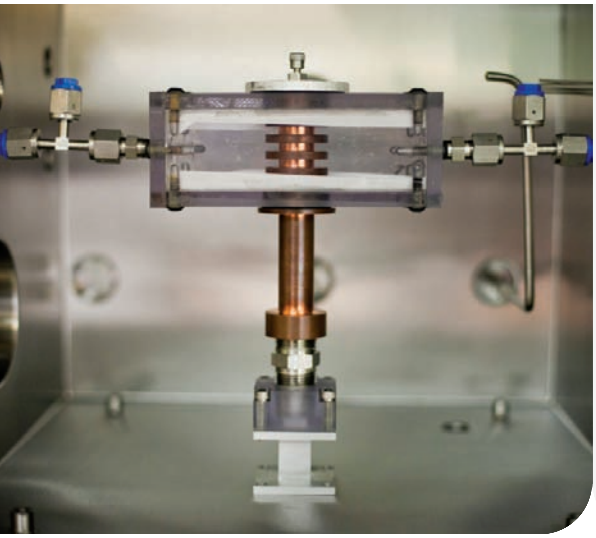
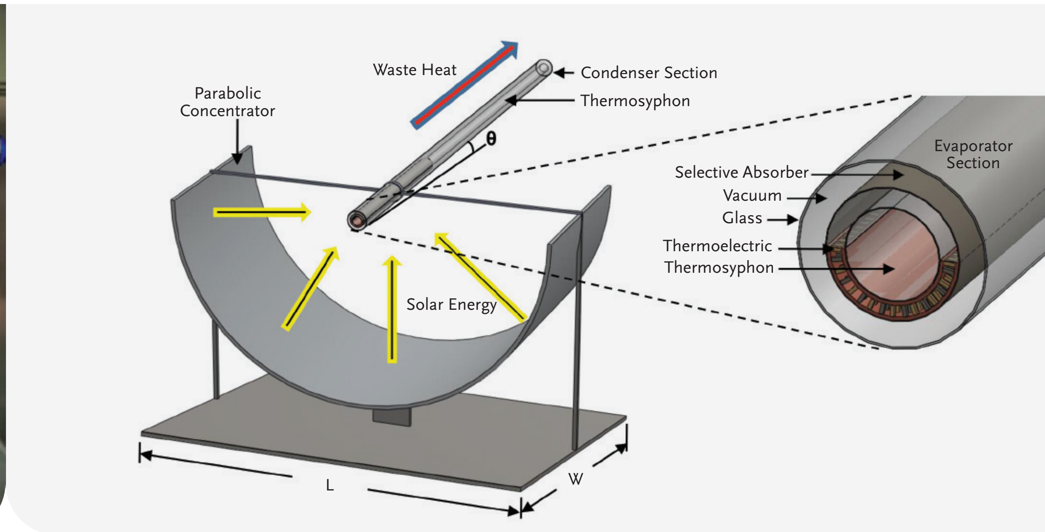


Image of the hybrid solar thermoelectric system (HSTE) prototype tested in a vacuum chamber. Research carried out by graduate student Nenad Miljkovic.



Schematic of the hybrid solar thermoelectric system (HSTE). Solar energy is focused by a parabolic concentrator on the evaporator section of the evacuated tube absorber (thermosyphon), which heats the TE hot side. The resulting temperature difference between the TE hot and cold sides produces electrical power while heat carried away (waste heat) by the thermosyphon (adjacent to the cold side) is transferred to the condenser section for the bottoming cycle. Research carried out by graduate student Nenad Miljkovic.

By now, most people agree that CO_2 emissions from "dirty" energy such as fossil fuels will have an increasingly degenerative effect on our planet, if it hasn't already. We know that the increase in CO_2 emissions reduces heat transfer from the Earth outwards, increasing the Earth's own temperature. We also know that our current sources of energy are limited, and while we may not be able to predict exactly when, at some point in the future, they will run out.

"There is no debate as to whether humans are causing an increase of carbon in the atmosphere because of our energy use," says Professor Tonio Buonassisi. "We are. You can debate whether or not that's an issue, but I think once you start doing the numbers, you quickly realize it's a real problem."

As a result, in the past few decades, many scientists, politicians, and the public at large have become increasingly concerned with going green and being clean, each with their own ideas about what the most important element is to address. The implications of energy are profound and impact the environment, the economy, and national security.

But what is clean energy exactly? It's worth defining, because there are many ways to go green. Clean energy refers specifically to energy technologies that either replace or eliminate CO_2 emissions in the atmosphere and instead rely on renewable sources of energy such as wind, solar, or biofuels, as well as technologies that reduce CO_2 emissions through carbon capture or other similar emerging technologies. Clean energy can be achieved and aided in many ways through energy storage or conversion techniques.

But the solutions – and we need a lot of them – as well as the expertise required to discover those solutions – are complicated and multidimensional.

"Clean energy is a technology that requires a lot of depth in a variety of disciplines in science and engineering, and is the kind of sector that is likely to bring innovation," says Professor Paul Sclavounos. "It is widely accepted for bringing economic growth and training students and entrepreneurs in the engineering complexities of energy technologies, including the understanding that it's not only the technology that matters, but also the acceptance of the technology by society both on economic and environmental grounds. For all these reasons, I believe clean energy is going to be one of the most important technologies of the 21st century."

Clean energy technologies utilizing the sun and the wind aren't new concepts, but there are still significant hurdles to making them viable – such as the cost and public acceptance Professor Sclavounos refers to, as well as the ever-important element of efficiency.

"When you think about green energy, you have to think about cost," says Professor Gang Chen. "Passionate people will put solar cells on their rooftop, but ordinary people are worried about putting food on the table and will take the cheapest available option. Research needs a fundamental side that doesn't concern itself with cost, but if you want to have real-world impact, you have to think about that too."

One way to decrease costs – and thus increase public acceptance – is to improve the efficiency of technological ideas that have already been discovered. In MechE, our professors are solving the need for efficient and cheap clean energy by looking at it in a myriad of ways, from solar and wind to thermal and chemical, from a myriad of increasingly multi-disciplinary perspectives, including design, mechanics, chemistry, physics, materials, architecture, and mathematics. Some are applying old methods to these new problems in creative and innovative ways, and some are discovering entirely new methods altogether.

Gang Chen: Nanostructures and Heat Transfer

One MechE faculty member, Gang Chen, the Carl Richard Soderberg Professor of Power Engineering and director of the Pappalardo Micro and Nano Engineering Laboratories, is tackling the problem with thermoelectrics at the nanoscale. Chen and his team recently developed a new material that conducts electricity well but not heat. By breaking up a piece of material into nanopowders and then reconnecting it, they realized that they could create a multitude of interfaces between the particles to impede heat flow.

Chen foresaw a way to utilize the resulting temperature difference to create a low-cost thermoelectric generator for converting solar energy into electricity. It is approximately eight times more efficient than any previously reported solar thermoelectric device, and, without any moving parts, would be much less expensive to produce.

The device, which is placed inside an airless vacuum chamber, works by collecting heat from the sun that warms up a black copper plate inside the generator. Meanwhile, because of the new material that impedes heat, the other side of the device remains at ambient temperatures, thus creating a 200-degree temperature difference and allowing the captured solar energy to be converted into electricity.

"This is a discovery we're quite proud of," says Chen. "It's an example where innovation in design can lead to eight times better performance than anything anyone has tried before."

Evelyn N. Wang: Heat Transfer and Energy Conversion

Evelyn N. Wang, Associate Professor of Mechanical Engineering, is similarly focused on heat transfer as a means of increasing efficiency and decreasing costs.

"Heat and mass transfer are one of the critical bottlenecks in making more efficient energy systems," says Wang. "Solutions in these areas allow us to rely less on fossil fuels and think more about which renewable resources we can take advantage of. When you think about clean energy, there's an important generation aspect, but I think the conservation side is very important as well."

Wang's most recent research has led to the development of a hybrid solar-thermoelectric system to more efficiently collect the sun's heat, rethinking existing systems that were costly and difficult to implement because of the inefficiency in their design.

"Our goal was to identify the key components of the system that were causing the bottleneck and find a way to fix them. In terms of a heat-transfer perspective, we asked ourselves questions such as, How do you collect solar energy more efficiently? How do you minimize emissive losses from the surface of absorbers? Can you utilize different novel structures or materials such that you can make phase change processes more efficient?"

The answers to those questions can be found in Wang's hybrid device, wherein a thermoelectric system is placed in the central tub of a parabolic trough so that it produces both hot water and electricity at the same time. A thermosiphon pulls heat from the thermoelectric "cold" side, and the resulting temperature gradient produces electricity. The thermosiphon, designed by Wang, is filled with a fluid that experiences phase change when it's heated up, allowing it to transport heat efficiently.

Paul Sclavounous: Wind Energy Design

Professor of Mechanical Engineering and Naval Architecture Paul Sclavounos went about solving the clean energy crisis yet another way: by using a floating turbine to gather offshore wind. His idea sprung from 30 years of experience as a naval architect and ocean engineer, designing and analyzing ships, high-speed vessels, sailing yachts, and offshore platforms. Sclavounos recognized an opportunity to apply technology used in deep oil and gas exploration to solve the public's NIMBY (Not in My Back Yard) outcry about turbines that were too close to shore. Even more, he realized he could harness a large amount of offshore wind energy at prices competitive with natural gas because the wind is so strong and steady at such distances.

Sclavounos's floating turbines rely on buoyancy for support, using steel cables that connect the corners of the turbine platform to a concrete block or other mooring system on the ocean floor.

"The specific design of a floater is a complex process," says Sclavounos. "The final product may look simple, but it is not easy. The size of the floater, the thickness of the anchoring lines, the type of anchors, how they will weather a big storm, and how much energy they can gather at a low cost are all complicated elements that have to work together."

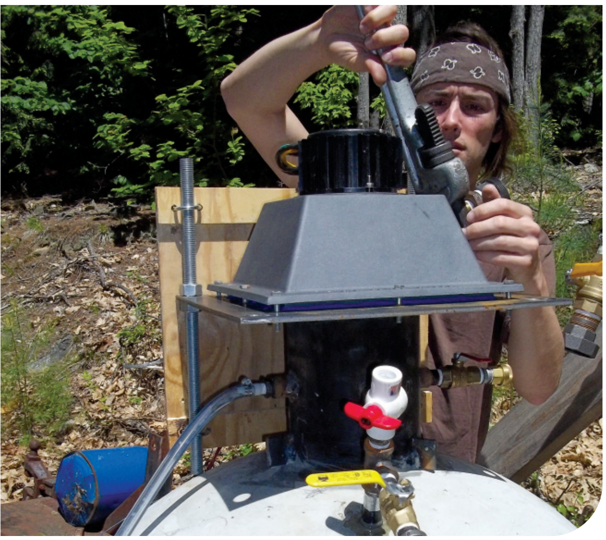
Like Chen, Sclavounos is concerned with more than just fundamentals. "At the end of the day, economics matter," he says. "Not only do you face competition and public acceptance, but you need to demonstrate that you can generate electricity at an acceptable cost. You might have a new technology, but if it's produced at twice the cost of fossil fuel, it's not easy to persuade the public, despite the fact that it's a cleaner source of energy."

Alexander Slocum: Wind and Solar Storage Design

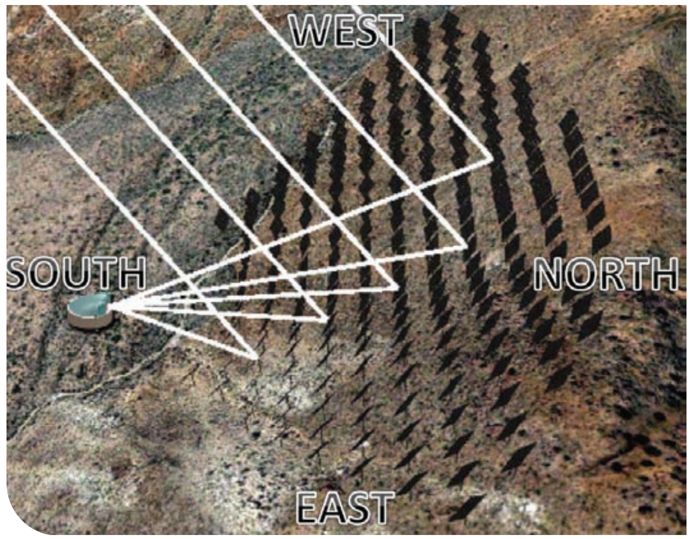
Where Sclavounos leaves off, Alexander H. Slocum, the Pappalardo Professor of Engineering, dives in designing machines for renewable energy systems. He takes Sclavounos's design for floating turbines and adds a method of storage to it.

Slocum's concept places hollow concrete spheres on the ocean floor to act as mooring balls for floating wind turbines and to create a pumped hydroelectric energy storage system. When the wind turbine generates excess electricity energy, the pumped hydro unit begins pumping water from inside the sphere out into the ocean, storing the energy for later use. Then, when the time comes, the water flows back in through the pumped hydro unit to generate electricity.

With one eye on wind energy storage, Slocum's fixed his other eye on solar storage. He and his team have created 24/7 solar power potential by developing a hybrid solar thermal receiver and storage device. In place of a tower that gathers concentrated solar power via a field of heliostats



Professor Slocum's student James Meredith installs a turbine on the latest Ocean Renewable Energy Storage (ORES) prototype in Pittsfield, NH.



Beam-Down Site to Ground Receiver in White Sands, NM.
Icons denote receiver location and sampled locations, not actual heliostats.
[Noone et al http://dx.doi.org/10.1016/j.solener.2011.01.017]

C. J. Noone, A. Ghobeity, A. H. Slocum, G. Tzamtzis, and A. Mitsos. Site Selection for Hillside Central Receiver Solar Thermal Plants. Solar Energy, 85(5):839-848. http://dx.doi.org/10.1016/j.solener.2011.01.017. 2011.

around the tower, the team's "CSPonD" uses a 25-meter-diameter by 5-meter-deep tank mounted to the ground and filled with molten salt. An array of hillside mirrors focuses sunlight on the tank, heating the molten salt inside. As the salt heats, a moving plate gradually descends to accommodate the growing layer of very hot salt and forces the still cold molten salt upward to be heated. The hot salt then flows into a steam generator to power a steam turbine that generates electricity. The unheated salt leaves the steam generator and flows to the bottom of the tank. Two installations could supply enough 24-hour electricity for about 20,000 homes, and could last through one full cloudy day.

Alexander Mitsos: Mathematics and Process Design

Professor Alexander Mitsos takes product designs such as Slocum's and other ideas from his lab and develops mathematical algorithms coupled with physics-based models to determine optimal ways of implementing such products. In one project, his team employed the math of nature — for instance, that found on the sunflower's florets — to create an optimized pattern for the placement of heliostats found in any central receiver solar thermal plant.

"Using the Fibonacci spiral as inspiration, my team and I defined and optimized a new pattern to increase the amount of collected heat from the sun and minimize the land area needed," says Professor Mitsos. "By applying our accurate yet efficient model of field performance, we can reduce the cost of clean energy by literally moving the heliostats around."

He calls what he does process-design engineering, and he doesn't stop with solar. He's also looking at ways to apply this same approach to carbon capture and sequestration, as well as desalination, honing in on time-variable operation. In order to achieve a large-scale penetration of renewable energy into electricity production, it is necessary to optimally use storage as well as modulate the electricity demand. To this end, Mitsos's lab again uses mathematical models to determine the best time of day to run desalination and the most crucial times to inject clean energy into the market, increasing the efficiency of the processes while simultaneously decreasing the costs to society.

"For most of our work," says Professor Mitsos, "the challenge is to identify the design variables that optimize the performance or minimize the cost. We've come up with a new metric that finds the best combination of technologies to identify tradeoffs between objectives."

Yang Shao-Horn: Energy Conversion and Storage

It's not all design and process in the Department of Mechanical Engineering though. Yang Shao-Horn, the Gail E. Kendall Professor of Mechanical Engineering, is sharply focused on the development of fundamental science for solar energy conversion and storage. She is working to increase the efficiency of electro-catalysis, a poorly understood catalyst process that promotes electro-chemical reactions. In particular, she and her team are looking at the naturally occurring process of oxygen reduction, an electro-chemical reaction that happens in our cells all the time as our body converts the oxygen we breathe. During this process, oxygen is split from water molecules, creating chemical bonds that can store energy and be distributed later to produce electricity.

"The reaction times for oxygen electro-catalysis are among the slowest and most difficult to promote; and because they are slow, it limits the efficiency of many devices that rely on this process," says Shao-Horn. "We are trying to understand how these reactions occur at the molecular level, and then how to enhance them to make them faster."

One of the best ways to increase the reaction time is to use a highly reactive catalyst, but it's been a mystery until now which characteristics make catalysts the most reactive.

Shao-Horn and her team recently discovered that it was the configuration of the outermost electron of transition metal ions that best predicted their level of reactivity and, through this discovery, also found one of the most effective catalysts yet for water splitting – composed of cobalt, iron, and oxygen, with other metals. Now that they know what to look for, Shao-Horn and her team will continue the search for even yet more efficient catalysts.

Tonio Buonassisi: Solar Cell Performance

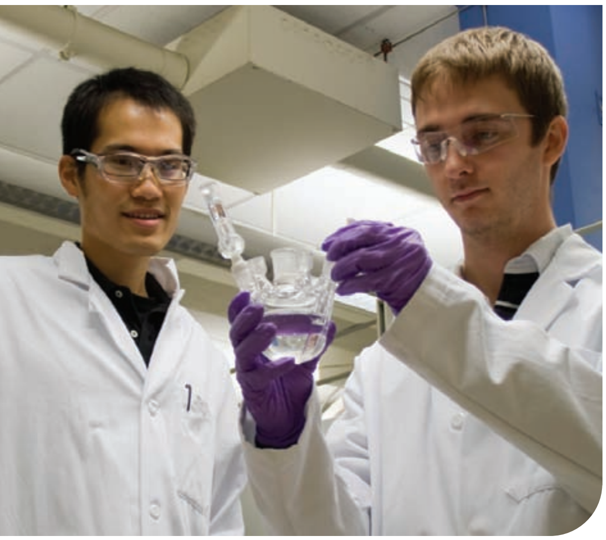
SMA Assistant Professor of Mechanical Engineering and Manufacturing Tonio Buonassisi's interest in clean energy began when he was 16 years old and living in the then-polluted city of São Paulo, Brazil. One day on his bus ride home from school, he vowed to make it his career to help clean up the world.

And indeed he did. Today, Buonassisi is focused on identifying the limitations and defects of solar cells and using that information to increase their efficiency and decrease their cost. First, he and his team developed a unique device in partnership with a synchrotron facility, which uses a beam of highly focused X-rays to peer inside solar cell materials and identify the performance-limiting defects therein.

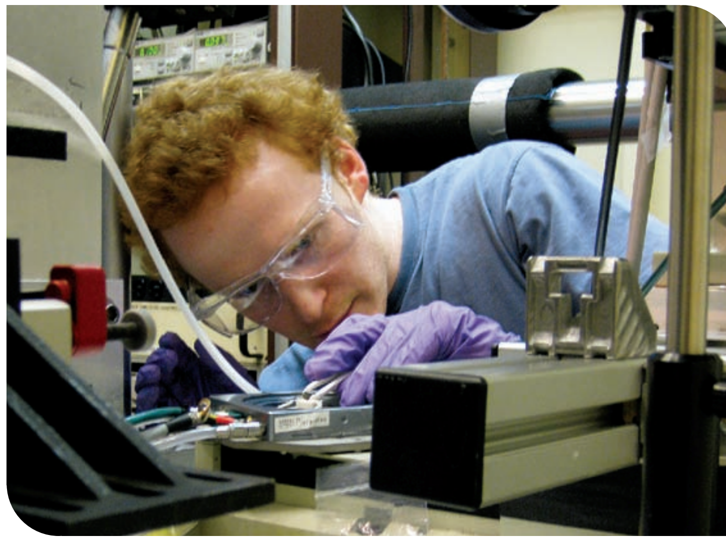
He gives the example of iron. "Iron is a big problem in silicon-based solar cells. Only a few nano-grams of it are needed to corrupt the efficiency of silicon devices, but to detect something that small is very, very hard. Fortunately, we are able to conduct these defect analyses using an X-ray beam that's a thousand times thinner than your hair, then engineer a way to move the iron toward innocuous places where it doesn't affect charge transport within the device."

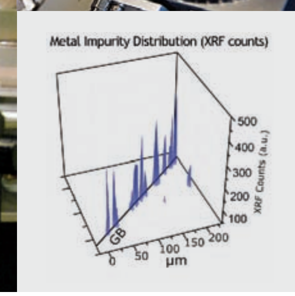
With this knowledge, Buonassisi and his team have developed a model that determines final solar cell efficiency based on the input material quality and the time-temperature profile used to process the material.

"We want to provide a tool that industry can use to improve the quality of the cells based on the materials used without spending precious resources on a 'trial and error' approach," he says.



Graduate Students Jin Suntivich and Kevin J. May preparing an electro-chemical cell for a water-splitting experiment.





Graduate student David Fenning mounts a sample onto the sample stage at the synchrotron (see close up on upper right). Underneath, a sample measurement reveals micron-size impurity precipitates clustered along a grain boundary in multicrystalline silicon solar cell material.

Ahmed Ghoniem: Efficient Systems for Carbon Capture and the Deployment of Renewables

While many faculty members are busy devising new methods of creating clean energy, Professor Ahmed Ghoniem, the Ronald C. Crane Professor of Engineering, is developing ways to utilize fossil fuels while reducing or eliminating their negative impact on the environment. Since almost 85% of the worldwide energy production comes from fossil fuels, Ghoniem's focus on the high-efficiency separation and affordable oxy-combustion processes that enable carbon capture is crucial in the search to solve the world's energy crisis.

A near-term solution is one Professor Ghoniem has recently demonstrated: the superior efficiency of pressurized oxy-fuel combustion, which separates carbon dioxide from burning coal by turning it into a concentrated, pressurized liquid stream for storage in deep geological formations. Another solution his group is currently working on: combustion systems that burn natural gas and other light fuels in pure oxygen while mitigating the extreme temperatures and instabilities resulting from the lack of nitrogen in the oxidizing stream.

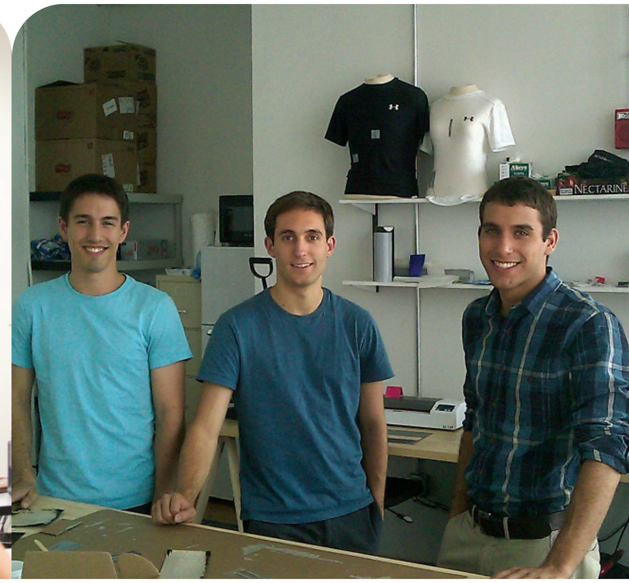
Ghoniem's group is also working on a novel ion transport membrane system to enable the separation of oxygen from air and the burning of fuel in the same reactor, thereby reducing the energy penalty and complexity of the process. In parallel, they are also exploring solid oxide fuel cells that use heavy hydrocarbons instead of hydrogen to produce electricity directly, while separating the CO_2 stream in the products.

Lastly, Ghoniem's group is looking at the integration of renewable energy with conventional sources to reduce the cost of renewables and improve their dispatchability. First, they are exploring the co-gasification of coal and biomass to produce syngas for use in the production of liquid fuels or electricity, while removing a fraction of CO_2. Second, they are researching approaches to integrating concentrated solar energy with fossil fuel heat to power electricity plants while allowing for solar energy storage in a chemical form.

2.75: Precision Machine Design

In MechE, Theory is Just the Beginning

Professor Alex Slocum and students in 2.75 class.



Nyx Devices founding team in new 319 A Street, Boston, Offices. Left to right: Thomas Lipoma, Carson Darling, Pablo Bello.

Just one minute with Professor Alexander Slocum and you can see why his course 2.75 is so popular – and successful. He has a way of inciting passion and excitement in his students while imbuing them with the confidence (and intellectual and practical tools) to meet whatever challenge he's presented.

In the case of Precision Machine Design, Course 2.75, the challenge is to create an innovative new medical device to the specifications of a client with a current problem.

Professor Slocum has been guiding senior undergraduates as well as graduate students through this process since 2004, when he founded the class on the famous MIT credo "mens et manus," meaning "mind and hand." His purpose was to take the deep fundamental understanding of mechanical engineering that the students already possess and add real-world experience and deterministic design philosophy that engineering students at other schools often don't get – and then top it off with one of the most eccentric professors around.

"There's no extraneous theory here," says Slocum, the Pappalardo Professor of Mechanical Engineering and recipient of the 2000 Massachusetts Professor of the Year Award. "It's all hands-on and brains-on. It's a perfect class for me to teach because I'm wild and hyper, and with about 10 projects going all at once involving about 30 to 50 kids, that's what you need – you have to be all over the map instantaneously. I couldn't imagine teaching a regular class out of a textbook."

The 14-week course centers around a major project that matches teams of students with Boston-area clinicians. It's a win-win situation because the clinicians, who begin the process working with the class's partner, the Center for Integration of Medicine and Innovative Technology (CIMIT), gain willing and passionate partners with the engineering background to solve their particular medical problem – often receiving several viable solutions – and the students, who already have a high-level understanding of the underlying mechanics, have a chance to experience the process of product development in a real situation. They work for a real client, on a team with fellow classmates, following a real-world deterministic process step by step, from brainstorming and designing a proof-of-concept device, to building the hardware and developing and testing a prototype – all along the way being constantly challenged by Slocum to identify risks and viable countermeasures to design and production ideas.

"Pitching clinical challenges to bright and enthusiastic engineering students resulted in several home runs for me," says Dr. Matt Bianchi, who presented his problem to last year's class, "including the good fortune of working with a team of three students to go from concept, to prototype, to bench testing, to laboratory testing, to patent application in just a few months. What an amazing opportunity, and the fruits of this collaborative work continues to drive my clinical research."

Course 2.75 is similar to the undergraduate 2.009 course, taught by Professor David Wallace with equal success, with a few important distinctions. Both courses incorporate communication, professionalism, and hands-on development, but 2.75 is the direct response to a real-time problem of a medical professional. "In a way," says Slocum, "2.75 starts where 2.009 leaves off. I'm much more concerned with the analysis and hardware needed to solve a given problem, rather than with the design process that involves identifying a problem. 2.75 is very much along the lines of 'Here's what the customer wants, now figure out how to do it.'"

Each team of students has a budget of $5,000, provided by course sponsors, and a fixed period of time to complete the project. They have to learn to communicate their ideas and plans professionally, both to a team as well as to the client, without going over time or over budget. According to Slocum, by the end of this class, students should be able to provide a prospective employer with the same level of value as a typical employee with several years of experience.

But why is that real-world project management experience such an important part of a mechanical engineer's education? Isn't the science enough?

"At MIT, we teach really great engineering science, machine elements, and introduction to design," says Slocum, "but we really needed a class that melded the engineering science with practical application. We needed to teach students how to actually make machines work and last a long time. Anybody can put Legos together and say, 'Ooh, look at this cool thing.' But the questions is, 'Will it work in 1 year, 2 years, 10 years?' How do you design a medical device to achieve not only the function, but, just as importantly, to be robust and durable?"

One look at the list of devices and start-up companies that have spun off from the work done by students in 2.75, and it's easy to see that Slocum's plan works. For example, in 2004, Robopsy(TM), a robotic device to assist radiologists during tumor biopsies, won the 2007 $100K Entrepreneurship Competition and the first-place award at the 2008 ASME Innovation Showcase. This year, a team of students who created the Somnus(TM) Sleep Shirt, a snug-fitting, washable shirt with embedded capacitive displacement sensors that monitor patient respiration, a detachable electronics package, and a custom online interface and algorithm that automates sleep "scoring," won a prize at the prestigious Three-in-Five Competition at this year's Design of Medical Devices Conference. They recently began a startup called Nyx Devices based on their invention, securing $500,000 in financing this past summer.

There are many more success stories where those came from, and, we suspect, there will be many more in the future as well.

"We teach students how to make machines that work and last a long time."

Professor Alexander Slocum

Master's in Ocean Engineering Systems Management

MechE Teams Up with Sloan to Offer New Track in Ocean Systems Management

The Ocean Engineering Systems Management track will provide future managers in the shipping industry with both business and engineering skills.

A new collaboration between the Department of Mechanical Engineering and the Sloan School of Management in the Leaders in Global Operations (LGO) program has yielded a new track. The track in Ocean Engineering Systems Management will commence in the fall of 2012.

The new collaborative degree came about as a result of the increased demand in the ocean industry for highly skilled managers with strong technical background. More than 70% of all trade in the US is conducted via ships, accounting for more than $3 trillion of our annual economic activity, and in the European Union, the percentage of ship trading is even higher. Add to that the new demand for "greener" ships and the prediction that the trade between the US and Europe with Asian countries is expected to double by 2025, and there couldn't be a better time to start offering a degree that teaches the hard and soft business skills of a great leader and a manager alongside the technical ocean engineering skills needed to back it up.

"We are very excited about this new track in Ocean Engineering Systems Management," says Professor Michael S. Triantafyllou, the William I. Koch Professor of Marine Technology and Director of the Center of Ocean Engineering. "We expect it to produce the new leaders that will guide the industry through radical changes and great opportunities that lie ahead in the near future."

The new degree is a 2-year program, including a six-month apprenticeship. Students receive both an MBA from the Sloan School of Management and an SM from the Department of Mechanical Engineering. The LGO program already offers three other successful degree tracks in a three-way partnership between Sloan, Mechanical Engineering, and industry: Manufacturing Systems, Environmental Sustainability, and Biomechanics.

More than 70% of all trade in the US is conducted via ships, accounting for more than $3 trillion of our annual economic activity.

MechE Department News

Robocon 2011 Held at MIT

Every summer for the past 21 years, the International Design Competition (IDC) Robocon takes place, pitting multi-national teams of students against each other in a competition of robotic knowledge and design skills.

The 22nd annual Robocon, hosted at MIT, commenced this year on July 25 when student representatives from 12 universities arrived in Cambridge to begin the 2-week long process of designing and building their best robot to meet a specified challenge. Each team was comprised of students from different universities representing Brazil, China, France, Korea, Japan, Morocco, Singapore, Thailand, and the US.

This year's challenge was based on famous hacks in MIT history: stealing the Caltech cannon, inflating a balloon on the Harvard Yard football field, dropping superballs in Killian Court, and placing a police car on the Great Dome.

The event culminated on Friday, August 5, from 9am to 12pm, when 16 teams had a showdown in several rounds of play to be one of the top four winning teams. The competition held more than 100 onlookers awestruck as two weeks' worth of work finally came to a head. Tension permeated the room as each team vied to complete as many of the four challenges as possible for the highest number of points.

In the end, Team Copper won third place, Team Gold won second place, and Team Brown won first place, winning 140 points to Team Gold's 5 points in the final match.

Two MechE Students Compete in International RoboCup Competition

This past July, Baker Logan and Julie Henion, both MechE undergraduate students, made their way to Istanbul, Turkey, to compete in the International RoboCup Competition as part of the RFC Cambridge team, comprised of 12 students from both MIT and Harvard.

An international organization designed to advance robotics research, RoboCup's ultimate goal is to develop a team of autonomous, humanoid robots that can defeat the 2050 World Cup champion team.

RFC Cambridge competes in the "small size" league with five 8-inch cylindrical robots driven by four omni wheels. The robots run autonomously via a global vision system that captures data about the position and orientation of all the robots with respect to the ball. That data is sent to the players' computer, which uses strategy algorithms to determine what each robot should do next and then sends those commands to the robots.

This year, the 22 small-size league teams were divided among four fields, and RFC faced stiff competition on the field from teams from Japan, Iran, Germany, and Brazil. Unfortunately, they were unable to advance to the semifinals, losing three matches and tying one, but gained encouraging insight into several problems with their design on both the mechanical and electrical fronts.

"It was especially rewarding to see some of our new designs this year – including a new dribbler, kicker, and wheels – significantly improve the performance of our robots at the competition," says Julie Henion. "Next year we'll be even better."

MechE's Brian Anthony Co-Founds The Medical Device Electronics Realization Center

Brian Anthony, director of the Master of Engineering and Manufacturing program in the Department of Mechanical Engineering, along with Charles Sodini, LeBel Professor of Electrical Engineering at MIT, and Joel Voldman, Associate Professor of Electrical Engineering and Computer Science at MIT, recently co-founded a new center at MIT focused on medical device realization.

Their collective aim with MEDRC is to serve as a focal point for large business, venture-funded startups, and the medical community. Acting as such an intersection, their primary focus is to create prototype devices and intellectual property, and serve as the catalyst for the deployment of innovative health care technology that will reduce costs in both the developed and developing world. To those ends, they've identified several areas of focus: wearable devices, minimally invasive monitoring devices, medical imaging, point-of-care instrumentation, and data communication.

While theirs isn't the only medical device research being conducted, Sodini, Voldman, and Anthony are excited about the innovative collaborations the MEDRC model initiates between technologists at MIT, clinicians, and companies. With input from all three areas, MEDRC projects have the advantage of insight from the technology arena, the medical arena, and the business arena, thus significantly increasing the chances that their devices will fulfill a real health care need as well as be profitable for companies.

National Instruments Makes Generous Donation Commitment to MechE

In a supportive effort to expand the use of its design equipment in MechE, National Instruments has committed to donating significant hardware and software over the next five years to a variety of mechatronics, robotics, manufacturing, control and design courses.

The donation also intersects with some research efforts of several MechE professors, including Professor Sangbae Kim for biomimetic robots, Professor Kamal Youcef-Toumi for atomic force microscopy, and Professor Harry Asada for various projects in robotic inspection.

"We are very appreciative of the support from National Instruments," says Department Head Mary Boyce. "Use of state-of-the-art NI tools enhances the classroom experience and reinforces student learning at multiple points in the curriculum. The NI tools can also help accelerate the department's research into new areas, such as agile biomimetic robotics, high-speed imaging at the nanoscale, and precision motion control."

In Memoriam: Warren M. Rohsenow

It is with great sadness that we report the death of Professor Warren M. Rohsenow this past June at his home in Falmouth, Maine. He was 90 years old.

Professor Rohsenow joined MIT's Department of Mechanical Engineering in the mid-1940s after beginning his teaching career at Yale. Before Yale, he worked for two years in the Navy developing temperature instrumentation for the first gas turbine tested in the US. He earned his BA from Northwestern University in his hometown of Chicago, and his MA and PhD from Yale University.

Professor Rohsenow was the director of MIT's Heat Transfer Lab for many years. Rohsenow led cutting-edge research on nucleate boiling, gas turbines, heat exchangers, heat transfer in nuclear reactors, and condensation in cooling towers. He was a leader in his field, making many discoveries throughout his career that led to the contemporary understanding of thermal power and heat transfer. In the late 1950s, Rohsenow co-founded Dynatech, a consulting and manufacturing company, and became its chairman. In 1992, some years after his retirement from MIT in 1984, the Heat Transfer Lab was renamed in his honor.

Professor Rohsenow also served as graduate officer of Mechanical Engineering for nearly 30 years.

Professor Rohsenow was a fellow of the American Academy of Arts and Science and the National Academy of Engineering. He was a recipient of the Max Jakob Memorial Award from the American Society of Mechanical Engineers (ASME) and the American Institute of Chemical Engineers, as well as the ASME Medal from the American Society of Mechanical Engineers.

Alumni Profiles

Peter Lehner (SB '49)


Peter Lehner

Peter Lehner had always been interested in mechanics, even as a teenager. He loved rebuilding old cars and wanted to become an aircraft engineer after college.

"I knew a man named Mr. Cotchett who was a mechanical engineer during the Depression," explains Lehner. "He was involved in the textile industry, which the family company Leigh Fibers was in, and that's how I met him. He ran a machine shop too, and eventually took me on as an apprentice. He understood mechanics and how to control fibers better than anyone else I knew."

Lehner was 16, and his time as an apprentice in Cotchett's machine shop solidified his interest in mechanical engineering. A few years later, he came to MIT on the GI Bill and majored in mechanical engineering. Back then, says Lehner, a lot of students were wearing uniforms, and there were only two women in his class.

In 1948 and 1949, Lehner was a member of the MIT Crew team. In '48, his team beat everyone they rowed against and was asked by the Olympic Committee to try out for the Olympics. They rowed in Princeton, NJ, against a team they had beaten before, but this time, they lost out by six inches. "That was definitely a highlight of my time at MIT," he recalls, "topped only by meeting my wife Mary, without whom I might not have made it through."

After graduation, Lehner started a plastics company with his mentor, Cotchett. According to him, they were the first company outside of Dupont to mold Fm-10,001, but they eventually went out of business. "I'd say it was a very good thing actually," he says, "because going bust makes you realize that the bottom line really does count, and that's something I think a lot of young engineers could stick in the back of their brain."

Soon after, Lehner went off to work at a shipyard, but when Leigh Fibers started having trouble with some of its machines, he focused his attention on the place he least expected: the textile industry.

At Leigh, Lehner not only fixed the machines but also significantly increased their efficiency and, ultimately, the company's throughput and product range as well. But his real value wasn't revealed until he started helping customers solve *their* mechanical engineering and fiber problems too. Lehner was able to see new ideas and develop new solutions that others had not; he worked in this way to the point where, according to him, he didn't have to find a single customer – they all came to him with a problem and, once he solved it for them, became a customer.

"The fact that I knew how machines and textile fibers worked together was the best thing I had. Once I helped companies with that, I could sell them my product," he says.

Today, Peter is still active in the textile waste business at Leigh Fibers, which has since transferred its focus to carpets.

"Right now, our biggest operational challenge is trying to find a way to use the carpet carcass. That's our biggest worry because 70% of every carpet is carcass. Nobody knows what the value of the leftover is yet, but we'll find it."

Inside the Innards of a Nuclear Reactor

Tiny robots may monitor underground pipes for radioactive leaks.

The radioactive crisis in Japan has served to shine a bright light on nuclear reactors around the world. In June, The Associated Press released results from a yearlong investigation, revealing evidence of "unrelenting wear" in many of the oldest-running facilities in the United States.

Harry Asada, the Ford Professor of Engineering in the Department of Mechanical Engineering and director of MIT's d'Arbeloff Laboratory for Information Systems and Technology, says one of the major challenges for safety inspectors is identifying corrosion in a reactor's underground pipes. Currently, plant inspectors use indirect methods to monitor buried piping; the only direct monitoring requires digging out the pipes and visually inspecting them — a costly and time-intensive operation.

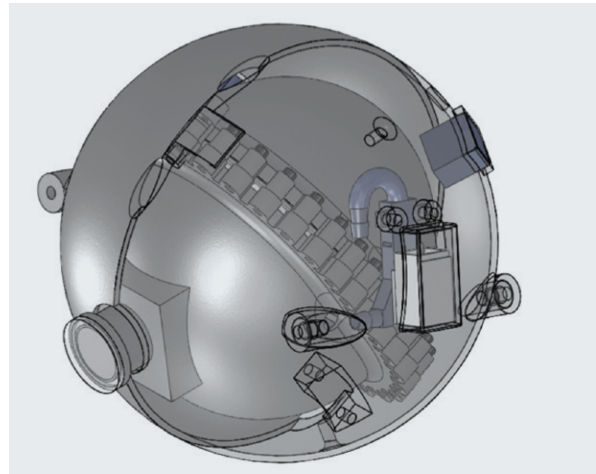
Now Asada and his colleagues at the d'Arbeloff Laboratory are working on a direct monitoring alternative: small, egg-sized robots designed to dive into nuclear reactors and swim through underground pipes, checking for signs of corrosion. The underwater patrollers, equipped with cameras, are able to withstand a reactor's extreme, radioactive environment, transmitting images in real-time from within.

Cannonball

At first glance, Asada's robotic inspector looks like nothing more than a small metallic cannonball. There are no propellers or rudders, or any obvious mechanism on its surface to power the robot through an underwater environment. Asada says such "appendages," common in many autonomous underwater vehicles (AUVs), are too bulky for his purposes and would easily lodge in a reactor's intricate structures, including sensor probes, networks of pipes and joints. "You would have to shut down the plant just to get the robot out," Asada says. "So we had to make [our design] extremely fail-safe."

He and his graduate students, Anirban Mazumdar and Ian Rust, decided to make the robot a smooth sphere, devising a propulsion system that can harness the considerable force of water rushing through a reactor. The group devised a special valve for switching the direction of a flow with a tiny change in pressure and embedded a network of the Y-shaped valves within the hull, or "skin," of the small, spherical robot, using 3-D printing to construct the network of valves, layer by layer.

Depending on the direction they want their robot to swim, the researchers can close off various channels to shoot water through a specific valve. The high-pressure water pushes open a window at the end of the valve, rushing out of the robot and creating a jet stream that propels the robot in the opposite direction.



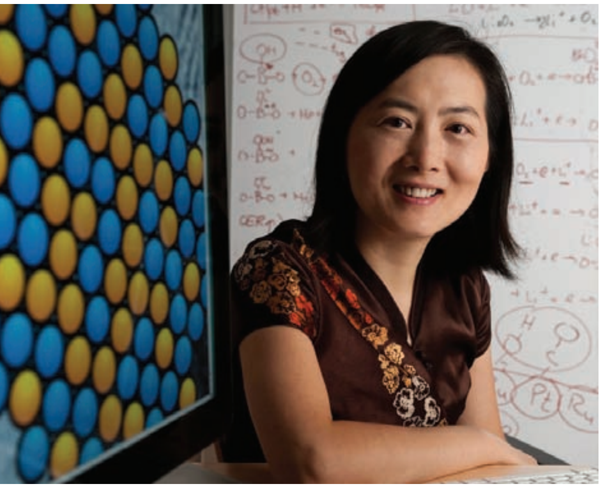
A spherical robot equipped with a camera may navigate underground pipes of a nuclear reactor by propelling itself with an internal network of valves and pumps.

Robo-patrol

As the robot navigates a pipe system, the onboard camera takes images along the pipe's interior. Asada's original plan was to retrieve the robot and examine the images afterward. But now he and his students are working to equip the robot with wireless underwater communications, using laser optics to transmit images in real time across distances of up to 100 meters. The team is also working on an "eyeball" mechanism that would let the camera pan and tilt in place.

Find out more ► **To read the whole story by Jennifer Chu, visit MIT's New Office: http://web.mit.edu/newsoffice/2011/nuclear-robots-0721.html**

Exploring Surfaces of Nanomaterials



Yang Shao-Horn is tackling the world's energy problem by exploring — and manipulating — the surfaces of particles only billionths of a meter in diameter. Hundreds of thousands of these particles could fit on the period at the end of this sentence.

"We are working to understand the surface chemistry and atomic structure of nanoparticles that help control key reactions relevant to clean and sustainable energy conversion and storage," says the Gail E. Kendall Associate Professor of Mechanical Engineering and Materials Science and Engineering. Her work could lead to everything from better fuel cells — environmentally friendly energy storage devices — to state-of-the-art batteries.

Over the nine years Shao-Horn has been at MIT, the Electrochemical Energy Laboratory she directs has grown "to one with a research team of 20 students and postdocs," she says.

Shao-Horn has made several key contributions to the field. These include the first images of atoms on and near the surface of nanoparticles key to the catalytic activity of oxygen chemistry that limits the efficiency of fuel cells. Chemical reactions catalyzed by these nanoparticles, composed of platinum and cobalt, run up to four times faster than reactions catalyzed by particles of platinum alone. Why?

Shao-Horn's images show that the platinum and cobalt atoms form a sandwich-like structure, with platinum on the top followed by a layer of cobalt. Successive layers contain mixtures of the two. She and her team explain that the resulting nanoparticles are so active because the platinum ions on the surface are constrained by the cobalt atoms underneath.

Later, she showed that the nanoparticle surface is also important to its performance. By creating tiny stair steps on the surface of platinum nanoparticles, the team increased catalytic activity by 200 times over particles with smooth surfaces.

"We find that the reaction happens at the step site," Shao-Horn says.

Working with Paula Hammond, a professor of chemical engineering, Shao-Horn recently created a novel lithium battery composed only of carbon nanotubes, or cylinders of carbon only one atom thick. The battery produced up to 10 times the amount of power possible with a conventional lithium battery. The technology has been licensed to a company that aims to commercialize it, Shao-Horn says.

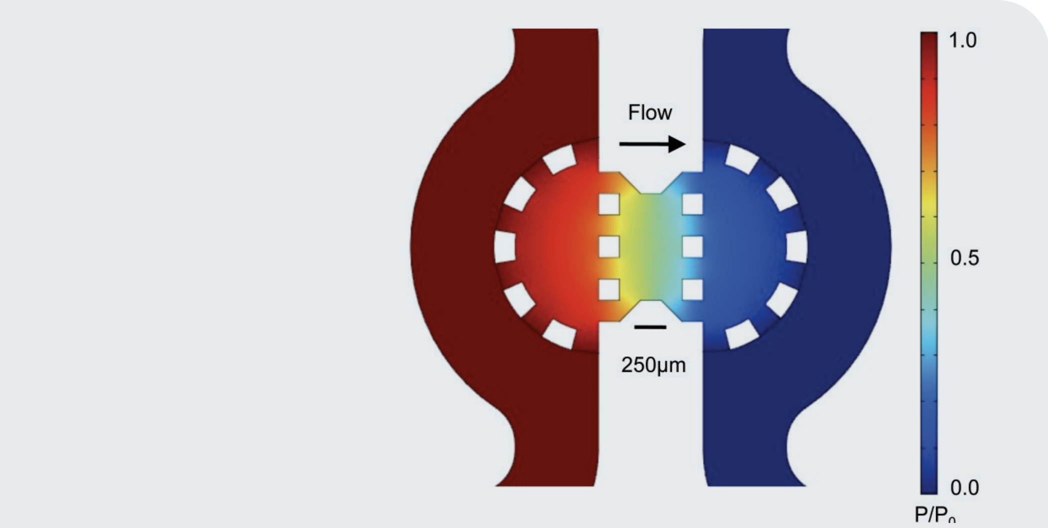
Much of her work is done with her "brilliant, committed" students, she says. "Over the years, I'm very much inspired by them to work here."

Shao-Horn's work could lead to everything from better fuel cells to state-of-the-art batteries.

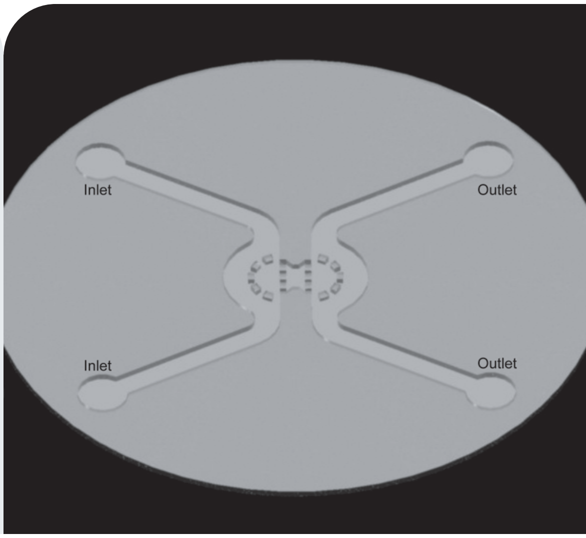
Find out more ▸

Read the full article by Elizabeth Thomson at http://spectrum.mit.edu/articles/features/exploring-surfaces-of-nanomaterials/

Competing Mechanisms Influence Tumor Cell Migration



Color map showing the distribution of pressure across the gel region (between the two rows of semi-circular posts) containing the cancer cells.



Schematic showing the full microfluidic system used to generate interstitial flow for the study of cancer cell migration.

It's no secret that cancer is deadly. But did you know that it's actually the uncontrolled spread of cancer throughout the body that most often leads to death? Understanding how cancer cells break loose from their original tumor, make their way into the body's vascular system, and travel to another location is a critical step in the fight against cancer.

Roger Kamm, Singapore Research Professor of Biological and Mechanical Engineering at MIT, and Mechanical Engineering graduate student William Polacheck, in collaboration with Joseph Charest from the Charles Stark Draper Laboratory, have discovered that the direction in which fluid flows through bodily tissue determines how likely the cancer cells are to spread, or metastasize. Armed with that information, they say it may be possible to limit the spread of cancer.

Almost as important as their discovery – published in *Proceedings of the National Academy of Sciences* – is the 3D microfluidic system they invented that allowed them to make it. Whereas previous insights were based solely on the visualization of individual cells in an artificial flow, Polacheck and Kamm's system allows them to look at the way cells interact with tissue that mimics natural breast tissue.

"There isn't a single drug currently on the market that addresses how cancer cells break lose from a primary tumor and get into the vascular system, migrate out, and form a secondary tumor. But those are processes that we can actually simulate in our microfluidic system," says Kamm.

It was the limitation of previous studies that fueled Polacheck, Charest, and Kamm to develop this system and investigate the migration of cancer cells, with the hope of discovering additional details that were previously undetectable.

The basis of their experiments was the underlying knowledge that, due to their continual growth, tumors generate high fluid pressure in surrounding tissues. This pressure, in turn, is known to generate a fluid flow away from the tumor. A former post doctoral student of Kamm's, Melody Schwart (now a professor at École Polytechnique Fédérale de Lausanne) had previously discovered that, due to this flow, ligands secreted by a tumor cell selectively bind to receptors on the downstream side of the cell. She found that this process ultimately results in an asymmetry that stimulates cells to migrate in the direction of the flow.

If this were the full story, it would be a discouraging result, because it would mean that when the cells start to break lose from a tumor, they will automatically move toward the vascular system, thus spreading the cancer.

Luckily, the story continues. With their new 3D microfluidic platform, which consists of two channels separated by a region of single cells in a gel, or matrix, across which a flow can be generated, Polacheck and Kamm started experiments on breast cancer cells to simulate how the process of migration actually works in the context of the body—and hopefully build on Schwartz's findings.

To their surprise, they found just the opposite: Instead of moving with the flow, as Schwartz had found, the cancer cells moved upstream. At first, they questioned their findings, but then Polacheck and Kamm realized that the cause of the discrepancy is the existence of two competing mechanisms.

One is autologous chemotaxis, which occurs in low-cell-density situations or when the CCR7 receptor becomes activated. Autologous chemotaxis increases the appearance of ligands at the downstream side of the cell, producing downstream migration, as Schwartz had found.

The other, they discovered, happens in high-cell-density situations – like around a growing tumor – or when the CCR7 receptor is blocked. This newly discovered mechanism kicks in when the pressure of a fluid flowing past a cell leads to the activation of a class of receptors called integrins, ultimately prompting upstream migration. Both mechanisms are due to asymmetry in a tumor cell's interactions with its environment.

Polacheck and Kamm's discovery could stop cancer dead in its tracks. "Acting on this might significantly improve cancer survival rates," says Kamm. "Pharmaceutical companies can use this information to focus on creating drugs that would block the CCR7 receptor to prevent migration toward the vascular system, and confine the tumors."

Polacheck and Kamm's system allows them to look at the way cells interact with tissue that mimics natural breast tissue.

And it doesn't end there. Because of its ability to mimic the interactions cells experience inside the body—using real human cells, in real time—Polacheck and Kamm's system could be useful in a myriad of other biological studies as well, such as those focused on inflammation, liver disease, and liver toxicity, among others. "We're finding that the ability to visualize the interactions between different cell types is critical to learning how the cells behave," says Kamm.

Find out more ►

Read Polacheck, Kamm, and Charest's full paper in ***Proceedings of the National Academy of Sciences.***

MIT Electric Vehicle Team: An Electrifying Start

Professional motorcycle rider Allan Brew, seated, with, from left, MITEVT team members Mark Jeunnette, Lennon Rodgers, Radu Gogoana, Randall Briggs, and Erick Fuentes.

It was the first qualifying race of the event and MIT's electric motorcycle had never been raced on the road before. Each Electric Vehicle Team (EVT) member stood transfixed by an empty finish line, waiting anxiously for their bike to fly by. It was the moment they had all been waiting for, nearly two years in the making. After all their plans, strategies, late nights, and tests, team members Lennon Rodgers, Radu Gogoana, Mark Jeunnette, Randall Briggs, and Erick Fuentes wondered how their bike would perform in the real deal.

"The first qualifier is a big event," says MIT EVT Leader and mechanical engineering PhD student Lennon Rodgers. "The rider speeds off, circles the entire island, and you hope he appears again in less than 30 minutes. It was a great feeling when they announced that our rider was going 96 mph through the first speed trap, because before that we really had no idea how our bike would perform on the actual course. He finished in about 28 minutes, and I think we'll all remember that first race as one of the coolest, just because we were all so excited to see him come over the final hill and speed across the finish line."

An Idea is Born

The race in question was the famous Tourist Trophy (TT) race on the Isle of Man – a self-governing island located in the Irish Sea – that first started more than 100 years ago in 1907. Its legendary mountainous and curvy track has been the site of many motorcycle races throughout the years, and recently, in 2009, a new race for electric motorcycles was added to the lineup.

It was watching this new race on the Internet while working in an MIT machine shop that prompted Rodgers and the rest of the EVT to build a bike to race in the electric-only TT Zero race. Fast-forward two years later, in June of 2011, and they did exactly that, coming in as the third-place team with the fourth-place bike (one of the teams raced two bikes). Meanwhile, though, there was a lot of planning, developing, and strategizing necessary to build an electric bike that could make it to the starting line, never mind the finish line.

A Well Laid Plan

A main element of the team's strategy – beyond coming prepared with spare parts for just about everything and conducting a multitude of tests before, during, and after – was to figure out a way to give their rider the ability to go full throttle for the entirety of the race.

"That way our rider could focus on driving and not worry about the speed he was going," explains Rodgers. "A lot of the other bikes' motors were actually a lot more powerful than what their batteries could sustain, so if their riders didn't control the speed, they would run out of battery life before the end of the race."

Their strategy was possible because of mathematical models they developed to predict the energy consumption of the motorcycle along the entire 37-mile course. Extensive dynamometer readings and track tests gave them the confidence they needed that their calculations were correct. The motorcycle was fully instrumented and in the end used 95% of its battery energy during the race.

Never a Dull Moment

Despite being well prepared with a reliable, tested bike, the EVT still ran into some dramatic moments that made them doubt their ability to race at all. The most dramatic of times was after the first qualifier when Rodgers took the bike out to the countryside for some additional practice runs.

"Right before the second qualifier, we realized that there was something rubbing in the motors, but we didn't know why," says Rodgers. "It's a difficult situation in terms of risk management when you don't know why something is happening, since you don't know if it will happen again or get worse. What we did know is that rubbing creates heat, and heat makes things expands, and it's a runaway effect. It definitely wasn't something we could ignore."

As the time remaining before the next race ticked quickly by and tension steadily built, the team debated whether or not to rebuild the motors, not even knowing for sure if that would fix their problem. They were worried about how long it would take because they had to remove more than 10 parts just to access the motor, nevermind the time it would take to actually fix it. But in the heat of discussion, Gogoana, who was responsible for the motor, devised a clever "Apollo 13" plan that would avoid taking out all the parts. But it was risky.

"We worked into the night but got the bike back together and to the race just in time," says Rodgers. "We won fourth place in the second qualifier."

The Results are In

Not only was EVT the fastest first-year team, they were also the fastest student-run team. "The greatest strength for us was reliability," says Rodgers. "One of our main strategies was to build a very reliable bike, and we were one of the few teams that didn't have reliability issues during the race.

"We were all very pleased with the way things turned out," he says. "Of the two teams that finished ahead of us, one of them was a group of professional engineers, and the other was a university team led by a professor. But for us, a team of all students, we did everything beginning to end all on our own."

The EVT would like to acknowledge their sponsors – A123 Systems, BMW, MIT-Singapore International Design Center, Singapore University of Technology and Design, MIT Energy Initiative, MIT Transportation, MIT Department of Mechanical Engineering, and MIT School of Engineering – as well as their professional rider Allan Brew.

Find out more ►

To read more about the EVT's adventure on the Isle of Man:
http://mit-evt.blogspot.com

Faculty Awards

Lallit Anand

Lallit Anand, Warren and Towneley Rohsenow Professor of Mechanical Engineering, was recently awarded a 2011 Distinguished Alumnus Award from the Indian Institute of Technology Kharagpur at the Institute's 57th Annual Convocation this past August.

Mary Cunningham Boyce

Mary C. Boyce, Department Head of Mechanical Engineering, was recently appointed Ford Professor of Engineering.

Steven Dubowsky

Steven Dubowsky, Professor of Mechanical Engineering, recently won an award for the Best Compliant Mechanisms Paper at the ASME 2011 International Design Engineering Technical Conferences & Computers and Information in Engineering Conference this past August in Washington, DC. The paper, titled "A Novel Approach for Designing Parabolic Mirrors Using Optimized Compliant Bands," was co-authored by Lifang Li, Andres Kecskemethy, and A.F.M. Arif.

Nicholas X. Fang

Nicholas X. Fang, Associate Professor of Mechanical Engineering, was recently awarded the 2011 International Commission for Optics (ICO) Prize "for his pioneering work in optical metamaterials, optical superlenses, and nanofocusing." The ICO Prize is awarded to individuals who have made outstanding contributions to optics before reaching age 40. Nick was also recently appointed to the d'Arbeloff Career Development Chair.

Daniel Frey

Daniel Frey, Associate Professor of Mechanical Engineering, recently won the 2011 IEEE International Conference on Quality and Reliability Outstanding Paper Award for his paper titled "Efficiently Estimating Expectation Shift Due to Variability."

Nicolas G. Hadjiconstantinou

Nicolas Hadjiconstantinou, Associate Professor and co-director of Computation for Design and Optimization, was recently named a fellow of the American Society of Mechanical Engineers (ASME).

Ken Kamrin

Ken Kamrin, Assistant Professor of Mechanical Engineering, has been appointed to the Class of '56 Career Development Chair.

Sang-Gook Kim

Sang-Gook Kim, Professor of Mechanical Engineering, was recently named a fellow of the American Society of Mechanical Engineers (ASME).

Alexander Mitsos

Alexander Mitsos, Rockwell International Assistant Professor, recently won the Best Poster First Prize award at the 9th Planet xMap Congress held this past September in Vienna, Austria. The co-authored paper, titled "Construction of Large Signaling Pathways from Phosphoproteomic Data," is an extension on previous work on large-scale systems.

Yang Shao-Horn

Yang Shao-Horn, Associate Professor, has been appointed to the Gail E. Kendall Chair.

Kostya Turitsyn

Kostya Turitsyn, Assistant Professor, was recently appointed to the Edgerton Career Development Chair.

J. Kim Vandiver

J. Kim Vandiver, Professor of Mechanical Engineering and Ocean Engineering and Dean for Undergraduate Research, recently won the Arthur C. Smith Award for Meaningful Contributions and Devotion to Student Life and Learning.

Talking Shop
Domitilla Del Vecchio

What areas does your research focus on?

Broadly speaking, my group works in control systems, which are systems for which you have to design something that works autonomously. We have two main applications: one is intelligent transportation systems and the other is biomolecular circuits.

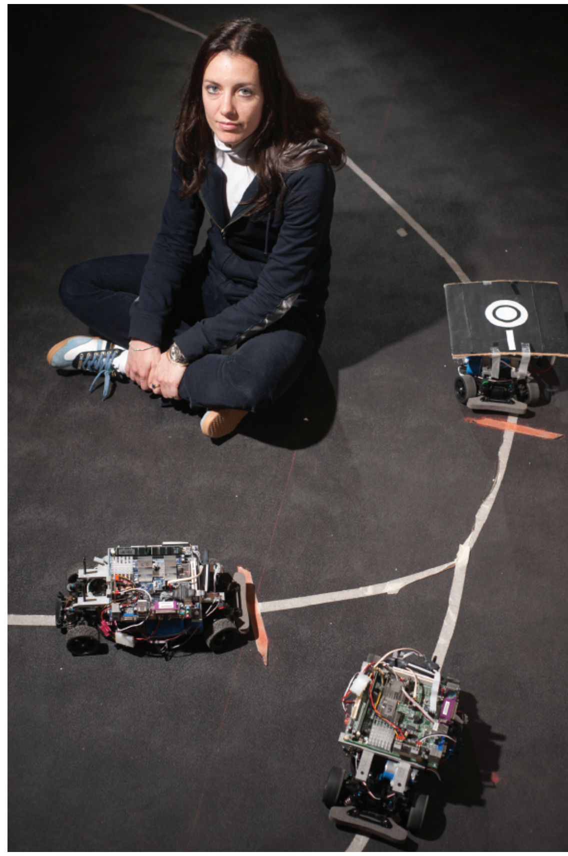
For transportation, we are working on designing on-board vehicle controllers that communicate with each other to predict and prevent collisions at intersections. We are simultaneously working on the design of small biomolecular circuits within cells to control cellular behavior. Our focus is on understanding the fundamental principles by which you can create these designs modularly, starting from smaller components and putting them together to make bigger systems.

What is your current focus as you research these two areas?

Transportation systems involve a lot of vehicles and agents, as well as communication among those agents. There are severe complexity issues in solving this design problem, because if you start looking at all the possible ways in which agents can interact, you get an exponential explosion of the number of possibilities. Let's say you have a very busy intersection and you have 15 vehicles all merging at an intersection – some are closer, some are farther, and their speeds are all different. How can you tell each of the drivers what they should do to avoiding crashing? A naïve way to solve the problem would be to look at all possible combinations of all those variables, because if you have 15 cars, this type of computation is going to take forever.

The question I've been trying to answer is, how do you exploit the specific structure of the problem at hand to discover ways in which you can reduce complexity? In my research, we exploit what we call partial order structures to reduce the complexity from exponential to linear. We exploit the fact that vehicles evolve unidirectionally on roads, so that higher speeds and higher accelerations will result in higher displacements. This property is a key enabler for reducing complexity.

I have also been focusing on how to incorporate human operators in the design of an autonomous system. We have made initial discoveries about easy ways to incorporate simple behavior and take into account what the human is doing in order to take safe next steps. Specifically, we are designing autonomous on-board systems that estimate the intention of human-driven vehicles at an intersection and use this information to design safe maneuvers.



Domitilla Del Vecchio works on intelligent transportation systems that communicate to prevent collisions.

In cellular research, the hardware we use is not electronic mechanical – it's actually biomolecular. When you compose systems together, you get effects that are similar to impedance in electrical circuits that we call retroactivity. When a system is connected to another one, loading effects due to the interconnection change the system behavior. We have experimental results that show that these things exist, and we are currently trying to use control theory to design systems that are insensitive to the presence of this impedance.

For the application of control theory to the biomolecular area, the goal is to understand how one can use the specific mechanism you have in biological systems to modify or come up with new control techniques that are useful in that new domain.

What is the real-world application for your biomolecular research?

The application is very long term for this, because it's still at the initial stages, but one of the applications we're working on is bio-sensing systems that can detect a special molecule in the environment, determine whether it's dangerous, and then make it visible to the eye. Even longer-term applications involve targeted drug delivery that involves designing cells that can be placed in the bloodstream and directed to chase down pathogens and cancer cells directly. The biological infrastructures are already there, so we're trying to take pieces out and combine them to achieve the end functionality we're looking for.

Are there any precedents for the type of advancements you've mentioned?

From the principles point of view, for transportation systems, we are building on a lot of existing work on how human behavior can be modeled and how to design safe systems and guarantee their safety. We are trying to combine the two by bringing in the human factors without giving up guarantees of safety. For intelligent transportation in general, there is a lot being brought to the market right now – for example, there is the automatic adaptive cruise control, one of the oldest smart transportation technologies. Now companies are trying to use the fact that vehicles can communicate with each other to make more complicated things. This is where we can make a valuable contribution.

On the other hand, control theory had not been widely applied to the design of biomolecular systems before four or five years ago, so there is a lot of room for advancement there.

Del Vecchio's secondary research focus is on the design of small biomolecular circuits within cells to control cellular behavior.

"The question I've been trying to answer is, how do you exploit the specific structure of the problem at hand to discover ways in which you can reduce complexity."

Domitilla Del Vecchio

Faculty Promotions

Domitilla Del Vecchio
Associate Professor

Evelyn Wang
Associate Professor

We are pleased to announce the promotions of Professor Domitilla Del Vecchio and Professor Evelyn Wang, each from the rank of Assistant Professor to the rank of Associate Professor without Tenure, as well as the promotion of Professor Sang-Gook Kim from Associate Professor with Tenure to Full Professor. Each brings a unique signature to the Department and the Institute in terms of their individual achievements and contributions to research, education, mentorship, and service.

Domitilla Del Vecchio

Domitilla Del Vecchio received her PhD from the California Institute of Technology in 2005 and, before joining MIT, worked as an Assistant Professor at the University of Michigan, Ann Arbor. Professor Del Vecchio's research focuses on control of nonlinear systems and has two main thrusts: one in control of multi-vehicle systems and one in modular control versus retroactivity of the bio-molecular networks of genes and proteins in living cells. She has demonstrated expertise in multidisciplinary dynamical system modeling, the ability to realize her research results in physical form, the ability to synthesize new methodologies, and the ability to work productively across broad multi-disciplinary areas. Professor Del Vecchio was awarded an NSF Career Award in 2007 and received the prestigious Donald P. Eckman Award from the American Automatic Control Council in 2010.

Evelyn Wang

Evelyn Wang received her SB from MIT, and her MS and PhD from Stanford University. She is an emerging leader in the areas of micro and nanoscale heat and mass transfer processes, with a focus on the development of novel engineered structures that enable innovative solutions in thermal management, energy, and desalination systems. Her work is distinguished by a unique combination of state-of-the art micro/nano-fabrication, physical modeling, and quantitative analysis that enables insight into the underlying physics, as well as an understanding of the engineering performance of complex interfacial engineering applications. Professor Wang has been recognized with a DARPA Young Faculty Award, a best paper award at ITherm 2010, and an Air Force Office of Scientific Research Young Investigator Award in 2011.

Retirements

Sang-Gook Kim
Professor

Ernest Cravalho
Professor

Sang-Gook Kim

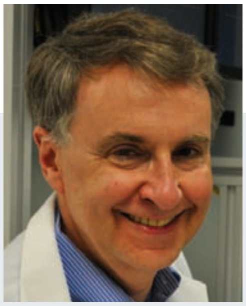
Sang-Gook Kim joined the MIT faculty in 2000. He earned a BS from Seoul National University in Korea, an SM from KAIST in Korea, and a PhD from MIT. He is considered an innovator and leader in multiscale systems design and manufacturing. His contributions to the fields of energy harvesting and PZT processing for small-scale devices include breakthrough "firsts" as well as designs and processes that enable the wide-scale and practical implementation of these technologies. Professor Kim's piezoelectric-coated cantilevered beam energy harvester is considered a milestone as the first functional MEMS harvester that uses the resonant vibrational mode of the beam to harvest energy from the environment. He has recently trumped this development with a broadband energy harvester that capitalizes on the nonlinear stiffness of doubly anchored beams. He is also recognized for his innovation in PZT processing, specifically aimed at integrating thin film PZT films with MEMS fabrication.

Professor Kim has been both a leader and an innovator in our undergraduate curriculum as well. He oversaw the highly successful accredited flexible engineering degree within Mechanical Engineering (Course 2-A, now the sixth largest major at MIT) during a critical stage of its growth. He also led the development and implementation of a new undergraduate laboratory-based course on micro/nanoengineering that has been enthusiastically received by the students and the faculty, rapidly expanding in enrollment from six students to more than 50 in just three years.

Ernest Cravalho

For the past 44 years, Professor Ernest (Ernie) Cravalho has been a leading authority in the fields of thermodynamics, heat transfer, cryopreservation of biomaterials, and energy conversion. He was Associate Dean of the MIT School of Engineering between 1975 and 1977, and the Associate Director of the Harvard-MIT Division of Health Sciences and Technology from 1977 to 1982. Ernie is a member of the American Society of Mechanical Engineers (ASME), the Institute of Medicine, and the National Academy of Sciences, and is a Founding Fellow in the American Institute of Biological and Medical Sciences. In recognition of his commitment to outstanding teaching, Ernie was named a Margaret MacVicar Faculty Fellow in 2000. He recently retired from his position as Professor of Mechanical Engineering in December 2010.

Borijove Mikic
Professor



Emanuel M. Sachs
Professor

Borijove Mikic

For the past 45 years, Professor Borijove (Bora) Mikic has been a leading authority in heat transfer, establishing groundbreaking theories for nucleate boiling, contact resistance in heat conduction, biological heat transfer, heat transfer enhancement, and the onset of turbulence. For 30 of those years, Bora and his wife Liba were housemasters at MIT, serving at Senior House from 1976 to 1981 and at Next House from 1981 to 2006. Bora was the Associate Head of the Department of Mechanical Engineering for 7 years. He has received numerous awards for his research, including the ASME Heat Transfer Memorial Award, and is broadly recognized as an outstanding teacher at MIT. Bora retired from his position as Professor of Mechanical Engineering this past summer.

Emanuel M. Sachs

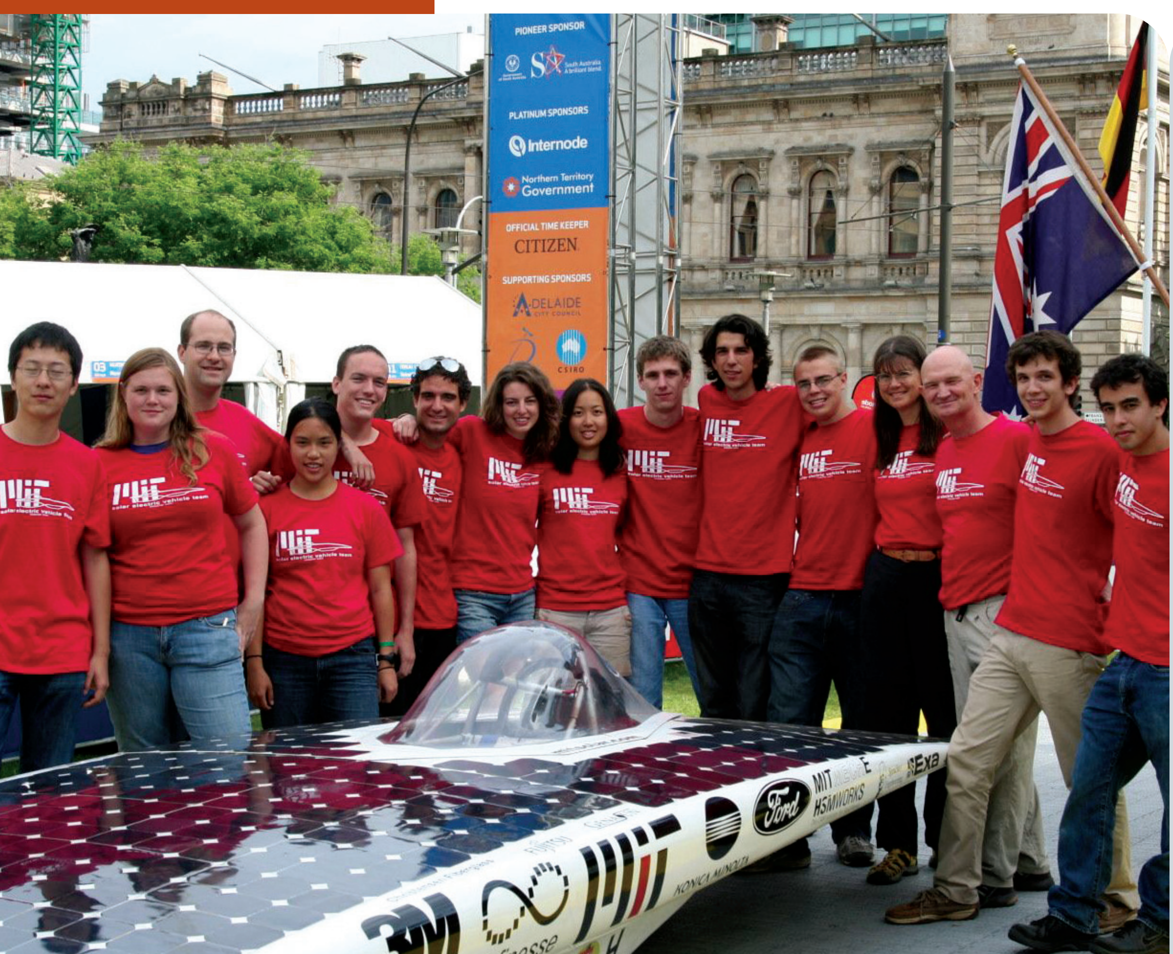
Professor Emanuel (Ely) M. Sachs, the Fred Fort Flowers and Daniel Fort Flowers Professor of Mechanical Engineering, has a long history of invention and development. He is the co-inventor of the revolutionary process of 3D printing and has made many valuable contributions to the photovoltaic industry, including string ribbon technology for making low-cost silicon wafers for solar cells. Most recently, he cofounded 1366 Technologies based on cell technology that improves the efficiency of silicon cells to potentially cut the cost of wafers to 1/3 the current level. Ely is also well known for his passion and commitment to education and, in particular, discovery-based learning. He was recognized for this dedication with the Joseph Henry Keenan Innovation in Undergraduate Education Award in 2006. Ely retired this past fall to pursue his work at 1366 Technologies as chief technology officer.

MITMECHE

Massachusetts Institute of Technology
Department of Mechanical Engineering
77 Massachusetts Avenue, Room 3-173
Cambridge, MA 02139

Coming in the next issue:

- Manufacturing Summit on Revitalizing US Manufacturing to Capitalize on Innovation
- MEng in Manufacturing: Leadership and Innovation in Manufacturing Education



The MIT Solar Vehicle Team took part in this year's World Solar Challenge this past October, placing 15th out of 37 international teams in a race across Australia of the world's best solar vehicles. Team members on the race included Alex Arambula, Alexander Hayman, Alix de Monts, Bruce Arensen, Chris Pentacoff, George Hansel, James (Adam) Delton, Kai Cao, Kelly Ran, Lauren Chai, Michael Buchman, Rachel Batzer, Simon Calcutt, Annette Batzer, and Andy Batzer. Robert Pilawa, Kojo Acquah, and Thomas Villalón were not present.

psb: 11-02-0117