

GREENER FIXES FOR TOXIC SITES

Nanoscale solutions remove oil from soil and harvest algae from a dying lake.

See page 18



ENERGY BRIGADE TAKES CHARGE

M.Eng. program in energy engineering sends first graduates quickly to industry.

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A FOCUS ON LEHIGH ENGINEERING • VOLUME 2, 2010

MANY DISCIPLINES, ONE GOAL

LEHIGH OPENS A LEED-CERTIFIED SHOWCASE FOR ENVIRONMENTAL RESEARCH, AND HARMONY. SEE PAGE 10

LEHIGH UNIVERSITY[®]

P.C. ROSSIN COLLEGE OF
ENGINEERING AND APPLIED SCIENCE

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A FOCUS ON LEHIGH ENGINEERING

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LEHIGH

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CHALLENGING GREAT MINDS...INSPIRING GREAT IMAGINATIONS

A fusion of interwoven endeavors

Welcome to the eighth issue of *Resolve*, a magazine dedicated to research and educational innovation in the P.C. Rossin College of Engineering and Applied Science at Lehigh University.

This issue of the magazine celebrates one of the most important additions to Lehigh's science and engineering landscape in recent years: the completion of the STEPS (Science, Technology, Environment, Policy and Society) building. The 135,000-square-foot building is part of a campus-wide initiative to strengthen Lehigh's commitment to research and education in the related areas of energy and the environment. In addition to the physical facility, the \$85-million STEPS initiative is funding endowed chairs, student fellowships, and technological improvements.

The core of Lehigh's research and educational agenda is to generate new knowledge that meets the grand challenges of our time. Satisfying society's need for energy while protecting the environment is a multifaceted test that will require unprecedented collaboration by scientists, engineers, policy and regulatory experts, social scientists and economists. Creating an environment that promotes cooperation is critical to meeting that challenge.

In the new STEPS building, researchers in environmentally related areas of political science, economics, education, history and journalism will work with scientists exploring alternative energy sources, groundwater decontamination, carbon-capture technologies, and smarter, leaner energy-consumption systems. Labs and offices have been designed and located to promote intellectual interaction. Casual gathering

spaces have been strategically placed to make it easy for people to meet informally.

Lehigh's faculty members are renowned for integrating research and teaching to provide opportunities for hands-on, inquiry-based student learning. STEPS reflects this. Nearly half the space in the new building is dedicated to teaching and research labs, and these are equipped with state-of-the-art instrumentation.

This issue of *Resolve* also showcases the emergence of our Energy Systems Engineering Institute (ESEI), which has moved to the STEPS building. Energy usage accounts for much of society's impact on the environment, thus the

development of cleaner energy systems represents wise stewardship. But according to the U.S. Department of Energy,

"Satisfying society's need for energy while protecting the environment is a multifaceted challenge that will require unprecedented collaboration." —S. David Wu

the labor force in America's energy industry is aging, while the number of young engineers prepared to fill their ranks is dwindling. The ESEI's innovative graduate program in energy systems engineering has attracted much support from industry. The innovative program recently graduated its first class, and all 22 M.Eng. recipients have found jobs.

In this issue, we also highlight new technologies that are being developed by Lehigh's environmental engineers.



Scrap iron, for example, is pretreating industrial wastewater in a historic pilot test in China. Smaller, cheaper biosand water filtration systems promise to make life easier for people who rely on the systems to remove contaminants from rain and surface water. With the addition of

STEPS, we expect to see Lehigh's impact in this important field grow.

I hope you enjoy this issue of *Resolve*. Please drop me a note to share your thoughts and comments.

S. David Wu, Dean and Iacocca Professor
P.C. Rossin College of Engineering and
Applied Science
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Measuring the stiffness of a single living cell

Changes in the mechanical properties of biological cells, many scientists believe, are a major contributing factor to the development of bone, kidney and vascular disease.

Svetlana Tatic-Lucic, Susan Perry, Sudhakar Neti and Arkady Voloshin are seeking a more rapid and cost-effective method. They have designed a novel MEMS (microelectromechanical

system) device to measure the compliance, or stiffness, of a single cell.

“The advantage that MEMS technology has over other systems is that it can integrate both micro-sensors and micro-actuators on a single chip,” says Tatic-Lucic, the principal investigator on the project.

The researchers’ first-generation device incorporates a cell-positioning system, a polymer V-shaped electro-thermal actuator (ETA) array capable of compressing a living cell by a desired amount, a sensor to measure the force exerted on the cell, and a thermal sensor.

“We chose an epoxy-based polymer for the ETA primarily because of its large thermal expansion coefficient,” says Tatic-Lucic, an associate professor of electrical and computer engineering who is affiliated with Lehigh’s Bioengineering Program. “Comparing it to an ETA made from polycrystalline silicon,

there should be a five-fold increase in thermal efficiency. In addition, the polymer ETA would be easier to fabricate.”

The integrity of any MEMS device is highly dependent on the way it is made. This requires a great deal of skill and attention to detail. Care must be taken to avoid any contamination, no matter how small. The fabrication was carried out in the clean room of Lehigh’s Sherman-Fairchild Laboratory for Solid-State Studies.

“Our initial goal was to find out if the polymer ETA could actually deliver the required compressive strain to a single cell,” says Tatic-Lucic.


To do this, the researchers immersed the entire MEMS device into a liquid medium. Mouse fibroblast cells were then introduced into the cell medium using a micropipette. One of the cells was then trapped in place by applying an AC voltage to the electrodes of the cell-positioning system, a technique known as dielectrophoretic positioning. The cell was compressed by applying another AC voltage to the actuator.

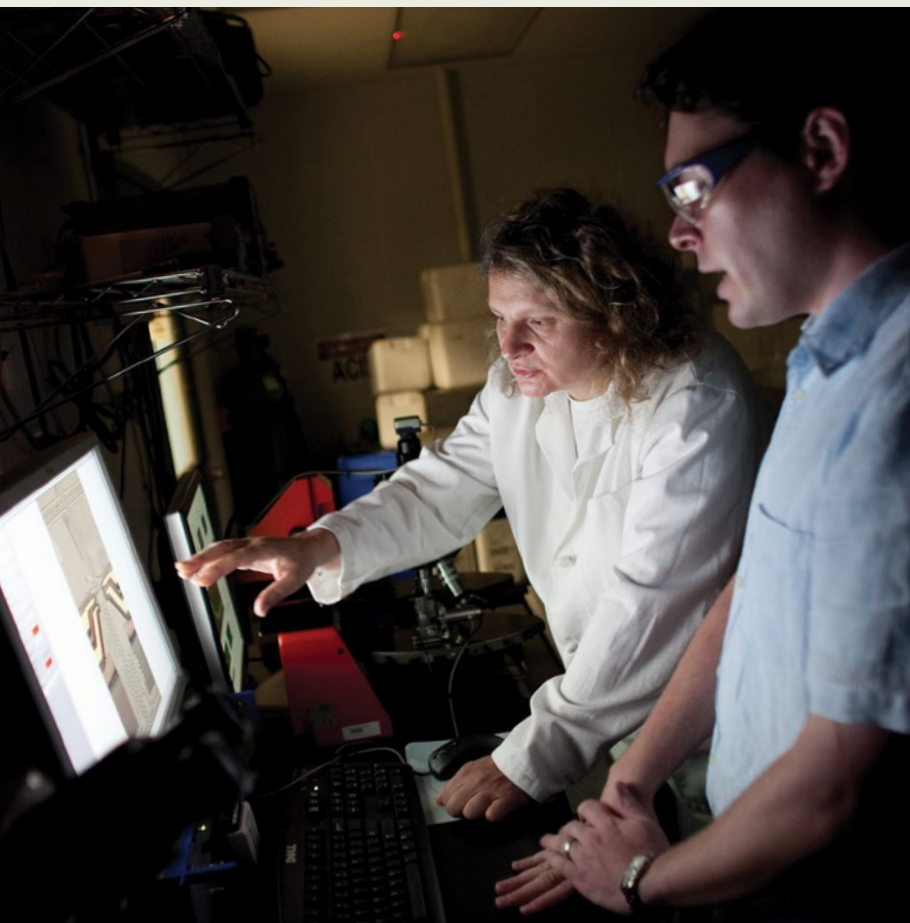
“We found that the cell could be compressed repeatedly and it did not disintegrate during or after the compression test,” says Tatic-Lucic. “The implemented displacement was 4 microns.”

In future experiments, the researchers will use a force sensor to

measure the reaction force exerted by the cell during a compression test. This will allow them to calculate the compliance of the cell.

The project is being funded in part by the

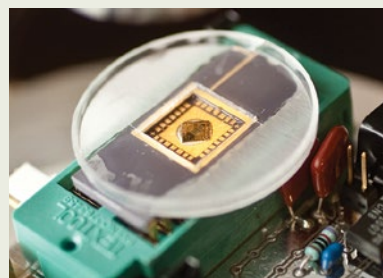
National Aeronautics and Space Administration (NASA). 



Svetlana Tatic-Lucic and her research group have designed a MEMS device that integrates sensors and actuators to measure the stiffness of a single cell.

Measuring the physical properties of individual living cells, however, is not an easy task because of their small size and because measurements must be made in a suitable aqueous medium in order to keep the cells alive.

Direct contact methods for measuring the stiffness of individual cells have involved the use of a cantilever in an atomic force microscope. Non-contact techniques involve magnetic and laser tweezers. Both have achieved success, but they require sophisticated and expensive equipment, and time, to collect necessary data.



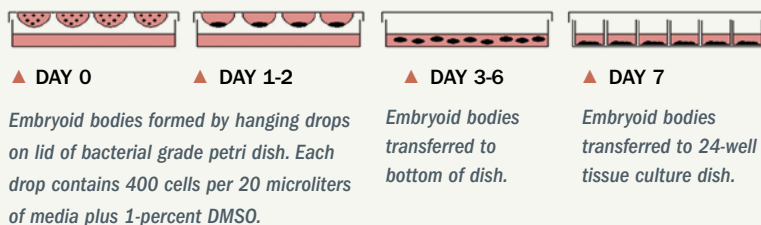
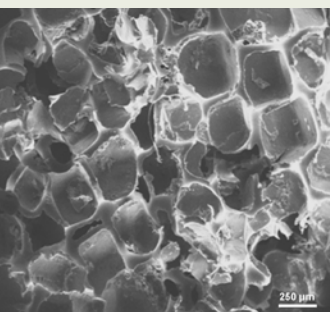
Mending a wounded heart

Heart muscle cells grown on an elastomeric polymer scaffold, says Sabrina Jedlicka, can be integrated into existing tissue.

A heart attack can cause extensive scarring of the cardiac muscle tissue, which the damaged tissue itself cannot repair. In an attempt to maintain a viable cardiac output, the walls of the heart narrow and the left ventricle dilates to increase stroke volume. Often this structural remodeling is not sufficient to restore normal blood flow and leads to congestive heart failure, the number one cause of death in the U.S.

modulus closest to that of healthy heart muscle is made of polyglycerol-sebacate (PGS)," says Jedlicka. "The chemical nature of this polymer, specifically its hydroxyl component, could also provide an ideal surface for the adhesion of cardiomyocytes."

Jedlicka and LeBlon seeded the new porous scaffold with cardiomyocyte cells from mouse embryonal P19 carcinoma cells to see if the cells would thrive on



A heart transplant is the ultimate solution, but a lack of donors and complications from immune-suppressive treatments have spurred scientists to seek new strategies to regenerate injured heart tissue.

One promising approach is to implant a cardiac patch composed of heart muscle cells, or cardiomyocytes, grown on a porous polymer scaffold.

"The scaffold provides mechanical support for the cardiomyocytes," says Sabrina Jedlicka, an assistant professor of materials science and engineering, "and facilitates their integration into existing tissue."

Many researchers have built scaffolds from conventional biomaterials like Dacron. Jedlicka and Courtney LeBlon, a graduate student, are evaluating scaffolds made of biodegradable polymers whose elastomeric properties mimic those of living heart muscle tissue.

"The scaffold with an elastic

the platform. P19 cells can be transformed into cardiomyocytes by exposing them to dimethyl sulfoxide using a "hanging drop" technique.

The researchers placed one droplet of P19 cells onto each side of the PGS scaffold and incubated them for 14 days. The P19 cells were transformed into cardiomyocyte-like cells with a contractile ability that was assessed every two days by taking voltage readings.

"While scaffolds made from other materials did support some level of cell contraction, PGS was by far the best," says LeBlon. "This is primarily because its mechanical properties are comparable to those of healthy heart muscle tissue."

"The only problem is that the cardiomyocytes on our current scaffolds are beating out of step," says Jedlicka. "We are trying to modify the scaffold to induce a more uniform alignment of the cells that will hopefully lead to synchronous contraction." ❶

A scanning electron micrograph (left) of the porous biodegradable scaffold before it is impregnated with cardiomyocytes.

Frank Zhang uses atomic force microscopy and laser tweezers to measure the forces required to unravel single molecules.

The mechanics of proteins

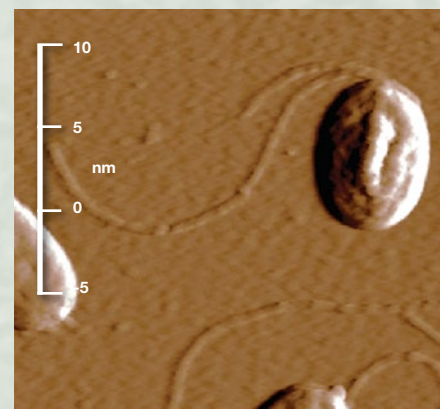
Protein molecules are made up of a linear chain of amino acids that folds into a 3-D globular form. Discovering the manner and conditions under which sections of a protein molecule unravel to reveal active sites is fundamental to understanding many biochemical processes, since these are potential binding sites for other molecules.

Only recently, with the development of ultrasensitive instruments such as atomic force microscopy (AFM) and laser tweezers, have scientists been able to measure the tensile forces required to induce chain unraveling of a single molecule, and determine the strength and stability of the bonds formed with other proteins.

Xiaohui "Frank" Zhang, an assistant professor in the bioengineering program and department of mechanical engineering and mechanics, was part of the Harvard Medical School research group that first measured the force required to unravel a single von Willebrand factor molecule—the protein that initiates blood clotting—using laser tweezers. Their work was published last year in *Science*.

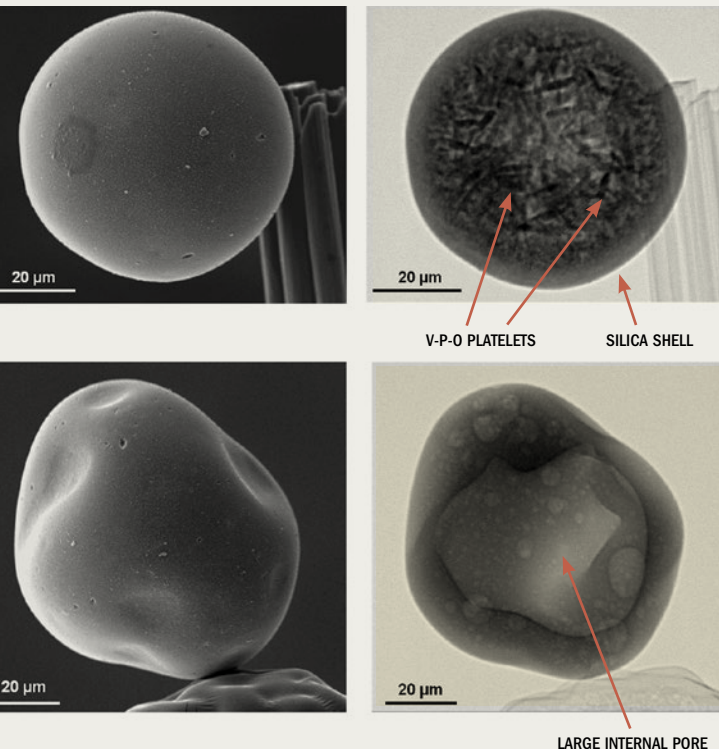
In a study published in *Nature* in 2010, they found that, depending on external forces, two different bonding states could exist between a protein and the surface of a blood platelet. A bond formed at shear forces above 10 pN had a lifetime 20 times longer than a bond formed at lower shear forces.

At Lehigh, Zhang is studying integrins, a family of proteins that play significant roles in cardiovascular diseases. Using laser tweezers and AFM-based techniques, he is examining the influence of drugs and intracellular activation signals on the 3-D structure and activation states of these molecules. ❷



Revealing the secrets of a commercial catalyst

It is not often that a large chemical company subjects a commercial catalyst to public scrutiny. Recently, DuPont distributed 3,000 kilograms of a vanadium phosphate-based catalyst (VPO)



SEM/XuM pair of the used catalyst together with the SEM/XuM micrographs of a distorted particle.

to more than 20 research groups. In DuPont's circulating fluidized bed reactor, VPO facilitates the production of maleic anhydride, which is used primarily in the manufacture of polyester resins.

Christopher Kiely, a professor of materials science and engineering, has worked many years with researchers from Cardiff University in the U.K. to

fixed-bed system and would not survive the mechanically abrasive environment of a fluidized bed reactor where the catalyst particles are continuously bounced around," says Kiely. "When DuPont offered us the chance to examine a commercial VPO catalyst modified to survive those conditions, we jumped at it."

To improve VPO's attrition resistance, DuPont scientists spray-dried a slurry of VPO precursor with polysilicic acid. The resulting particles comprise of delicate rosettes of VPO encased in a thin protective spherical shell of porous silica that provides free passage for reactants to enter and products to exit the catalyst.

Using various microscopy techniques, Weihao Weng, a graduate student working with Kiely, discovered that over time, some of the active VPO crystallites were transformed into less-active phases.

"The more critical observation was that the silica layer became very dense," says Kiely, "which might inhibit the reactants from reaching the catalyst. This would certainly account for the loss in catalytic activity observed in the used material."

Examination of the particles with Lehigh's X-ray ultramicroscope (XuM) revealed that not all the particles were actually filled with VPO. Some that appeared to be misshapen in the scanning electron microscope (SEM) images were actually hollow inside.

"This is the first time X-ray ultramicroscopy has been applied to an industrial catalyst," says Kiely. "The

"This is the first time X-ray ultramicroscopy has been applied to an industrial catalyst."

—Christopher Kiely

characterize and improve the performance of VPO catalysts. The group has found that the most productive form of VPO has a rose-like structure whose active phase is a nanometer-thin disordered layer on the surface of its "petals."

"The 'rose catalyst' is intended for a

technique allowed us to view the internal structure of individual particles without having to cut them open. This eliminated any concerns about the particles becoming damaged or material falling out of the shell during sample preparation." ❶

Researcher wins ceramics prize

Martin Harmer, director of Lehigh's Center for Advanced Materials and Nanotechnology, has received the 2010 W. David Kingery Award from the American Ceramic Society (ACerS).

The award recognizes "distinguished lifelong achievements involving multidisciplinary and global contributions to ceramic technology, science, education and art."

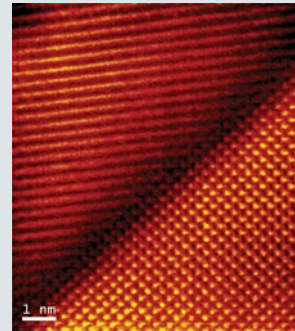
Harmer and his students, in one research project, have identified six grain-boundary "complexions," each characterized by a distinct rate of grain growth, in the ceramic alumina. The complexions can be controlled by making changes, often subtle, in chemistry and temperature.

The discovery could help engineers dramatically improve the formation and properties of ceramics, Harmer says, as grain boundaries play a key role in the creation of ceramic solids from powders and in the mechanical, chemical and other properties of the large bulk material.

In another project, Harmer has been applying the complexion concept to a long-standing problem in metallurgy—the fact that metals like nickel, aluminum and copper, which are intrinsically ductile, are prone to embrittlement when exposed to liquid metals such as bismuth and gallium.

Harmer has earned international acclaim for his studies of the properties of structural and electronic ceramic materials and their control at the micro- and nano-scale. In 2006, he was awarded a Humboldt Research Award for senior scientists by the Alexander von Humboldt Foundation.

In 2008, Harmer received ACerS' Robert B. Sosman Award, the top honor in ceramics, which is given annually to the person judged to have made the most significant contribution to the field of ceramics. ❶



A grain boundary of yttrium oxide, revealed by transmission electron microscopy.

Forty years at the cutting edge

The world-class Lehigh Microscopy School has taught more than 5,000 students on state-of-the-art instruments.

For the past 40 years leading experts in the field of electron microscopy and microanalysis have gathered at Lehigh each June to teach students from industry, government labs and universities how to get the best possible data from their own electron microscopes. Their goal is to instill a passion for the subject and pass on their collective expertise to the next generation of microscopists.

To date, more than 5,000 students from 50 states and 36 countries have taken courses at the school.

The idea for the Microscopy School was conceived by Joseph I. Goldstein, then a professor of materials science and engineering at Lehigh. “We had no scanning electron microscope here at Lehigh then,” Goldstein, now dean emeritus of engineering at the University of Massachusetts, recalls. “To convince the university it needed one, I recommended offering a course in microscopy and bringing in an instrument from a company.”

The first school was held in the summer of 1970 with three lecturers, a dozen students and a single scanning electron microscope (SEM). Since then it has grown to become the largest school of its kind.

Today, the two-week school offers basic and advanced courses that combine theory with lab practice. Manufacturers’ microscopes supplement the 11 scanning and transmission electron microscopes in Lehigh’s Nanocharacterization Laboratory, one of the largest of its kind in the U.S. This year’s school was attended by 130 students and included contributions from 37 lecturers (12 from Lehigh) and 22 instrument manufacturers.

“These microscopes are extraordinarily powerful platforms,” says lecturer Dale Newbury ’69, a Microscopy Society of America Fellow with the Surface and Microanalysis Science Division of the

National Institute of Standards and Technology. “How to interpret the images and how to apply that information usefully – that’s what we’re providing.”

Perhaps the defining mark of the school is the lecturers’ ability to stay current with the latest advances in the field.

“The Microscopy School began only five years after the first commercial SEMs were available,” says Charles Lyman, a professor of materials science and engineering at Lehigh who has taught courses

for 35 years at the school. “But it has followed the advances in scanning electron microscopy and microanalysis.”

The newer SEMs can feature advanced X-ray spectrometry; variable-pressure, low-voltage and high-resolution microscopy; electron backscatter diffraction; and focused ion-beam technology. The latest transmission electron microscopes (TEMs) have aberration correctors that improve image and chemical mapping resolution, and electron energy-loss spectroscopy for compositional analysis of lighter elements.

“For a long time the electron microscope was simply an imaging device,” says Newbury. “Now we use it to study morphology, composition and crystallography.”

All of these changes are reflected in the school’s continually updated course work. The school also uses the Internet to remotely access microscopes at other universities.

“A person who took the course some years ago,” says Lyman, “would hardly recognize it now, so much has changed.”

Engineers and scientists of all types attend the school.



“Many work in large-scale industrial laboratories that support the mainstream semiconductor and chemical industries,” says Christopher Kiely, director of the Microscopy School and of Lehigh’s Nanocharacterization Laboratory. “Others are from less conventional fields, including forensic scientists from the FBI investigating crime scene evidence and museum conservators seeking to determine the authenticity of paintings.”

Robert Edahl of the NASA Langley Research Center has taken five courses at the Microscopy School. “The faculty,” says Edahl, “are incomparable. They know the latest in their field. Things have changed just in the six years I’ve been attending the school.”

Several definitive textbooks have arisen out of the courses taught in the Microscopy School. For example, Goldstein, Lyman, Newbury and four other lecturers have coauthored *Scanning Electron Microscopy and X-ray Microanalysis: A Text for Biologists, Materials Scientists and Geologists*, whose fourth edition will be published next year.

“To maintain our position as the world’s premier microscopy school in this ever more competitive arena,” says Kiely, “Lehigh will need to continue to invest in first-class microscopy personnel and state-of-the-art instrumentation.”

Masashi Watanabe teaches the fundamentals and applications of scanning transmission electron microscopy.





Sougata Roy is testing an orthotropic deck prototype for New York City's Verrazano-Narrows Bridge.

Auditioning a new deck for a landmark bridge

With two towers reaching 700 feet into the sky and a span that stretches nearly a mile, the Verrazano-Narrows Bridge is a familiar beacon to travelers driving from New Jersey to New York City.

The bridge, the largest suspension bridge in the U.S., opened in 1964. Five years later, to accommodate increased traffic, a lower deck was added.

Now, New York City's Triborough Bridge and Tunnel Authority (TBTA) has decided to replace the original, upper deck – a grid of steel beams overlaid with concrete – with a steel orthotropic deck.

TBTA's decision, says Sougata Roy, was necessitated in part by security measures taken after Sept. 11, 2001. Fearful of a possible terrorist attack on the bridge, TBTA restricted truck traffic to the upper deck to limit damage from explosives that might be detonated inside a truck. The resulting heavier traffic loads accelerated damage to the upper deck. TBTA retrofitted the deck with new concrete, but with limited success.

Roy, a senior research scientist in Lehigh's ATLSS (Advanced Technology for Large Structural Systems) Center, is testing

a full-scale prototype of the orthotropic deck that will be used as the Verrazano-Narrows' replacement deck. The experiments are taking place in ATLSS' structural testing lab, whose test floor and fixed reaction walls, among the world's largest, impose multidirectional loads that simulate the demands structures sustain from traffic, wind and earthquakes.

Roy, the project's principal investigator, is being advised by former ATLSS director John W. Fisher, who supervised stress tests in the 1990s on prototypes of orthotropic decks for New York's Williamsburg and Bronx-Whitestone bridges.

"Orthotropic decks, properly designed, are the only decks that can enable bridges to achieve 100 years of service," says Roy. "That's the lifespan suggested by the U.S. Federal Highway Authority. Our goal is to verify whether it can be done."

An orthotropic deck has different stiffnesses in perpendicular directions. The stiffening ribs of the deck plate run parallel to the bridge's length. Transverse plates, or diaphragms, run perpendicular to the ribs and are spaced intermittently, providing less

stiffness transversely than longitudinally.

This asymmetry, says Roy, enables an orthotropic deck to distribute loads from trucks to a bridge's structural supporting elements with more efficient use of material. This allows for a more lightweight deck, which reduces stress to the deck and the suspension cables that support it.


But the asymmetry also increases the complexity of the stresses in the deck's components and requires sophisticated analysis of the deck and the welds connecting the bridge elements. If welded connections are not designed and fabricated correctly, says Roy, cracking and crack propagation can result.

Two connections pose particular challenges, says Roy. Cutout areas, where ribs pass through the transverse diaphragm plate, rotate across the diaphragm in response to truck loading and develop a complex combination of in-plane and out-of-plane stresses. Secondly, the connection between enclosed ribs and the deck plate must be made from outside. The heat applied for rib-to-deck plate welding requires careful calibration: Too much can cause melting through the thin ribs. Too little can result in inadequate penetration, a poor connection and premature cracking.

Roy's group is testing a prototype deck panel that measures roughly 25 feet by 25 feet and is integrated with floor beams and stringers to simulate actual bridge conditions.

Six hydraulic actuators above the deck impose loading in sequence to mimic the passage of trucks. Three actuators beneath the deck simulate the global deformation imposed by truck loads. Roy is using Lehigh's high performance computing (HPC) capabilities to model and analyze the entire setup.

"HPC enables us to better predict the system performance of a deck," says Roy. "The physical results allow us to calibrate our HPC models. Then we can develop a framework to design and simulate the behavior of bridge decks with computational modeling and without expensive lab work.

"Our goal is to develop specifications for the robust design of new decks that can last a century." 

Meeting HD's demands with a faster algorithm

In their insatiable demand for faster, smaller and more mobile communications gadgets, says Zhiyuan Yan, consumers are straining the capacity of information technology.

Handheld devices that offer high-definition (HD) images and portability require high throughput, or processing speed, says Yan, an assistant professor of electrical and computer engineering. They must also be able to operate with little power.

These two trends – greater performance and stringent power requirements – pose challenges to the technology and mathematical equations on which IT relies.

“HD applications require high throughput and low power in order to be handheld and mobile,” says Yan. “When you take these two together, you’re in a sense burning the candle at both ends.”

Yan and Meghanad Wagh, an associate professor of electrical and computer engineering, have an NSF grant to devise scalable bilinear algorithms to meet these challenges. They also have support from Thales Communications, the U.S. Department of Defense, and the Pennsylvania Infrastructure Technology Alliance.

“This project represents a different way of thinking about algorithms,” says Wagh. “Normally in signal processing, you write algorithms for standard computer architectures. But to achieve the

required speed, we have developed a new class of algorithms that can be directly cast into hardware. Our algorithms are extremely fast and take advantage of the new trend in technology.”

The new algorithms are more suitable for high-performance computing, says Yan.

“Until a few years ago, to improve computer speed, you used a larger processor. Now, you split the computation and do it in parallel with many smaller processors, which can be as good as or better than one superfast processor, while consuming less power.

“Many traditional signal-processing algorithms, however, are not parallelizable and cannot take advantage of these new ideas.”

Parallel processing allows separate applications of a multimedia system to be dedicated to specific processors. This avoids overloading a single processor with competing demands.

“Our algorithms are inherently structured,” says Yan. “This enables us to extract the maximum parallelism in processing and to offload tasks to dedicated hardware.”

The Lehigh algorithms can also

be scaled to handle the greater complexity required by computationally intensive jobs.

“Our algorithms scale gracefully and deal easily with size and complexity,” says Yan. “The earlier algorithms worked fine for small problems, but problems have



become more complex. Without algorithms like ours, this complexity would overwhelm processors.

“Our goal is to make it possible for information technologies to continue to improve at the rate that consumers are accustomed to.”

The algorithm developed by Zhiyuan Yan and Meghanad Wagh is well-suited for parallel processing.

A systems view for healthcare

American medicine leads the world in most fields of clinical research, training and practice, said a 2008 report by the Institute of Medicine and the National Academy of Engineering, but nearly 100,000 Americans nevertheless die each year because of “broken healthcare processes.”

The systems-engineering tools that have transformed telecommunications, transportation and manufacturing have not been applied to the delivery of healthcare, said the report. As a result, “best practice” procedures are often ignored, and hundreds of billions of dollars are lost each year to system failures, unnecessary repetition, poor communication and other inefficiencies.

To bring a systems perspective to healthcare, Lehigh's department of industrial and systems engineering is working with the Mayo Clinic and other leading healthcare providers to develop a 30-credit professional master's of

engineering degree program in Healthcare Systems Engineering.

The proposed new program will equip students with fundamental skills in industrial and systems engineering along with a solid foundation in healthcare delivery systems and processes. Graduates will be prepared to assume leadership roles aimed at streamlining processes and improving the quality and efficiency of healthcare systems.

Students in the program will take these core courses: Introduction to Healthcare Systems, Quality and Process Improvement in Healthcare, Financial Management in Healthcare, and Information Technology in Healthcare. They will complete foundation courses in industrial and systems engineering along with a capstone project working in industry with healthcare partners.

The program will seek students from a variety of engineering backgrounds, offer flexibility in elective courses, and allow students to tailor programs to their particular interests.



THE QUESTIONS THAT MATTER

FOR GREAT RESEARCHERS, HUMILITY IS INDISPENSABLE.

Alan J. Snyder became Lehigh's vice president and associate provost for research and graduate studies in August 2010 after a long tenure with Pennsylvania State University's College of Medicine, where he served as professor of surgery and bioengineering, associate vice president for health sciences research and vice dean for research at the College of Medicine, and director of the Office of Technology Development. At Penn State, Snyder spent 20 years working on the development of artificial hearts and ventricular assist devices for patients suffering heart failure. Snyder is a Fellow of the American Institute for Medical and Biological Engineering. He holds a Ph.D. in bioengineering from Penn State.

Q: What motivates you?

A: I'm excited by the great things we can do and the certainty they will have a tangible and positive impact on people.

Q: Beyond knowledge and intelligence, what are the qualities necessary to be a good researcher?

A: Curiosity, drive and intensity. Researchers identify questions that matter for which they don't know the answers. We dream of things we could do *if only*, especially if we think we can get to that *if only*. All great researchers have a touch of humility because they realize they don't know the answers to important questions.

Q: What attracted you to Lehigh?

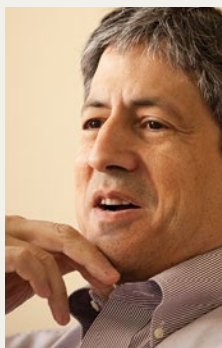
A: Lehigh has worthy aspirations and a sound foundation upon which to build. There is a

tradition of bringing ideas all the way to the point where they impact the world. There is a cohesive academic community that recognizes the inherent value of knowledge and the relevance of every discipline to understanding the world and acting more effectively in it.

Q: What is your most memorable research achievement?

A: Working on medical devices — from brainstorming ideas to designing and building to sitting with a patient whose life is supported by a device I had a role in developing. It's exceedingly important to me, as we do research and develop technologies, that we pay attention to the human impact — how implementation plays out in people's lives.

Q: You were part of the research team that worked in the 1990s on the preclinical development of the Arrow LionHeart, the first fully



The evolution of technology, says Alan Snyder, must be accompanied by attention to its human impact.

technology should be to enable people to meet their personal life goals. Telling someone what they can and cannot do is tantamount to telling them what their goals should be.

Q: Why are engineers well-suited to conduct medical research?

A: In addition to being adept at identifying and understanding problems, engineers have ways of understanding the world that are unique and they can lend that perspective to others. One is the ease with which engineers recognize systems — in which changing one thing affects many others. Systems thinking has become important in other fields, including biology. Today it is clearly recognized that systems thinking needs to be infused into the process of delivering healthcare. Systems thinking is also necessary in the application of technology. It is common to develop technologies and bring them into practice simply because we can. But we should also think of impact and how to manage it. I've worked on devices to keep people alive and allow them to get into better shape as they wait for heart transplants. But they also needed support in dealing with the stressful environment of a hospital and isolation from friends and families.

Q: What role does research play in educating students?

A: We want to provide students with experiences that enable them to make unique accomplishments. This includes ensuring that students are competent in their fields of concentration and confident of their ability to work in the real world with people who bring different perspectives. The environment of creative scholarship is an excellent venue for students to grow in competence, confidence and capability.

Q: Discuss the importance of fundamental research.

A: As scholars, we have faith in the innate value of knowledge and understanding. We also have full confidence that new knowledge will have an impact, whether or not we know exactly how that will happen. We should remind people why it's better to be enlightened on a topic than not. I recently heard someone point out that you need only open the newspaper to see what happens when the workings of the physical world are poorly understood and the perceptions and motivations of human beings remain inscrutable.

Q: What is your philosophy of technology transfer?


A: Technology transfer is the process of ensuring that the knowledge we generate has its full impact in the world. For that to happen, patenting and licensing are often necessary — to justify investment of risk capital — but they are only one way. When faculty members offer a workshop to people from industry, that's technology transfer. When they publish a paper so others understand and use their work, that's also technology transfer. Anytime we take theory to practice in a way that enables others to make practical use of it, we've succeeded in technology transfer.

Q: What is your most memorable achievement in technology transfer?

A: What I've enjoyed most is helping people shift their perspectives from their work as scientists to what others need. This can be difficult for people who have made major personal commitments to their research. Think of a scientist who has worked 15 to 20 years on a project that's about to give birth to an important new product. But first the scientist has to let someone else take ownership of the idea. Letting go can be incredibly difficult. I believe some of my most satisfying work has been in guiding scientists, whose focus is on discovery and understanding, to transfer their work to a startup company whose focus is, of necessity, on a product.

Q: How do we educate the next generation of scientists?

A: I was a gadgeteer as a kid; I knew I was going to be an engineer. If I were a 12- to 17-year-old today, I would feel that I had a far larger menu of opportunities. It's difficult to attract students to STEM (science, technology, engineering and mathematics) fields in part because they're so aware of their options and there is more competition for my students' curiosity and motivations.

We have to continuously humanize STEM learning. Students whose curiosity and talents suit them to these fields, and who are sensitive and plugged in socially, should know that study of science and technology will not bar them from any of the world's fascinating opportunities. The richer and more varied the experience that we can promise students, the easier it will be to attract them to STEM fields. 

implantable heart-assist device for patients with severe heart failure. How has the device progressed?

A: Our vision was to provide prosthetic blood pumps that support circulation in patients with intractable heart failure, and to do it in a way that minimized limitations in people's daily lives. Ours was the first group — and the only one to date — to develop fully wireless systems that allow patients to shower normally and swim.

The fundamental core technology — pumps that move blood safely and reliably — has continued to evolve. The newer pumps are smaller, more reliable and easier to implant. But the success of these smaller devices is due in part to what was learned from our experience.

The technology continues to evolve, and we've realized that people are incredibly adaptable, inventing ways to manage technology for their own purposes. There was recent publicity about a young woman with an implanted blood pump getting married with her battery pack and electronics tucked neatly inside the back of her wedding dress. The goal of medical

MANY DISCIPLINES, ONE GOAL

One of the STEPS building's most salient features, especially in early evening, is its five-story atrium.

Glass is used throughout STEPS to soften the boundaries between building and environment.



LEHIGH'S NEW STEPS BUILDING ENHANCES THE ENVIRONMENT FOR RESEARCH.



"When we try to pick out anything by itself," the American naturalist John Muir wrote a century ago,

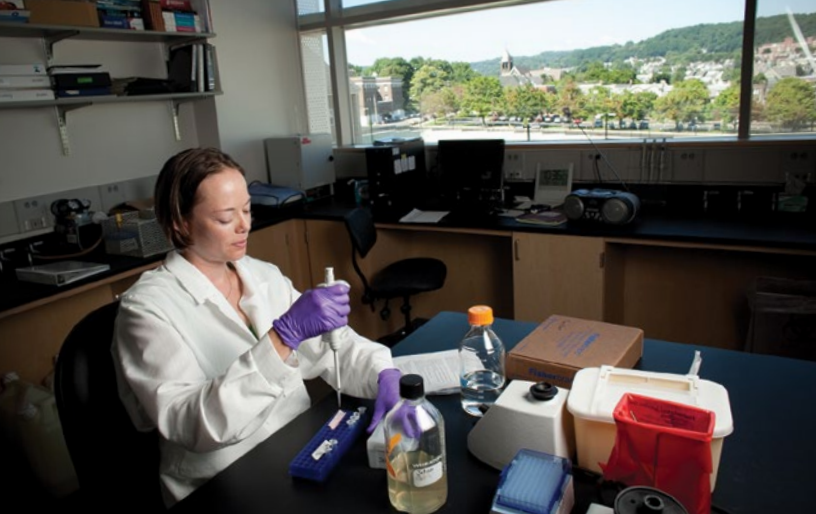
"we find it hitched to everything else in the universe."

Muir's words are engraved on the granite floor of Lehigh's newest academic building near a fountain of water and a 20-foot-high window. Etched into the window is an enlargement of a leaf from the American chestnut tree, the one-time canopy of eastern forests that was decimated by a fungus but is now being reintroduced. Through the glass, the stone façade of Packard Laboratory, home of Lehigh's P.C. Rossin

College of Engineering and Applied Science, appears across Packer Avenue.

Completed last summer at a cost of \$62 million, the STEPS (Science, Technology, Environment, Policy and Society) building embodies the interconnectedness of life that Muir embraced and the conviction that the solutions to the world's most pressing challenges require collaborations across multiple disciplines.

STEPS' bold mission flows from its name. The 135,000-square-foot structure is part of an \$85-million initiative that has assembled engineers, natural scientists and social scientists to tackle problems in energy and environmental sustainability that are too complex to confine to one field of study. How can changes in Earth's climate be accurately



Labs in the B and C wings (above) face the rising sun. The spacious new chemistry labs (left) contain state-of-the-art instrumentation and glass hoods.



modeled and projected? How can contaminated air and water be most effectively remediated, and clean drinking water most efficiently provided? How many factors, from government land-use policies to power transmission to the terrestrial absorption of carbon dioxide, are hitched to the desire to clear trees for a wind farm?

Lehigh's scientists and engineers have investigated issues like these for decades. STEPS promises to enhance their efforts by fostering new partnerships among researchers who just months ago worked in different buildings. While the initiative will endow faculty chairs and student fellowships, the building will house researchers from earth and environmental sciences, environmental engineering, and energy systems engineering.

"Being under one roof," says Derick Brown, associate professor of civil and environmental engineering and codirector of Lehigh's Environmental Initiative (EI), "will enable all of us working on environmentally related research to interact daily. Most ideas for collaborative research come from chance meetings. You can't plan ideas."

Anne Meltzer, dean of the College of Arts and Sciences and professor of earth and environmental sciences, agrees.



THE BIGGER RESEARCH PICTURE

Lehigh's environmental engineers and scientists are already working to improve the quality of drinking water in the developing world (see sidebar, page 14) and to remove arsenic from groundwater (sidebar, page 13). Engineers are pioneering nanotechnologies to remove toxins from groundwater and surface water (story, page 18),

while journalists are studying the media's coverage of nanotechnology's promise and potential pitfalls.

Their new proximity in the STEPS building, researchers say, will make it possible to join forces on other areas of common

interest. These include climate change, alternative energies, carbon capture and sequestration, and resource development. Graduate students in the Energy Systems Engineering Institute (stories, pages 22-23), which has also moved into the STEPS building, conduct research in these areas under the guidance of industry sponsors.

Proximity will also make it easier to address multifaceted topics. A case in point, says Frank Pazzaglia, is the management of carbon dioxide. As much as half the CO₂ emitted as a result of human activity is absorbed by oceans and land surface. The myriad factors governing carbon cycling are not fully understood but are affected

"STEPS is creating a vibrant atmosphere for interdisciplinary research and education. There's a high level of excitement and activity in the new building." —Derick Brown

"There are many ways to communicate over large distances," says Meltzer, "but they don't really substitute for working in the same building."

by forest and watershed management policies. Meanwhile, engineers are developing new technologies to capture CO₂ from power plants and sequester it in underground reservoirs, while

geologists are probing the behavior of those subterranean traps.

“STEPS will help us develop overarching research programs that tie together the science, technology and policy issues that underlie virtually all modern environmental issues,” says Pazzaglia, who is EI codirector and department chair of earth and environmental sciences in the College of Arts and Sciences.

“Often, the most interesting research problems lie where disciplines overlap. At these boundaries, researchers need to rely on each other’s expertise to push knowledge forward.”

A FLOW OF PEOPLE AND IDEAS

With 50 research and teaching laboratories, STEPS represents Lehigh’s largest investment in a decade in undergraduate science and engineering education. Ten teaching labs are dedicated to undergraduate courses in biological sciences and chemistry, including cell and molecular biology, genetics, integrative biology and vertebrate anatomy, as well as chemical principles and organic chemistry. The introductory courses are required of all engineering majors, and the advanced courses are required in bioengineering, chemical engineering, environmental engineering, and materials science and engineering.

The new teaching labs contain state-of-the-art instrumentation and sterilization and incubation facilities, and more seats, hood space and preparation rooms. As a result, students work in smaller teams and use more analytical methods. The hoods in the chemistry labs are made of glass, and the organic chemistry labs are equipped to do gas, liquid and infrared chromatography and mass spectrometry.

A faculty committee worked five years with Lehigh’s office of facilities services



Simple test uses pH to detect toxic metals in water

A new technique that uses pH to sense toxic metals in water could lead to the development of an inexpensive, easy-to-use device that monitors water quality. Such a device could help detect contamination in water bodies, enable households to test drinking water, and prove invaluable in countries with limited access to conventional water-testing techniques.

The simple test, says Arup

SenGupta, the P.C. Rossin Professor of civil and environmental engineering, involves passing water through a mini-column of granular sorbent material and then testing its pH. The sorbent is a fused mixture of hydrated ferric oxide and akermanite (calcium magnesium silicate). When uncontaminated water passes through the column, it becomes alkaline due to the slow hydrolysis of the akermanite and the steady release of hydroxyl ions.

When a drop of phenolphthalein indicator is added to water exiting the column it turns pink. Trace concentrations of a heavy metal such as lead or zinc, however, cause the exit water to turn acidic and remain colorless when phenolphthalein is added.

“At first, the granular material in the column absorbs the heavy metal ions,” says SenGupta. “After a while, all the absorption sites become occupied and the remaining metal ions pass through the column. These ions then form metal-hydroxyl complexes by reacting with the hydroxyl ions in the exit water. Reducing the number of hydroxyl ions in the exit water changes its pH from alkaline to neutral — a neutral solution remains colorless when a drop of phenolphthalein indicator is added.”

SenGupta came up with the idea for the test several years ago while working on a project using much larger quantities of a similar fused mixture to clean up a water supply. With the help of his graduate student, Prasun Chatterjee, he was able to develop it.

According to EPA’s drinking water regulations, allowable levels for copper and zinc are 1.3 and 5 milligrams per liter of water. For lead, the acceptable level is 15 micrograms — about a hundred times lower.

“Because the target level for detecting lead is so low,” says Chatterjee, “we had to use a simple preconcentration step.”

Another hurdle encountered was the possible interference of phosphates and natural organic matter often present in water bodies. This was overcome by placing a small amount of one of SenGupta’s patented hybrid anion exchange materials, comprised of iron oxide nanoparticles dispersed inside polymer beads, above the fused sorbent mixture in the column. This first layer of material removes phosphates and other weak-acid anions from the water before it passes through the fused mixture of hydrated ferric oxide and akermanite.

“So far, the test has proved very successful for deliberately spiked samples of Lehigh River water,” says SenGupta. “Unfortunately, with our current device, a liter of water is needed to observe the required pH change.” The team is modifying the sorbent material to work with smaller volumes of water.

For their recent paper published in the *AIChE Journal*, Chatterjee will receive the prestigious 2010 C. Ellen Gonter Environmental Chemistry Award from the American Chemical Society. This is one of the highest honors bestowed on a graduate student working in environmental chemistry.



Chatterjee (left) and SenGupta, test the pH of water after it passes through a column of granular sorbent.



Moonlight highlights the roots, trunk and branches of artist Larry Kirkland's tree in the atrium's glass curtain wall.

and campus planning and with two architectural firms to plan the STEPS building. Their aspiration was to design a new model for multidisciplinary collaboration in research and education, and they are confident that STEPS' final design, by Bohlin Cywinski Jackson of Philadelphia, has succeeded.

The physical layout of the building makes it almost impossible for people not to cross paths. The administrative offices are clustered in a suite in the A wing, and faculty offices are situated along the east face of the B

and C wings. Research labs are shared by multiple groups and interspersed with teaching labs and classrooms. The long concourse in the one-story A wing is ideal for poster sessions. Lounges and informal seating areas are sprinkled throughout the building and equipped with whiteboards to stimulate discussions. Those in the upper floors of the B and C wings command vistas of the Bethlehem skyline and Lehigh's

145-year-old Packer Campus.

"The planning committee," says Pazzaglia, "wanted to create flexible spaces that promote synergy. We put a ton of effort into designing the labs, classrooms and open spaces so that one activity would flow into another."

A CRITICAL ROLE FOR GLASS

The junction of the B and C wings contains STEPS' largest open space. Here the building opens into a five-story atrium whose glass curtain wall is etched with the image of a tree – roots, trunk and branches – by artist Larry Kirkland.

The judicious use of glass throughout STEPS highlights the activities of researchers and softens the boundaries between building and environment. Windows in the hallways offer views into most of the labs, while display cases lit by LED light showcase discoveries from past and present.

The glass also connects visitors with the outside environment. A floor-to-ceiling window wall runs the length

Water purification made simpler

Inside a growing number of homes in the developing world, sand and biological organisms are collaborating to decontaminate drinking water.

Arranged in barrels of concrete or plastic, these biosand water filtration systems (BSFs) remove 95 to 99 percent of the bacteria, viruses, worms and particles contained in rain or surface water. A layer of microorganisms at the top of the sand bed consumes biological and other organic contaminants, while the sand below removes contaminants that cause cloudiness and odor.

A BSF can produce several dozen liters of clean water in an hour. But it can weigh several hundred pounds and cost up to \$30, an expense some families in developing countries cannot afford.

Kristen Jellison and her students are trying to

build a BSF that is smaller than the standard system, but just as effective.

"Smaller, lighter BSFs," says Jellison, an associate professor of civil and environmental engineering, "would be cheaper, easier to transport and available to a broader global market. Preliminary research has shown the potential for smaller systems to remove most disease-causing organisms, except possibly viruses."

Jellison has devoted most of her career to improving drinking water. As coadvisor to

Lehigh's chapter of Engineers Without Borders, she helped lead efforts to design and build a 20,000-gallon water-storage tank and chlorination system in Pueblo Nuevo, Honduras.

With support from NSF and the Philadelphia

Water Department, she has spent five years studying the parasite *Cryptosporidium parvum* and its transport and fate in water bodies. The parasite is found in multiple hosts, is difficult to eradicate, and can be deadly to people with compromised immune systems.



In an effort to identify possible sources of *Cryptosporidium* contamination in the Philadelphia watershed, Jellison studies the DNA

of the A wing's north face and looks onto a courtyard of native plants and grass. Faculty offices and labs are aligned east to west and have good exposure to the sun. The windows in each room feature fritted glass, vertical fins and horizontal sunshades that mitigate glare while allowing the optimum amount of sunlight to penetrate.

"The transparency," says Tony Corallo, associate vice president for facilities services and campus planning, "helps eliminate boundaries between the inside and outside of the building. It also encourages a sense of community among the building's occupants."

A GOOD ENVIRONMENTAL NEIGHBOR

With a variety of features that minimize energy and water use while maximizing the benefit of natural light and heat, the STEPS building has been designed for silver certification by the Leadership in Energy and Environmental Design (LEED) Green Building Rating System.

The new building also pays deference to its environment, natural and man-made. An 8,000-square-foot green roof atop



the A wing retains excess storm water and releases it gradually to avoid overwhelming the city's storm sewer system. The green roof absorbs the sun's heat and CO₂, and releases oxygen.

To reduce the environmental impact of STEPS, planners limited the A wing to a single story.

"Packard Lab across the street is four stories high," notes Corallo. "Placing two multistory buildings on opposite sides of the same street would have created a canyon effect that we wanted to avoid. Also, as the sun traverses the southern portion of the sky, the low height of the A wing will allow more light to reach the courtyard lawn."

Along the south face of the A wing, the planners added a wall of gray quartzite to match the iron-rich quartzite patina of many of the buildings on Lehigh's main Asa Packer Campus.

STEPS' overall design, says Derick Brown, is at one with its mission.

"Lehigh has long been a leader in environmental science and engineering," says Brown. "STEPS will help us reach the next level by creating a vibrant atmosphere for interdisciplinary research and education.

"There's a high level of excitement and activity in the new building. We're looking forward to moving from hallway conversations to collaborative research projects that take aim at some of the grand challenges facing society." 

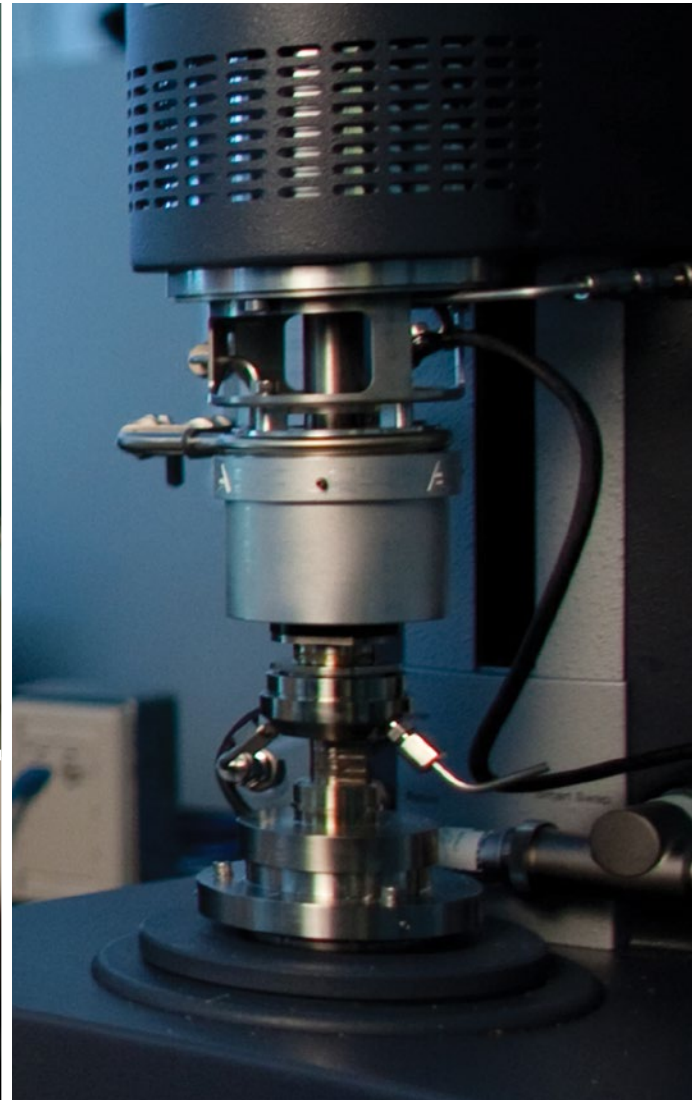
A low-velocity, high-output fan atop the atrium (left) pushes warm air down to mix with cool air. The green roof on the A wing (right) absorbs CO₂ and releases oxygen.

of various species using a technique called polymerase chain reaction (PCR). She also studies the impact on *Cryptosporidium* of biofilms, the slimy layers of microorganisms that form on rocks, pipes and other surfaces in water.

Jellison's group is conducting experiments on BSFs of various sizes, including systems that fit inside two- and five-gallon plastic pails. (The typical BSF is 3 feet high.) The group will change the depth of the sand column, add rusty nails to several pails (in an effort to increase virus removal), and alter other parameters.

"BSFs were developed in the 1980s," says Jellison. "This is the most comprehensive study to date to characterize the efficiency of different filter types."

The project is funded by EPA and the Lindbergh Foundation.



MODELING A POLYMER'S

A BIODEGRADABLE FIBER'S LIGHTNING-QUICK BEHAVIORS POSE A CHALLENGE.

A new generation of synthetic polymer fibers is starting to transform the textile industry. The fibers are made from polylactic acid (PLA) and have the potential to replace polyesters such as polyethylene terephthalate (PET), which accounts for 40 percent of the world's textile production.

Unlike PET, the manufacture of PLA fibers is not a drain on fossil fuels: the fibers are polymerized from lactic acid produced by the fermentation of natural sugars in agricultural crops. The fibers are also biocompatible and biodegradable.

Polymer fibers are often fabricated with a melt-

spinning technique. Viscous molten polymer is pumped through a plate filled with small holes, leaving strands of viscous liquid that stretch and begin to solidify as they wind onto a takeup spool.

All of this happens extremely quickly. Fiber spinning rates can reach 9,000 meters per minute and transit times from plane to take-up spool can last less than a millisecond. During this process, the properties of the fiber are governed by the way in which the flexible molecular chains align.

Melt-spinning conditions must be optimized to improve efficiency and maintain quality control.

This requires an ability to predict how changes in processing conditions affect fiber properties.

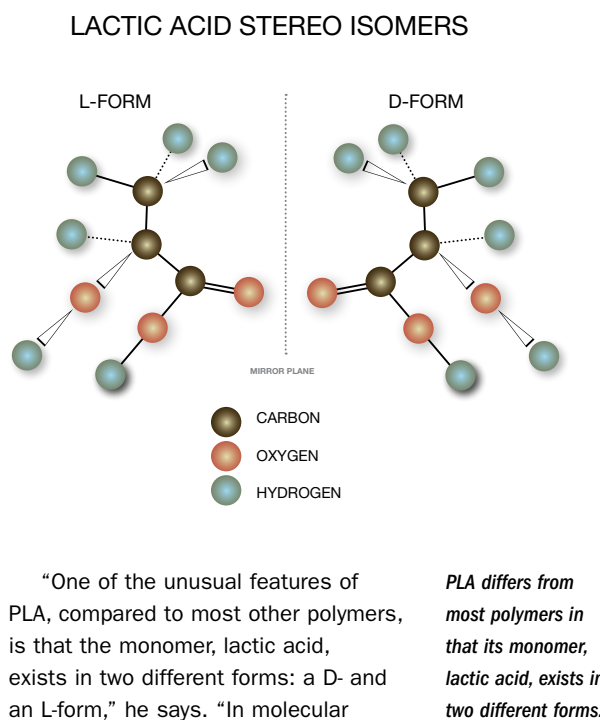
Anthony McHugh has developed theoretical models for the fiber melt-spinning of conventional polymers, and is now working on PLA fibers. “The main challenge is to incorporate the physical changes that occur in such short time scales into the model,” says McHugh, a professor of chemical engineering.

McHugh’s models are unique in that they include explicit equations to describe the stresses in both the molten polymer and the crystalline forms. The two equations are linked through the crystallization process, enabling researchers to predict two critical phenomena – the manner in which polymer molecules align under changing stress and temperature conditions and, ultimately, the amount of flow-induced and flow-enhanced crystallization that occurs as a function of take-up speed.

A major advantage of McHugh’s models is their ability to predict the reduction in polymer chain orientation that occurs in nylon fibers drawn at high speeds. “This is counterintuitive,”

DuPont and ExxonMobil, are now using McHugh’s models.

In 2002, with the help of graduate student William Kohler and postdoctoral associate Prashant Shrikhande, McHugh turned his attention to polylactic acid.



crystalline polymer (PLLA) with superior mechanical properties and a melting temperature of 175 degrees C. Combining equal amounts of both forms into a “racemic” mixture, however, results in the formation of a co-crystal phase that exhibits an even higher melting temperature and superior mechanical properties.

The manufacture of PLA fibers requires processing conditions greater than 190 degrees C. At these temperatures, reactions can cause a reduction in the polymer’s molecular weight and a degradation of its mechanical properties.

“Clearly, this polymer has a very narrow processing window,” says McHugh, “which puts an even greater emphasis on the need to develop a reliable theoretical model.”

The first attempts to apply McHugh’s model did not meet expectations for PLLA. The chain-entangled nature of the polymer led to increased viscosity and greater spin speed. McHugh responded by using a newer constitutive equation that accounts for chain entanglements, the so-called “extended pom-pom” model.

“This modification has allowed us to accurately predict fiber diameter profiles and elongation of fibers made from both PLLA and rPLA as a function of spinning rate,” says McHugh. “Moreover, we have been able to predict the experimentally observed enhancement in the co-crystal formation that occurs at high spin speeds.”

McHugh believes the robustness of the model will enable him to examine other parameters, such as the effect that polymer chain branching and molecular weight dispersity have on spinning behavior.

The work was funded by NSF through the Center for Advanced Fibers and Films at Clemson University. ①

PROPERTIES

he says. “Normally you would expect to see the increase in orientation with takeup speed to continue.” This phenomenon had been observed by DuPont researchers but never fully understood.

“The practical implication,” says McHugh, “is that we can now identify beforehand the upper limit in spin-speed for processing fibers with maximum orientational properties.”

Some of the world’s leading synthetic fiber producers, including Dow Chemical, Celanese Acetate,

Anthony McHugh’s mathematical models account for physical changes that occur in a millisecond or less.

terms, the D-form is simply a mirror image of the L-form.”

Polymerizing a mixture of the two forms produces a polymer with a relatively low melting point and mechanical properties poorly suited for fiber applications. Using just one of these forms, say, the L-type, produces a highly

think at the nanoscale, act globally

WEI-XIAN ZHANG'S
TECHNOLOGIES ARE
CLEANING UP
POLLUTION ON
THREE CONTINENTS.

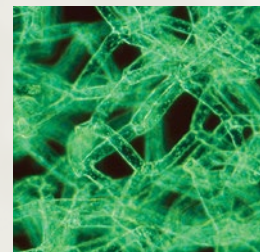


Wei-xian Zhang, professor of civil and environmental engineering, was working in his lab, pondering oil spills in the Gulf of Mexico and in Dalian, China, when a call came from Hoboken, New Jersey. A pedestrian had smelled fumes in one of the city's brownstone neighborhoods. Police had discovered heating oil gushing from a corroded tank beneath the sidewalk in front of a house.

Zhang, who applies nanotechnology solutions to some of the world's most notorious environmental disasters, knew time was of the essence. The leak had to be stopped and the oil removed before it spread farther into the soil and groundwater.

Ten years ago, Zhang recalled as he drove to Hoboken, a construction crew would have rushed to the scene to perform an intervention as elaborately choreographed, and almost as dated, as the million-dollar brownstone's ornate facade. Inch by inch, workers would have jacked the house off its foundation. A backhoe would have dug up the tainted soil to a depth of dozens of feet, and a line of trucks would have hauled it to a landfill. Workers would have refilled the foundation with fresh dirt before lowering and resealing the house. The entire process would have taken weeks or months.

Zhang found these excavations fascinating to watch – “like a fossil dig,” he says – but decided there had to be a smarter way to decontaminate soil and groundwater. A decade ago, he took particles of iron measuring 50 nanometers in diameter, or about 1,000 times



thinner than a human hair, and coated them with infinitesimal dots of palladium. He spent 30 minutes drilling a 3-inch hole, then pumped the nanoparticles into the soil and groundwater.

The nanoparticles spread quickly through the narrow pathways of soil and sediment. The greater proportional surface afforded by the particles' tiny size gave the catalyst an unprecedented degree of contact and reactivity with toxins. The agile nanoparticles "chased" the contaminants in the water and converted them into harmless compounds.

Lehigh licensed the commercial rights to the nanoparticles to several companies, including the global engineering firm Golder Associates and local start-up Lehigh Nanotech LLC of Bethlehem, Pa. To date, the nanoparticles have remediated more than 50 toxic waste sites in 10 states and in Europe and Asia. They have decontaminated soil and groundwater in one-tenth the time, and at a much greater economy of scale, than traditional cleanup methods. At landfills, factories, gas stations, dry-cleaning shops and military sites, they have removed pesticides, vinyl chloride, TCE, chromium and other toxins.

"This revolutionary breakthrough in nanotechnology is helping clean up hazardous waste sites faster and more economically than ever before," said *Better World Report*, a publication of the Association of University Technology Managers, which named Lehigh Nanotech one of the nation's top 25 technology-collaboration stories in 2008.

"It takes only a few pounds of the nanomaterials, versus a ton of larger compounds, to make sweeping changes in cleaning up contaminated environments."

A green role for scrap metal

Not all environmental challenges, says Zhang, are suited to nano-solutions.

In 2002, Zhang received a call from an industrial wastewater treatment plant in

the Taopu Industrial District of Shanghai. Zhang knows the area well; he earned his bachelor's degree from Shanghai's Tongji University, one of China's top engineering schools.

"China is experiencing serious environmental problems," says Zhang. "The area around Shanghai has 6,000 industrial parks. Many of them are huge, and they generate a tremendous amount of industrial wastewater."

The Taopu facility was using traditional biological methods, called activated sludge, to treat wastewater from chemical, materials and pharmaceutical companies. Zhang and his collaborator, Luming Ma, professor of environmental engineering at Tongji, identified two challenges. Biological microorganisms effectively treat municipal wastewater but not the compounds in industrial wastewater, many of which are loaded with toxic metals and synthetic organic chemicals. And the iron nanoparticles from Zhang's lab that could remove those toxins were too expensive – at about \$50 a pound – for a large, 13-million-gallon-a-day treatment plant in a developing country like China.

Zhang and Ma thought of the countless pieces of cheap scrap metal being generated by nearby factories. With its composition of zero valent iron (ZVI) – iron that has not been oxidized, he and Ma reasoned, the scrap metal could pretreat the industrial wastewater. After the iron degraded the toxic chemicals, the wastewater could be treated a second time with biological methods.

The two researchers coated the scrap

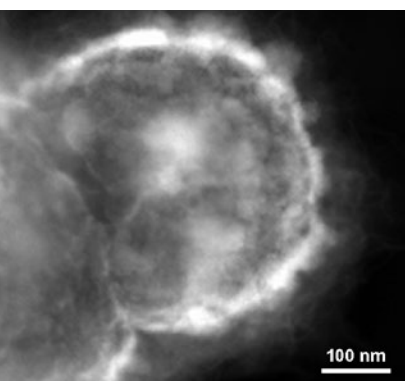
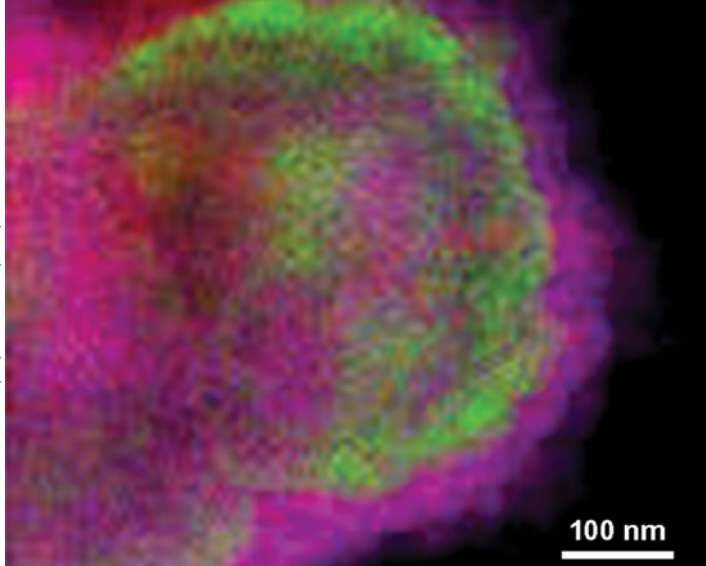
100nm

"Only a few pounds of the nanomaterials, versus a ton of larger compounds, make sweeping changes in cleaning contaminated environments." —Better World Report



Workers remove algae (above) from China's Lake Tai.





An electron micrograph and chemical map (green = Pd and purple = iron oxide) of an iron nanoparticle doped with palladium used to treat ground water contaminated with halogenated organic compounds.

metal with copper to improve its effectiveness, then ran lab experiments and conducted a successful pilot test at the Taopu plant. The city of Shanghai approved construction of a full-scale reactor with 2 million pounds of iron shavings, the largest test in history to use iron in an environmental application. The results were immediately positive. When the ZVI reactor was connected

to the existing biological treatment plant, removal rates improved for biological oxygen demand, nitrogen, phosphorus, and colors and dyes.

The “green” iron, Zhang reported in an article published by *The Economist* in November 2008, enhanced the treatability of the industrial wastewater by reducing the toxicity and increasing the biodegradability of recalcitrant organic compounds.

“This project,” he says, “has uncovered a fascinating use for recycled materials.”

Extracting value from scum

Not far from the Taopu Industrial District, in the delta of the lower Yangtze River, lies Lake Tai, third-largest body of fresh water in China. The lake’s misty vistas and peaceful waters have inspired centuries of artists. Millions of Chinese depend on the lake for food – rice, fish and world-famous crab and shrimp – and for drinking water.

Today, much of Lake Tai is veiled in green, covered from April to October with algae feeding on agricultural, municipal and industrial wastes. Two million people, *The New York Times* recently reported, have had to stop using water from the lake, and stench from the algae can be smelled a mile from Tai’s shores.

In the past two years, Zhang has helped the city of Wuxi build a \$25-million plant that filters and recovers 45,000 pounds of algae a day from Lake Tai. The goal is to develop new technologies that utilize algae. Possible uses range from organic fertilizer to

A LOW-COST CATALYST PREPARES TO TAKE ON NO_x

A group led by Charles Lyman, professor of materials science and engineering, has designed and tested low-cost, bimetallic, nanoparticle-based catalysts that can convert harmful NO_x gases, which are emitted from coal- and gas-fired power plants, to nitrogen and water vapor.

The use of catalysts for pollution control in power plants is not new. A technique called selective catalytic reduction (SCR) can convert 95 percent of NO_x to nitrogen and water – but with a catch.

“Conventional SCR requires another toxic gas, ammonia, to carry out the reduction,” says Rick Herman, a senior research scientist. “In addition, these catalysts only perform well at high temperatures.”

Lyman and Herman sought first to improve the performance of a platinum-rhodium nanoparticle-based catalyst that uses hydrogen, rather than ammonia, as a reducing agent. This catalyst works at much lower temperatures.

“Choosing the correct catalyst preparation procedure was critical to ensuring that all these criteria were met,” says Paul Dimick, a Ph.D. candidate in chemical engineering working with Lyman.

To obtain the desired microstructure, researchers sequentially impregnated an alumina support with aqueous solutions of platinum and rhodium chlorides. Then they applied a series of thermal treatments to convert the metal chlorides into active bimetallic nanoparticles.

By replacing rhodium with much cheaper cobalt, the group developed an inexpensive catalyst capable of reducing NO_x with hydrogen instead of ammonia.

“This procedure was chosen so that the desired microstructure would be achieved under reaction conditions,” says Dimick.

When the researchers examined the prepared catalysts with Lehigh’s high-resolution aberration-corrected scanning transmission electron microscope, they found nanoparticles with an average

diameter of 2 nm that were well-dispersed on the alumina support.

In situ Fourier transform infrared (FTIR) spectroscopy revealed that the N-O chemical bond in a catalyst containing 5-percent rhodium was broken as soon as the molecule made contact with the nanoparticle. In a catalyst of 10-percent rhodium, however, the NO molecules tended to adhere to clusters of rhodium atoms present on the surface, which could potentially inhibit the desired reaction.

Catalyst performance data also showed that the catalyst containing only 5-percent rhodium exhibited a much higher activity.

Rhodium, however, is rare and expensive. It now trades at around \$2,400 per troy ounce after exceeding \$10,000 in 2008. To reduce NO_x emissions more cheaply, the researchers turned to

diesel fuel to methane, and from pharmaceutical compounds to insecticides to fungicides. The organism could even be converted into a tofu-like food.

The government invited Zhang to take part in the project in hopes that his iron-based nanoparticles would help remove algae from Lake Tai. But the nanoparticles proved too expensive for the size of the job. As he had with the Taopu wastewater project, Zhang came up with a homegrown technology. Nanoparticles of clay, he found, neutralize the electric charge that causes algae particles to shun each other, thus allowing the algae to aggregate into clumps that can be skimmed from the water.

“Algae is a strange organism,” says Zhang. “It is 10 to 100 microns in size, and its density is nearly identical to that of water. So it is very difficult to separate from water.

“The clay gives the algae a life-preserver vessel. And it’s literally dirt cheap.”

A peroxide’s double life

Back in Hoboken, Zhang watches as technicians use a hydraulic machine to drill 3-inch holes to a depth of 40 to 50 feet in the soil around the corroded heating oil tank. The workers have mixed Zhang’s nanoparticles into a granular slurry for easier injection. They are drilling 10 holes in front of the house today and will drill another dozen tomorrow through the basement, where heating oil has also leaked.

Altogether, the workers will inject 600 pounds of the slurry through the holes. They will finish the job in two days. In three weeks, the New Jersey Department of Environmental Protection will inspect the soil and groundwater.

For this job, Zhang is using nanoparticles of a solid peroxide – the whitening agent in most toothpastes. The particles are more than 1,000 times smaller than those in Colgate. Instead of dissolving coffee stains, they transform oil’s long hydrocarbon chains

into water-soluble fats and alcohols. Zhang developed the nano-peroxide three years ago and has used it to remediate the soil beneath oil storage tanks at gas stations. Recently, he and his students showed in the lab that the nanoparticles can quickly break up oil spilled into water bodies like the Gulf of Mexico and the Bohai Sea off China’s coast.

“Guys, we have something special today,”

Nanoparticles of solid peroxide, a whitening agent in toothpaste, transform oil into water-soluble fats and alcohols.

Zhang says as he opens the trunk of his car. He lifts out two white five-gallon pails and carries them to the engineers operating a hydraulic drill. The pails contain a catalyst he believes will make the peroxide nanoparticles more reactive.

Zhang does not reveal the composition of the catalyst, except to say that it contains four or five materials.

“I’ll let you know,” he says, “when I get it patented.” ⓘ

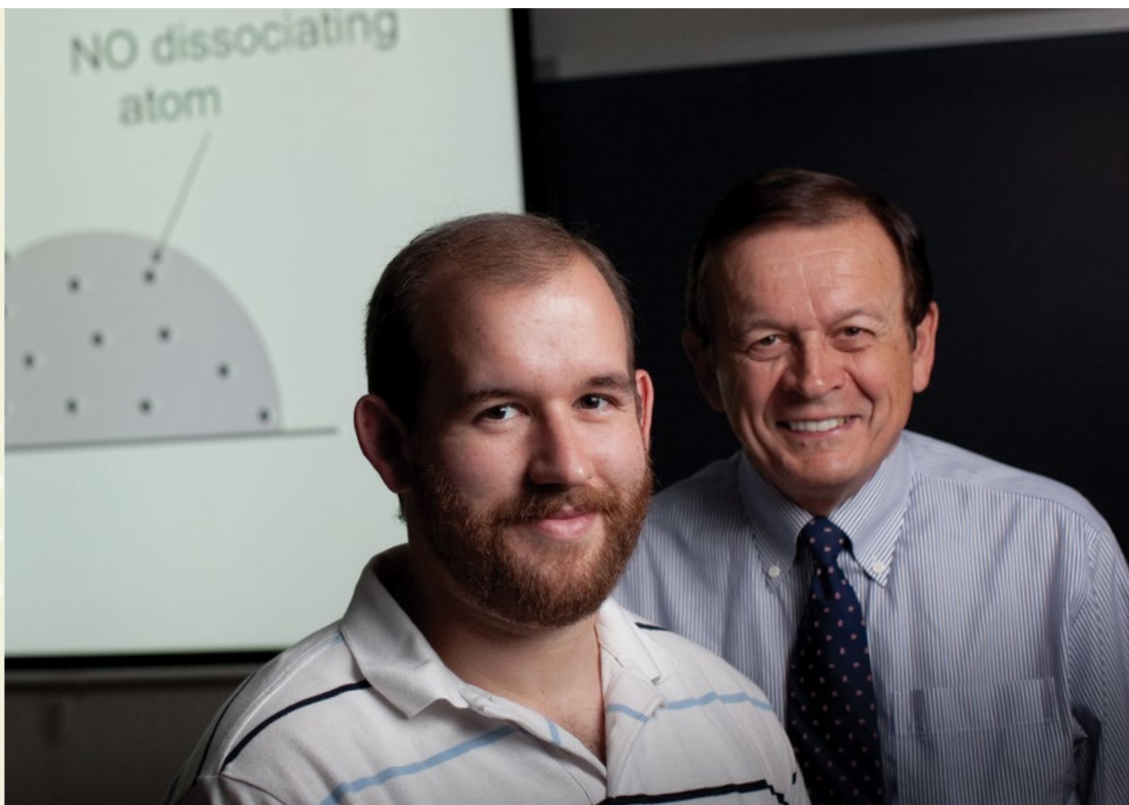
cobalt, which is 900 times less expensive than rhodium.

“Cobalt is also capable of breaking the N-O bond,” says Lyman. “It forms a solid solution with platinum at low concentrations and finds its way to the surface of a nanoparticle under reaction conditions.”

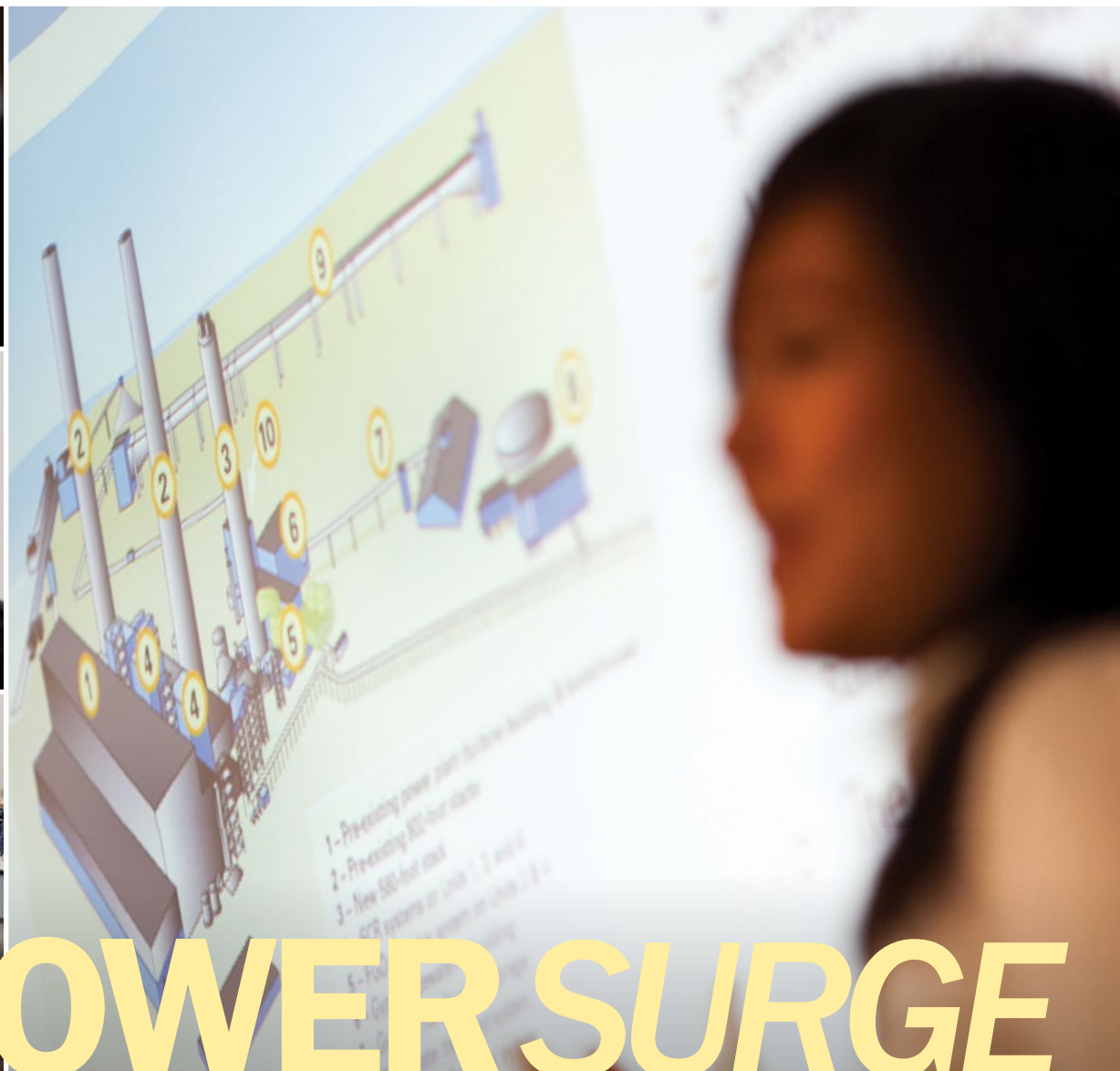
The preparation of cobalt-platinum catalysts is almost identical to that of rhodium-platinum. The researchers merely substituted metal nitrates for chlorides.

While all catalysts containing less than 5-percent cobalt were found to be capable of reducing NO_x to nitrogen and water vapor, the 2-percent cobalt catalyst performed best. “*In situ* FTIR spectroscopy revealed that the 2-percent catalyst was the only one capable of immediately breaking the N-O bond,” says Dimick.

The same methodology has now been applied to a nickel-platinum catalyst system with equally promising results.



Dimick and Lyman: Dimick’s work on NO_x reduction was cited by the Catalysis Society of Metropolitan New York.



POWER SURGE

**A NEW CENTER OF EXCELLENCE SEEKS
TO BRIGHTEN AMERICA'S ENERGY FUTURE.**

*The Energy Systems Engineering
Institute is producing leaders
who understand power
generation and distribution,
and their economic and
environmental impacts.*

The first wave of Baby Boomers had not yet reached retirement age in 2006 when the U.S. Department of Energy issued a sober warning to America's energy industry. In a report titled "Workforce Trends in the Electric Utility Industry," the DOE said America's energy labor force – its utility workers, plant operators, technicians and engineers – were aging quickly, while the number of personnel qualified to replace them was declining.

One year later, the Center for Energy Workforce Development released a paper titled "Gaps in the Energy Workforce Pipeline." As

many as half the workers in several sectors of the energy industry, the CEWD reported, would be eligible to retire by 2012.

The reports by DOE, CEWD and other groups have not fallen on deaf ears at Lehigh. In 2009, to help the energy industry secure its future, the university established the Energy Systems Engineering Institute. The ESEI, a partnership of Lehigh and the Electric Power Research Institute (EPRI) with support from power companies, serves as a center of excellence to promote research, education and technology transfer

in energy systems engineering.

The ESEI's focal point is a 10-month, 30-credit master's of engineering (M.Eng.) in energy systems engineering. The new degree program graduated 22 students in its first class in May 2010 (see story at right) and has enrolled 26 students in its 2011 class.

The M.Eng. program, says ESEI director Andrew Coleman '90, deals with the myriad of issues related to energy use and energy policy. These include economic growth, the environment, national security, climate change, energy independence, clean energy and renewable resources.

Students in the program receive an intensive education in energy generation, distribution and management, as well as environmental issues. They study capital investment, all forms of power (coal, natural gas, nuclear, bio-fuels, solar, wind), photovoltaic cells, semiconductors, the smart grid, a carbon-constrained future, and renewable and alternative energy sources.

Each student also completes a research project related to such industry challenges as aging infrastructure, less environmentally invasive systems, and solar energy.

The M.Eng. program benefits from Lehigh's strengths in technology transfer and entrepreneurship, and its ties with industry. Potential employers guide the curriculum and the student research projects.

The recent recession, says Coleman, has prompted many workers to postpone retiring. The ESEI has responded by forging ties with energy supply chain companies like Siemens and Dresser-Rand and with companies that are developing novel ways of generating and storing electricity, and preparing for the smart grid.

"Our goal remains the same," says Coleman, "and that is to train energy managers who understand power generation, the grid that translates and distributes power, and the overall economical and environmental impact of energy use." ❶

HITTING THE GROUND IN FULL STRIDE

As an undergraduate majoring in mechanical engineering, Andy Edmonds '09 had little interest in the power industry until he learned of Lehigh's new master's of engineering (M.Eng.) in energy systems engineering (ESE).

Edmonds enrolled in the 10-month ESE program, finished in May 2010, and was hired by Southern California Edison's San Onofre Nuclear Generating Station near San Clemente, Calif. He has begun a four-year apprenticeship for nuclear plant equipment operators and will move through several positions, from equipment operator to reactor operator to shift manager.

The ESE degree, says Edmonds, proved invaluable in landing a job.

"The ESE's industry-focused curriculum," says Edmonds, "sets us apart. I had to take an entrance exam just to qualify for the interview at Southern California Ed. Only a small percentage of candidates pass. But thanks to what I learned in the ESE program, it was not too difficult.

"Now I find I can talk intelligently with the Navy veterans here who have operated reactors."

Edmonds' story is typical of the 22 students who earned M.Eng. degrees in ESE's first year. Despite the recession, all the new graduates were offered jobs within three months after completing the program.

Jeff Zubernis '09 also enrolled in the ESE program after earning a B.S. in mechanical engineering.

"The emphasis on management and business was certainly one of the strengths of the program," says Zubernis. "We had courses in project management and energy economics. A lot of power plant managers spoke to our classes. All of this proved very helpful."

Zubernis received an offer from Dresser-Rand, a manufacturer of compressors and turbines for the power, oil and gas industries, and recently began a five-year rotation in management development.

"My first assignment will be as an applications engineer at the steam turbine site in Wellsville, N.Y.," says Zubernis. "This equipment is used to turn excess heat into useful energy at refineries and petrochemical plants.

"As an undergrad you learn all the technical details — how a turbine works, how electric circuits work. But I had no idea what went on behind the scenes to make that happen. After taking the ESE program, I can talk on the same plane with people in the industry, using terms and concepts that people with just an undergraduate degree would not understand."

Joseph Mulhern, another alumnus from the ESE's first class, took a job with PJM Interconnection, a regional transmission organization

that coordinates the movement of wholesale electricity in 13 states and the District of Columbia.

"When I started," says Mulhern, "I needed to learn to use the company software. But I did not need any additional training in the general concepts of the electrical grid, which has impressed my co-workers who are helping train me.

"I'm learning to perform outage analysis. When a utility wants to shut down a line for maintenance, I can review their request, analyze how it would affect the grid, and then approve or deny, based on whether overloading would occur on other lines.

"The background knowledge I received at Lehigh, especially in the Transmission and Distribution: Smart Grid course, has enabled me to hit the ground running."

Every member of the program's first class of graduates was offered a job within three months after completing the degree.





Huang's computer models and software programs (below) help physicians make more intelligent analyses of medical images.

A computer's-eye view of the world of biology

Xiaolei Huang, the P.C. Rossin Assistant Professor of computer science and engineering, looks for three things in a research project.

"When I choose a project," says Huang, "I seek a difficult problem that allows me to push the state of the art in computer science and that also has societal impact."

Huang harnesses the power of the computer to process and interpret biomedical images. One of her software programs constructs 4-D computer models – with time as the fourth dimension – that measure the changes in the heart's structure as it expands and contracts. The models help cardiologists discern the differences between the normal deformations that occur in healthy hearts and the abnormal deformations that occur in damaged and diseased hearts.

In another project, recently funded for a fourth year by the National Library of Medicine, Huang uses object segmentation techniques to index NLM's database of 100,000 images of cervical lesions. By categorizing lesions according to color, texture, size and shape, she hopes to make it easier for medical personnel to retrieve and study images, and to determine the seriousness of new lesions by correlating more quickly and accurately between image features and diseases. A related project involving the analysis of cervigrams is funded by NSF.

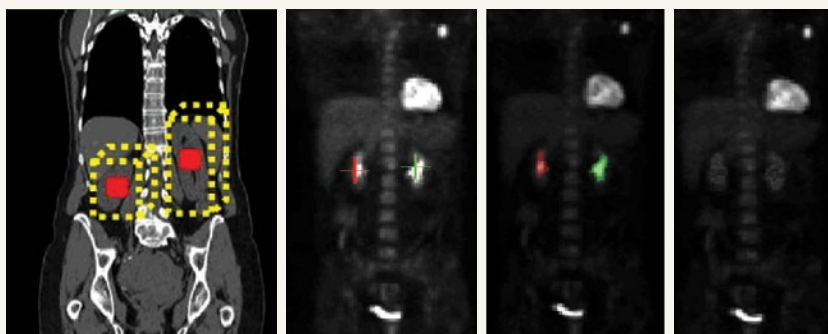
Huang also applies image analysis techniques to help study the cytoskeleton and its role in cell division. The cytoskeleton protects the cell, maintains its shape, enables it to move, and facilitates the intracellular transport of materials. It also governs cytokinesis, the final step in mitosis, during which tiny filaments assemble into a ring, constrict and cleave the cell into two identical daughter cells.

Huang writes algorithms to show how the cytoskeletal filaments form from the protein actin, and interact and interconnect as they assemble. She and

her students collaborate with Dimitrios Vavylonis, an assistant professor of physics in Lehigh's College of Arts and Sciences, who models the physical properties of cytoskeleton and other adaptive biological materials. The project is supported by the National Institutes of Health.

The researchers' goal is to determine the topology, or physical arrangement, of the filament network and how it changes over time. Their results could be useful in the drive to develop drugs that treat cancer by preventing the division of cancerous cells.

The task is complicated by the ever-changing topology of the cytoskeleton. And the microscopic images of actin filaments have a low signal-to-noise ratio, making it difficult to locate the filaments' centerline and determine their shape and position in the topology.



"I look for projects that have societal impact and allow me to push the state of the art in computer science." —Xiaolei Huang

"The filaments in the cytoskeleton assemble into a network before they form a ring," says Huang. "The filaments cross each other, grow and touch each other, and then disassemble. This is an extremely dynamic network."


Huang and Vavylonis have developed an interactive, open-source software tool called JFilament that visualizes individual filaments, segments them (extract-

ing their centerline and representing their geometry with curves) and tracks them (measuring motion and deformation over time) in 2-D and 3-D. The software is based on a Stretching Open Active Contours algorithm developed by Huang's Ph.D. student Hongsheng Li.

Active contours are deformable parametric curves that adapt to fit image features. Li uses open curves to represent filaments and has proposed strategies to enable the contours to grow over faint elements and handle crossed filaments. Other methods that segment linear structures produce binary pixel-wise segmentation results and have difficulties reconstructing a curve. In addition to segmenting and tracking filaments and cell boundaries, says Huang, JFilament can utilize the active contours' results to quantify the static and dynamic properties of cytoskeletal filaments, such as bending and elongation.

The researchers validated the performance of the new software by using it to measure the known properties of

simulated filaments. They then used JFilament to measure the dynamic properties of actin filaments imaged with total internal reflection fluorescence microscopy and, for the first time, of actin cables in yeast imaged with onfocal microscopy.

They described their results in a paper that will be published later this year in the journal *Cytoskeleton*. 

Lehigh and Tau Beta Pi

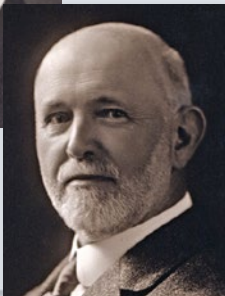
Tau Beta Pi, the international engineering honor society, was founded at Lehigh in 1885 and now has more than half a million members. In October 2010, Lehigh is hosting the society's annual convention and 125th anniversary celebration. The histories of the two institutions are intertwined, as the following examples show:

TBP founder **Edward Williams Jr.** earned degrees in chemistry and mining engineering from Lehigh and joined Lehigh's faculty in **1881**. To recognize technologically minded students, as Phi Beta Kappa honors candidates in the arts and sciences, he organized Tau Beta Pi and wrote its constitution.



National expansion: In **1892**, mechanical engineering professor **Lester Breckenridge** left Lehigh for the University of Michigan, where he established the second TBP chapter. In **1893**,

Lehigh professor **John Flather** joined the faculty at Purdue University and established the third chapter.



The "Bent"

the official symbol of Tau Beta Pi — was installed in front of Williams Hall (named for founder Edward) in **1885**.

This year, it is being moved to a more visible site in front of Packard Lab, home of Lehigh's engineering college.



The Bent, Tau Beta Pi's journal of record, was established in **1905**. The magazine's first issues were produced by **Harry R. Lee, Claude Hagy, Stewart J. Cort** and **Homer Hendricks** of Lehigh's Class of 1906.



Since **1895**, every Lehigh president, from **Thomas M. Drown** to **Alice P. Gast**, has been a member of Tau Beta Pi. And since Lehigh established college deanships in 1936, each leader of the engineering college has been a Tau Bate as well.

Some of Lehigh's most well-known and influential alumni, including

Lee Iacocca, Edward G. Uhl and **W. Beall Fowler**, have been Tau Bates.



To learn more about the achievements of Lehigh engineers, visit the Lehigh Engineering Heritage Initiative at

www.lehigh.edu/heritage




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THE QUESTIONS THAT MATTER



Scholars, says Alan J. Snyder, have faith in the innate value of knowledge and confidence that it will have an impact. Snyder, vice president for research and graduate studies, came to Lehigh last summer from Penn State University, where he helped develop artificial hearts and ventricular assist devices.

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