2013

Engineering Research 2013

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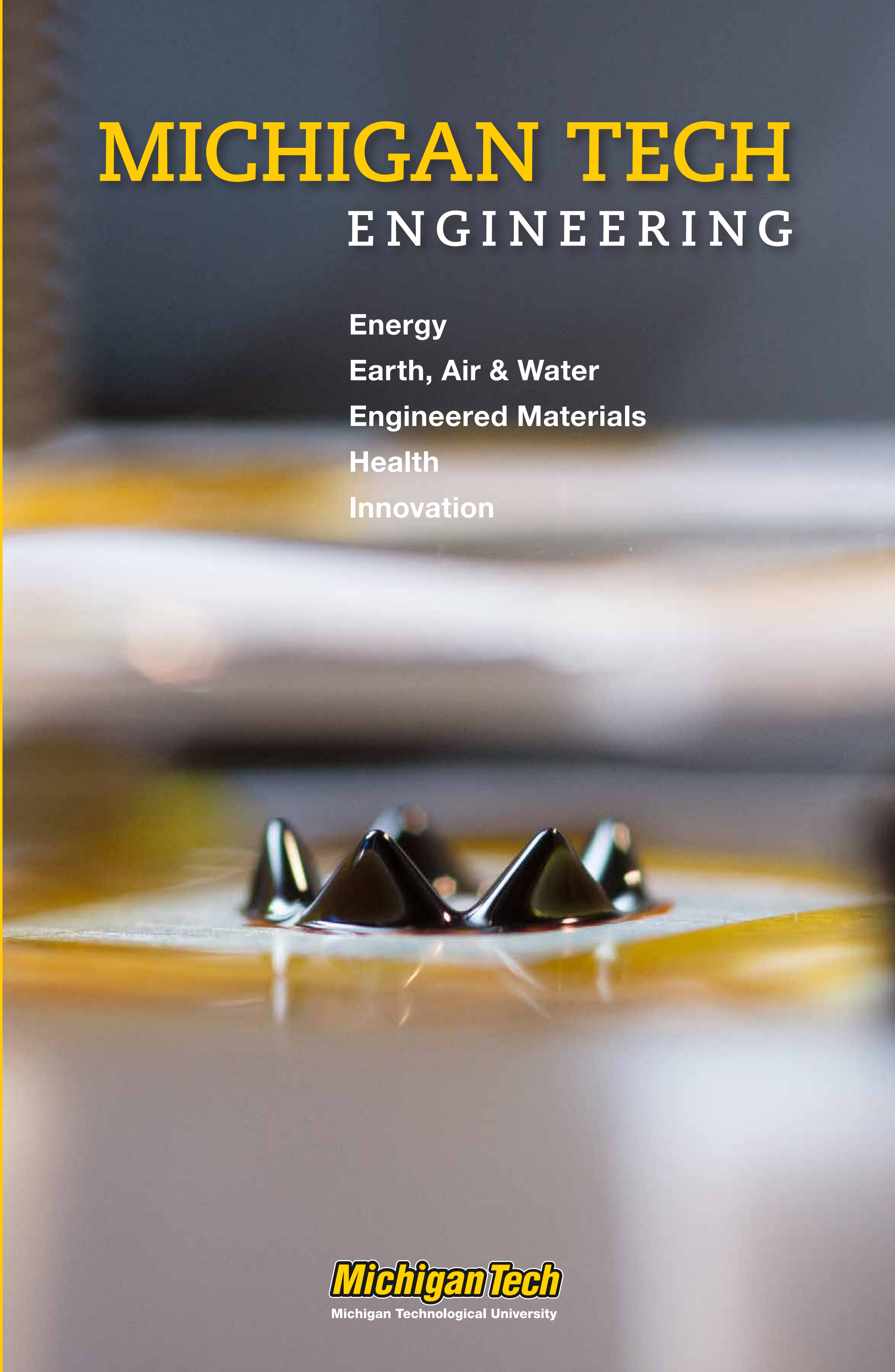

Michigan Tech

Michigan Technological University

Wayne D. Pennington

Carl L. Anderson

Leonard J. Bohmann

Letter from the Dean

We are proud of the work that our researchers conduct at Michigan Tech. Whether the work is done by a single investigator, or by a team of faculty, staff, and students, the results can be stunning.

The research we do may be conducted through computer modeling, in the laboratory, or in the field (which may range from inside Earth to outer space, and everywhere in between), but it will have common goals.

As a technological research university, we strive to undertake research that accomplishes three things: First, to expand the body of knowledge—to understand how nature works. Second, to make use of that knowledge for the betterment of humanity and our world—the basis of engineering and applied science. And, finally, to transform that knowledge into action, through innovation and entrepreneurship wherever appropriate.

Indeed, one of the primary components of Michigan Tech's vision in our "University Portrait 2035" is to be "recognized nationally and internationally for research development and innovation."

We hope you enjoy the stories selected for this issue of *Michigan Tech Engineering Research 2013*. Let us know your thoughts; we look forward to hearing from you.

Wayne D. Pennington
Interim Dean

Carl L. Anderson
Associate Dean for Research and Graduate Programs

Leonard J. Bohmann
Associate Dean for Academic Affairs

On the cover:
L. Brad King's prototype of a ferrofluid ion thruster. See page 13.

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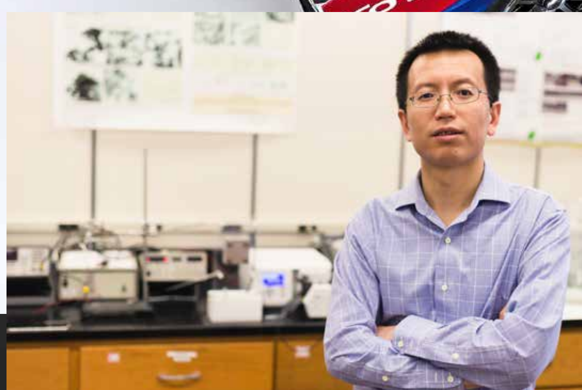


Dennis Desheng Meng
Mechanical Engineering–Engineering Mechanics

Pictured at right: Aligned nanorods grown in Dennis Desheng Meng's lab using electrophoretic deposition.

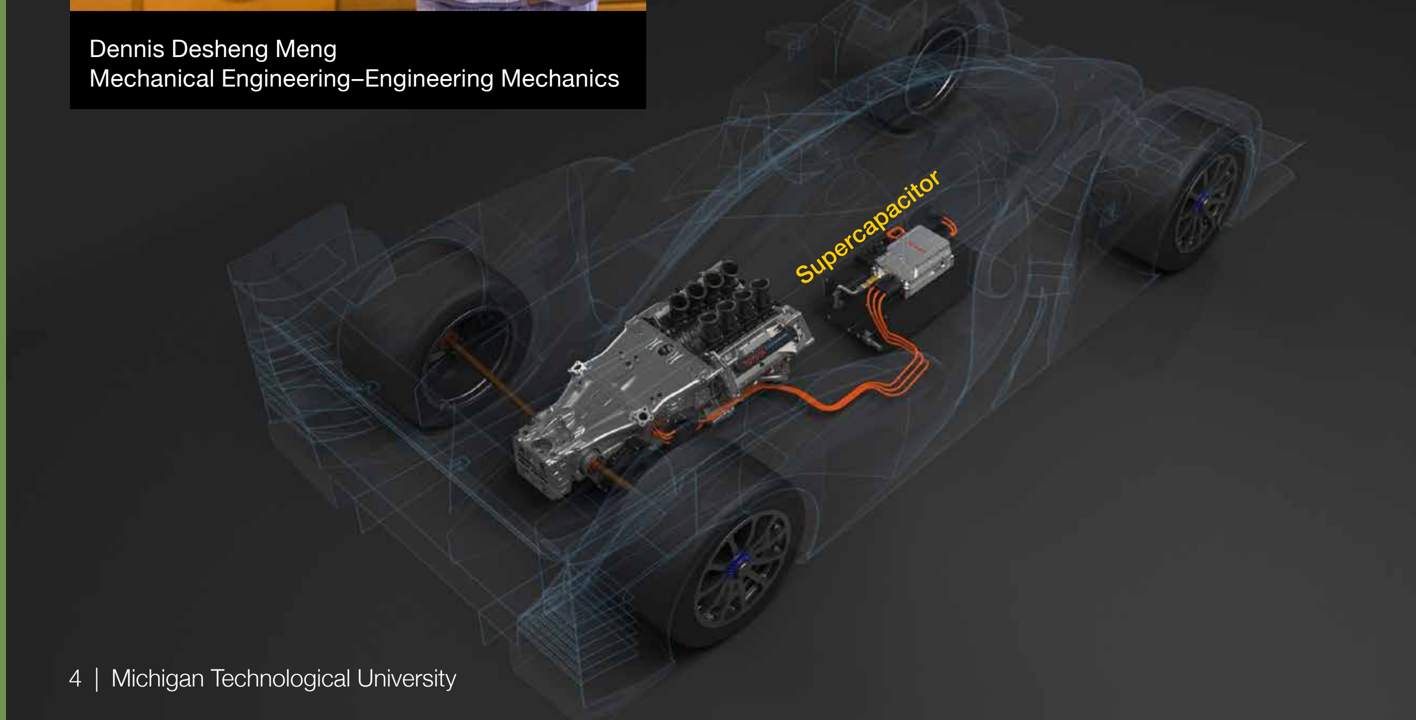


PHOTO CREDIT: TOYOTA TS030

Scalable supercapacitors

Growing a nanoforest

A new process for growing forests of manganese dioxide nanorods may lead to the next generation of high-performance capacitors.

As an energy-storage material for batteries and capacitors, manganese dioxide has a lot going for it: it's cheap, environmentally friendly and abundant. However, chemical capacitors made with manganese dioxide have lacked the power levels of the typical carbon-based physical capacitor.

Dennis Desheng Meng theorized that the situation could be improved if the manganese dioxide was made into nanorods. But making manganese dioxide nanorods with the right set of attributes has been a stumbling block. Until now, researchers have been able to grow nanorods that either have the best crystalline structure or were aligned, but not both.

Now, Meng's research group has developed a technique to grow manganese dioxide nanorods that are not only straight and tall (at least by nano-standards), but also have the optimal crystal structure, known as α-MnO_2. This minimizes the internal resistance, allowing the capacitor to charge and discharge repeatedly without wearing out. That's a recipe for a better capacitor: it can store more energy, extract that energy more quickly, and work longer between rechargings. Plus, it can be used over and over again. Even after Meng's group recharged their capacitor more than 2,000 times, it was still able to regain over 90 percent of its original charge.

Meng's device belongs to the family of chemical capacitors—hybrids between physical supercapacitors, which release a burst of energy and discharge quickly, and batteries, which generally store more energy and release it gradually over a longer period. Typically, chemical capacitors have more energy and less power than the physical ones.

The chemical capacitors made with Meng's manganese dioxide nanorods offer the best of both worlds: they hold more energy, like a battery, plus they deliver even more power than a comparable carbon-based physical capacitor.

His team was able to grow a nanoforest of manganese dioxide nanorods using electrophoretic deposition, a technique in which small particles are deposited on a substrate under the influence of an electric field. The process is not especially difficult. "We did it in a lab, but this is scalable manufacturing," he says. "We can continuously print it out on a roll, and even make the substrate very large, if desired."

Capacitors made with manganese dioxide nanorods could help hybrid and electric vehicles accelerate more quickly or could be coupled with solar cells. "The process also opens the door for many other applications, not just supercapacitors," says Meng.

PHOTO CREDIT: SUNAND SANTHANAGOPALAN

Energy

A new cyberdefense framework

Meeting the security challenges of the nation's power grid

Power grid communication has been gradually replaced by Ethernet instrumentation to enhance system monitoring and facilitate control. Over past decades, these centralized sensor networks have evolved from a monolithic system to a highly distributed and networked structure with standardized communication protocols. While this can be a cost-effective strategy for system deployment, there has been an increasing concern about the unprecedented worldwide growth of sophisticated, persistent threats targeted at these control systems.

While enforcement of North American Electric Reliability Corporation Critical Infrastructure Protection (NERC-CIP) policies and other industrial security standards may strengthen the audit processes related to existing critical cyber assets, an urgent need remains to establish a cyberdefense framework for power grids to combat new security threats.

Chee-Wooi Ten and his research team are working on a new cyberdefense architecture that would not only secure the power communication system, but also detect potential intruders and effectively present anomalous information to control system operators.

"Ours is a fundamentally new way to tackle emerging problems, based on the existing system structure," he explains. Operators at the control center constantly receive real-time measurements such as power, voltage, and current information from substations, pole-mounted devices, etc., but they are not yet being made aware of malicious activities initiated by potential intruders within a network or a tampered device. Ten and his team plan to introduce new applications into the operations control room to create that cyber-situation awareness.

"One way to prevent intrusion to a substation network is to restrict the information flow to a single direction," adds Ten. "Some vendors have been promoting 'information diode' by designing a unidirectional gateway with limited hardware capability. While protecting the grid from cyber attacks is of great interest to stakeholders, the lack of cost justification to prepare for 'high-impact, extremely low-probability' events often causes them to withhold technological investment in those areas. One cannot simply propose a solution that will work out in theory without taking into account what has already been implemented," he emphasizes.

Instead, generations of existing communication infrastructure must be carefully considered. "Introducing new technologies to deploy a cyber infrastructure with anomaly detectors and a trap set of 'honeypots' can be implemented but will require close collaboration with utility stakeholders to understand their current situation and any future implications," says Ten. "New technologies must be formulated with multistage cyber infrastructure deployment, and allow for a longer system-planning time horizon."

Chee-Wooi Ten
Electrical & Computer Engineering

Lahars in El Salvador

Building capacity to mitigate catastrophes

Steep slopes, seasons of persistent and intense rainfall, and unmanaged anthropogenic changes in the landscape all contribute to the potential for landslides. Superimpose limited financial and technical resources on the propensity for natural disasters and the situation becomes a recurring series of catastrophes, where the victims are often unable to completely recover from one before the next hits.

Michigan Tech is building on decades of volcanic research work in El Salvador through a federal program to create partnerships for enhancing engagement in research. The program funds the foreign counterpart in collaborative studies. The research is aimed at building capacity for characterizing and monitoring flood and landslide hazards near San Vicente volcano, a region that was devastated by rains from Hurricane Ida in November 2009. Over 18 inches of rainfall occurred in 36 hours on grounds that had already been subject to nearly six months of wet season. Landslides and lahars killed over 300 residents in villages and towns.

John Gierke and his graduate students are working with faculty and students at the Universidad de El Salvador Facultad Multidisciplanaria Paracentral (UES FMP) in San Vicente to understand and monitor the hydrology of the area's watersheds, with the hopes of developing plans for managing water resources and warning systems for rainfall-induced hazards. The group has installed weather stations and conducted water-level monitoring in shallow wells and a major river. He and his team will return at the end of the 2013 rainy season in El Salvador to resurvey field sites in order to determine whether there are, in fact, perched water tables on the steep slopes that could be a factor in the formation of shallow landslides.

Gierke and his colleagues have also been sharing their expertise using remote sensing data to study landscapes, evaluate land-use changes and prioritize areas with the highest hazards for slope failures. Their counterparts have been eager to learn how to use tools for processing and interpreting remotely sensed data because remote sensing data is often publicly available.

Gierke has also been providing some basic training in hydrological modeling to the faculty, both in person and using online tools. "Basic modeling tools and monitoring instruments are so common in developed countries, like ours. It's easy to overlook just how out of reach these tools are for financially strapped countries," he says. "A little bit of technology transfer is enabling our partners to implement monitoring and mitigation plans for warning populations of hazardous conditions."

CREDIT: EDGAR ROMERO/ASSOCIATED PRESS

Pictured: Verapaz, El Salvador, an area severely damaged by a landslide caused by the passage of Hurricane Ida in November 2009.

John Gierke
Geological & Mining Engineering and Sciences

The carbon footprint of highway construction

Reducing greenhouse gas emissions

Unexpected disruptive events and delays tend to adversely affect highway construction costs and delay project completion. They also tend to increase project emissions.

One of Amlan Mukherjee's research interests is to investigate ways in which project greenhouse gas (GHG) emissions can be controlled by appropriately managing disruptive events. "While new highway construction materials and technologies have received significant attention, there has been a limited emphasis on understanding how construction processes can be best managed to control greenhouse gas emissions," Mukherjee explains. His goal: to lay the foundation for best practices in construction management that will both optimize project cost and duration and minimize emissions.

Mukherjee and his team use an empirical analysis of specific highway construction projects to illustrate the impact of unexpected schedule delays in increasing project emissions. The team has created a simulation-based method contractors can use to assess the effectiveness of alternative project management strategies in controlling those emissions.

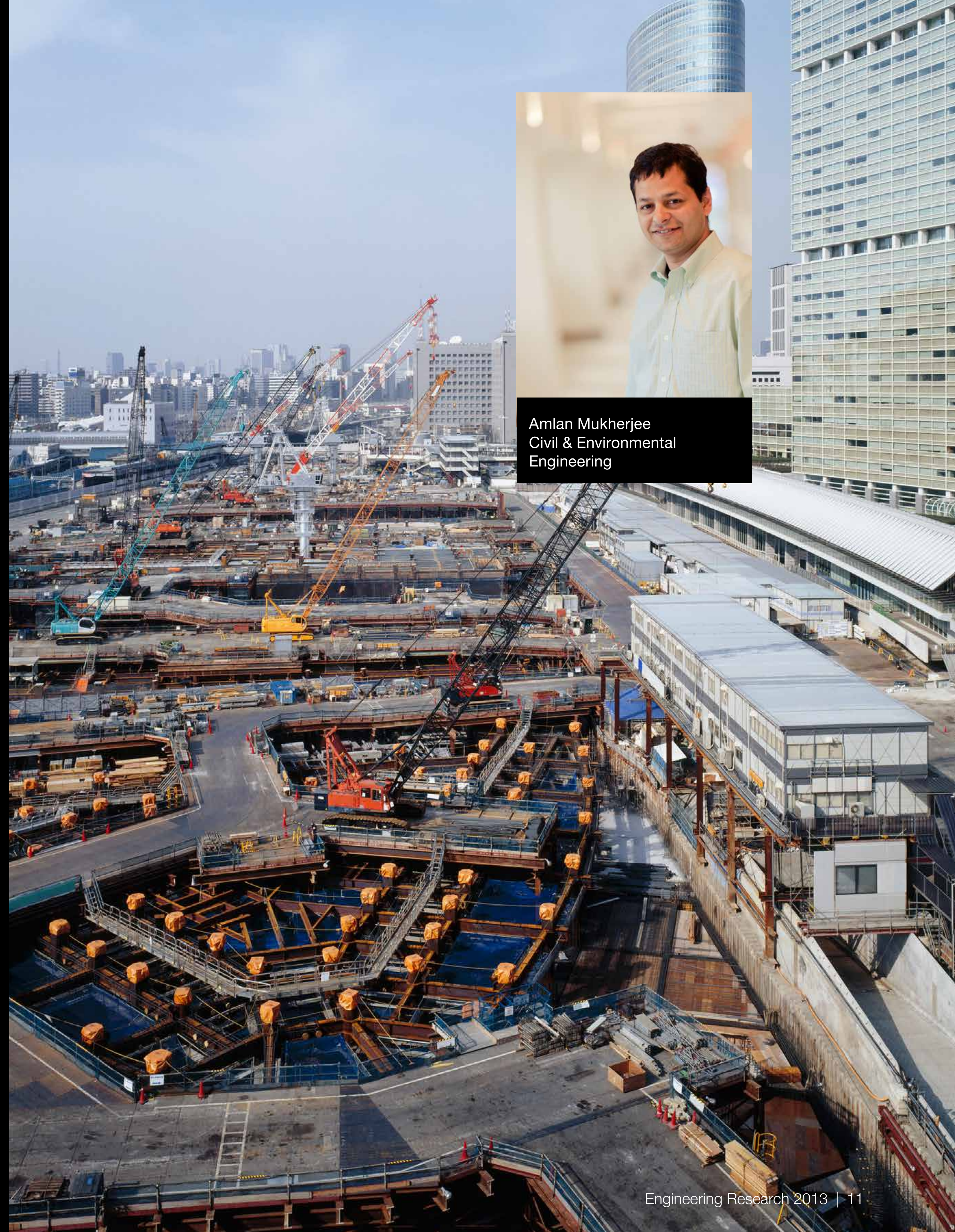
Appropriately selected strategies can reduce project GHG emissions without increasing a contractor's financial burden or causing project schedule delays, says Mukherjee. "It is now possible for construction firms to consider project emissions—in addition to cost and project duration—in developing project management strategies. Applying these methods will help them reduce their project emissions through strategic project management, and without significant investment in new technology."

Mukherjee has also developed a web-based tool, the Project Emission Estimator, or PE-2, that can be used to benchmark the carbon footprint of highway construction projects: www.mtu.edu/pe2.

Applying existing life cycle assessment methods and inventories, PE-2 considers the life cycle emissions of products and processes involved in the raw material acquisition and manufacturing phase, as well as the pavement construction phase. It also estimates emissions due to vehicular use and maintenance operations during the service life of the pavements. "It is important to note that the intention is not to compare and contrast alternative pavement materials, but instead, to promote improved decision-making, recognizing that the solutions for one project may not apply to another."

Recently California mandated the reduction of GHG emission to 1990 levels by 2020. "The highway construction industry is cautiously responding to challenges of emission reduction and related policy at the state and federal level. Cap-and-trade efforts have not gained significant political traction. Instead the increased emphasis on sustainability is likely to influence decision-making and directly impact their economic bottom line. This has presented an opportunity for increased innovation in alternative and improved construction processes," he says.

Recognizing a potential market opportunity, Mukherjee recently founded a start-up company called Life Cycle Solutions, LLC after receiving support through the NSF I-Corps program.



Amlan Mukherjee
Civil & Environmental Engineering

Frost-resistant concrete

Damage, diagnosis and simulation

The durability of concrete plays a central role in the sustainability of the US infrastructure system, with broad economic, social and environmental impacts. Internal frost damage is one of the major problems affecting the durability of concrete in cold regions.

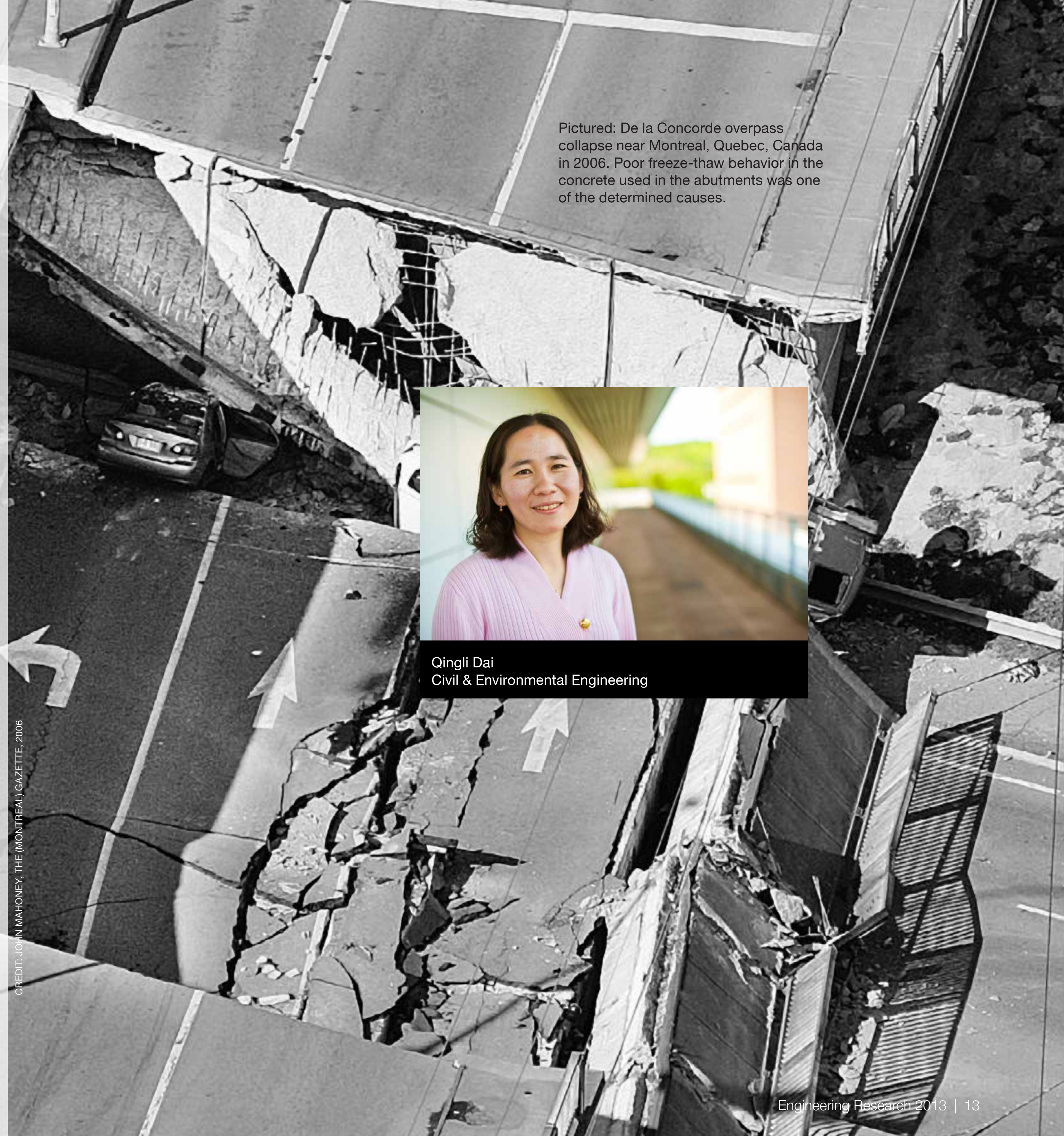
Qingli Dai has developed microstructure-based models to describe the effects of freeze-thaw cycles on the durability of concrete—computational tools that can prevent excessive internal frost damage through improved mix design and construction control. Her research includes the fabrication, analysis and testing of multifunctional structural materials, and the fusion of sensor detection and computational modeling to better understand damage mechanisms.

"Crystallization pressure due to ice nucleation within capillary pores is the primary cause of internal-frost damage of concrete," Dai explains. "When pressure is greater than the strength of the concrete, damage occurs." Dai has examined the multi-physical processes from basic fundamental thermodynamic principles to determine the magnitude of the ice crystallization pressure on the pore wall. She supplements her analyses with input parameters such as pore microstructure, temperature and free water content of the specimen.

Dai has also developed a unique time domain reflectometry sensor to monitor the amount of free water in concrete and the crystallization process in real time. Dai characterizes nanoscale or micronscale pore microstructure with Transmission X-ray Tomography (TXM) images.

Using two idealized pore systems based on these images, Dai simulated the damage processes that occur due to ice crystallization. Then, she calculated crystallization pressure in capillary pores with thermodynamic analysis at different subcooling temperatures. Dai found that crystallization pressure can significantly increase to cause internal damage when the subcooling temperature is reduced only a few degrees.

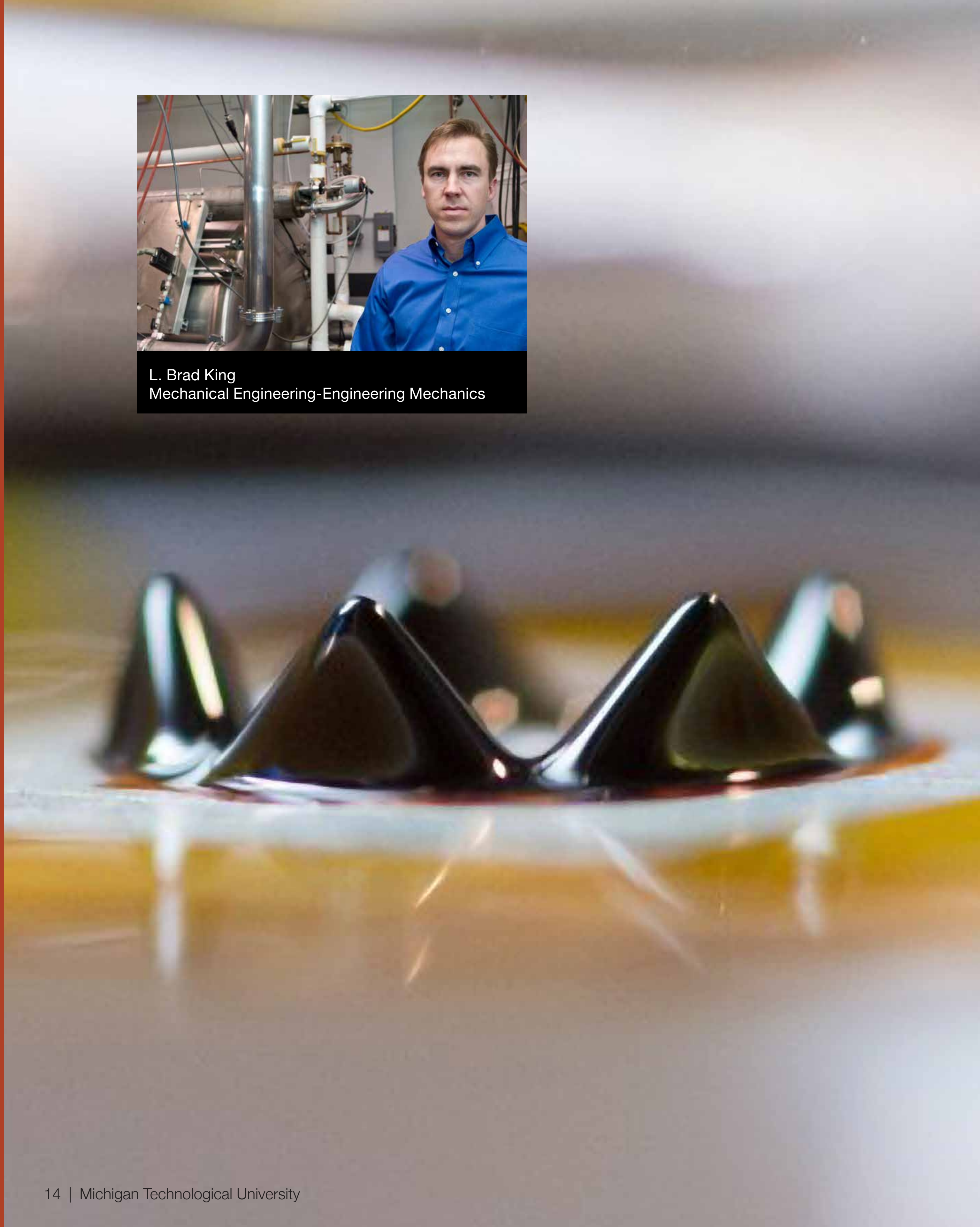
"I believe this research method, which integrates microstructure characterization and sensor detection, will reveal other damage mechanisms of infrastructure materials in nano- or micro-scales."



CREDIT: JOHN MAHONEY, THE (MONTREAL) GAZETTE, 2006

Pictured: De la Concorde overpass collapse near Montreal, Quebec, Canada in 2006. Poor freeze-thaw behavior in the concrete used in the abutments was one of the determined causes.

Qingli Dai
Civil & Environmental Engineering



L. Brad King
Mechanical Engineering-Engineering Mechanics

Nanosat micro rockets

From cancer treatment to ion thruster

Nanosatellites are smartphone-sized spacecraft that can perform simple, yet valuable, space missions. Dozens of these little vehicles are now tirelessly orbiting the earth performing valuable functions for NASA, the Department of Defense and even private companies.

Miniature rockets aren't needed to launch a nanosatellite from Earth. The small vehicles can hitchhike with a regular rocket that is going that way anyway. But because they are hitchhikers, these nanosats don't always get dropped off in their preferred location. Once in space, a nanosatellite might need some type of propulsion to move it from its drop-off point into its desired orbit. This is where the micro rocket engine comes in.

For the last few years, researchers around the world have been trying to build such rockets using microscopic hollow needles to electrically spray thin jets of fluid, which push the spacecraft in the opposite direction. These new electrospray thrusters face some design challenges, however. Because they are so small and intricate, they are expensive to make, and the needles are fragile. They are easily destroyed either by a careless bump or an electrical arc when they're running.

To get around this problem, L. Brad King and his team have developed an elegant strategy: eliminate the expensive and tedious microfabrication required to make the needles by letting Mother Nature take care of the assembly. "We're working with a unique type of liquid called a ferrofluid that naturally forms a stationary pattern of sharp tips in the liquid surface," he says. "Each tip in this self-assembling structure can spray a jet of fluid just like a micro-needle, so we don't actually have to make any needles." Ferrofluids have been around since the 1960s. They are made of tiny magnetic particles suspended in a solvent that moves when magnetic force is applied.

King's team was trying to make an ionic liquid that behaved like a ferrofluid when they learned about a research team at the University of Sydney that was already making these substances. The Sydney team was using magnetic nanoparticles made by the life-sciences company Sirtex, which are used to treat liver cancer. "They sent us a sample, and we've used it to develop a thruster," King said. "Now we have a nice collaboration going. It's amazing that the same technology used to treat cancer can also function as a micro rocket for spacecraft."

King's first ferrofluid thruster is made of a one-inch block of aluminum containing a small ring of the special fluid. When a magnet is placed beneath the block, the liquid forms a tiny, five-tipped crown. When an electric force is then applied to the ferrofluid crown, liquid jets emerge from each point, producing thrust. "It's fascinating to watch," King says. "The peaks get taller and skinnier, and taller and skinnier, and at some point the rounded tips instantly pop into nano-sharp points and start emitting ions."

The thruster appears to be almost immune to permanent damage. The tips automatically heal themselves and re-grow if they are somehow damaged.

Integrate to transform

Using synchrotron x-ray diffraction

Steam. Water. Ice. The properties, functionalities and performance of materials are determined by their structures. Phase transformations provide effective and efficient means to control the structures and tailor the properties of materials. But despite their fundamental and practical significance to science and technology, our understanding of some important phase transformations is still incomplete.

For Yu U. Wang, scientific curiosity drives his efforts to unravel some of the mysterious behaviors of materials exhibited during phase transformations. The phase transformations of ferroelastic and ferroelectric materials are his primary interest. “These materials undergo highly coordinated atomic displacements to transform from one crystal structure to another and form microscopic domains and exhibit macroscopic responses as a result of such displacive transformations. These behaviors enable the materials to function as transducers, converting energy among thermal, mechanical and electrical forms as sensors and actuators in intelligent systems, and in memory devices to store information. They also exhibit some puzzling behaviors, such as precursor and relaxor phenomena that we do not completely understand,” says Wang.

“Better understanding of these interesting behaviors can help us make better materials and find wider applications,” he explains.

To test new ideas, Wang first develops models and runs computer simulations. “As a theoretician, computation has been my tool of choice,” he admits. “Computation alone has its inadequacies, however, so I also started to do experiments.” Wang’s critical experiments require unique capabilities that are not possible using conventional equipment. He uses the high-energy synchrotron X-ray diffraction facility of the Advanced Photon Source at Argonne National Laboratory, which allows him to simultaneously measure Bragg reflections and diffuse scattering of single crystals in three-dimensional reciprocal space under in-situ conditions.

“Bragg reflections measure average crystal structures, and diffuse scattering detects the deviated variations associated with various nanoscale defects—especially phonons that are quantized lattice vibrations,” he explains. “Both are important for understanding solid-state phase transformations. Sir Charles Frank said, ‘Crystals are like people: it is the defects in them that make them interesting!’”

“Integrating theory, computation and experiment has transformed my research at Michigan Tech,” he adds. “The project starts to yield exciting results.”

ILLUSTRATION CREDIT: YU U. WANG

Pictured: Simulated multi-phase, multi-domain microstructures in ferroelectric materials

Yu U. Wang
Materials Science & Engineering

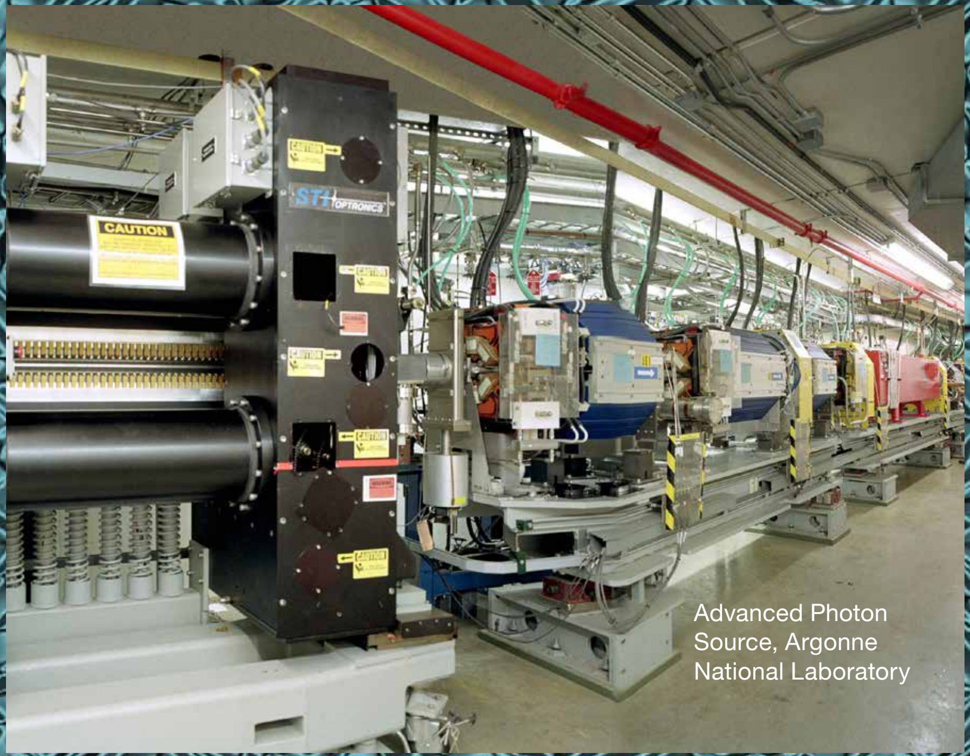


PHOTO CREDIT: ARGONNE NATIONAL LABORATORY

Advanced Photon Source, Argonne National Laboratory

Pictured: *Escherichia coli* or *E.coli* bacterium.

Jaroslaw Drelich
Materials Science & Engineering

Contamination control

Killing harmful microbes with copper nanoparticles

Microbes lurk almost everywhere, from fresh food and air filters to toilet seats and folding money. Most of the time, they are harmless to humans. But sometimes they aren't. Every year, thousands of people sicken from *E. coli* infections and hundreds die in the US alone.

Jaroslaw Drelich has found a new way to get them before they get us. His innovation relies on copper, an element valued for centuries for its antibiotic properties. Drelich has discovered how to embed nanoparticles of the red metal into vermiculite, an inexpensive, inert compound sometimes used in potting soil. In preliminary tests on local lake water, it killed 100 percent of *E. coli* bacteria in the sample. Drelich also found that it was effective in killing *Staphylococcus aureus,* the common staph bacteria.

Other studies have shown that copper is toxic to *Listeria, Salmonella* and even the antibiotic-resistant bacteria MRSA.

Bacteria aren't the only microorganisms that copper can kill. It is also toxic to viruses and fungi. If it were incorporated into food packaging materials, it could help prevent a variety of foodborne diseases, Drelich says.

The copper-vermiculite material mixes well with many other materials, like cardboard and plastic, so it could be used in packing beads, boxes, even cellulose-based egg cartons. It would be an inexpensive, effective way to improve the safety of the food supply, especially fruits and vegetables.

The material could have many other applications as well. It could be used to treat drinking water, industrial effluent, even sewage. "I've had inquiries from companies interested in purifying water," Drelich says. Applications include aquatic filters for drinking water and ground water.

And it could be embedded in products used in public places where disease transmission is a concern: toilet seats, showerheads, even paper toweling.

"When you make a discovery like this, it's hard to envision all the potential applications," he says. It could even be mixed into that wad of dollar bills in your wallet. "Money is the most contaminated product on the market."

Drelich is working with the Michigan Tech SmartZone to commercialize the product through his business, Micro Techno Solutions, the recipient of the 2012 Great Lakes Entrepreneur's Quest Food Safety Innovation Award. He expects to further test the material and eventually license it to companies that pack fresh food.

Better bioadhesives

Tending to tendons

Tendon and ligament injuries have been occurring with increasing frequency over the last several decades. While methods for the fixation of torn tendons and ligaments have improved, none has proven ideal.

Securing the repaired tissue more effectively means that patients can potentially begin post-operative rehabilitation much sooner, a critical development, as early mobilization has been found to be crucial for regenerating well-organized and functional collagen fibers in tendons and ligaments.

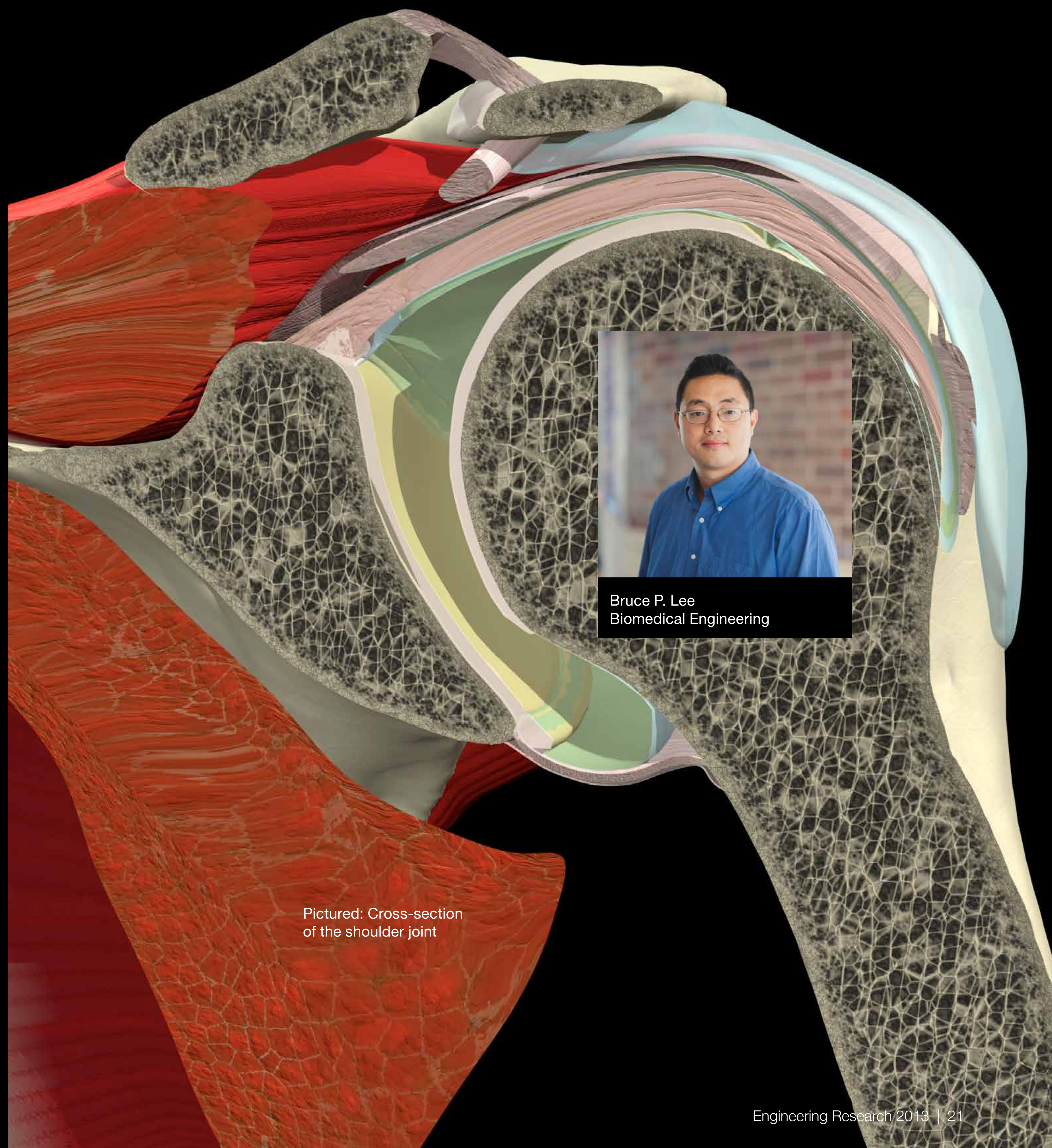
Bruce P. Lee has developed bioadhesives with improved adhesive properties for repairing tendons and ligaments—tissues that routinely experience large, repeated loads. He would like to potentially eliminate or reduce the need to use sutures, staples, tacks and the like to secure or repair damaged tissue.

“The performance of most man-made adhesives and coatings is significantly compromised in the presence of moisture, which has traditionally been treated as a surface contaminant that needs to be removed to prevent the formation of a weak bond layer,” Lee explains. “Particularly in the medical field, there is a high demand for the development of moisture-resistant adhesives. Marine animals, such as common blue mussels, secrete remarkable underwater adhesives that allow these organisms to anchor to surfaces in turbulent intertidal zones. In particular, 3,4-dihydroxyphenylalanine (DOPA) is found in large abundance in their adhesive proteins. DOPA is responsible for both rapid curing of the adhesive and interfacial binding.”

Chemically linking DOPA and other dihydroxyphenyl (DHP) derivatives onto inert, synthetic polymers has imparted these materials with strong, water-resistant adhesive properties. “The simplicity and versatility of DHP chemistry has spawned a large volume of literature in designing functional biomaterials. But there’s a glitch: their performance is severely compromised when pH levels change. They also require higher oxidant concentration to cure, which may limit their usefulness,” he adds.

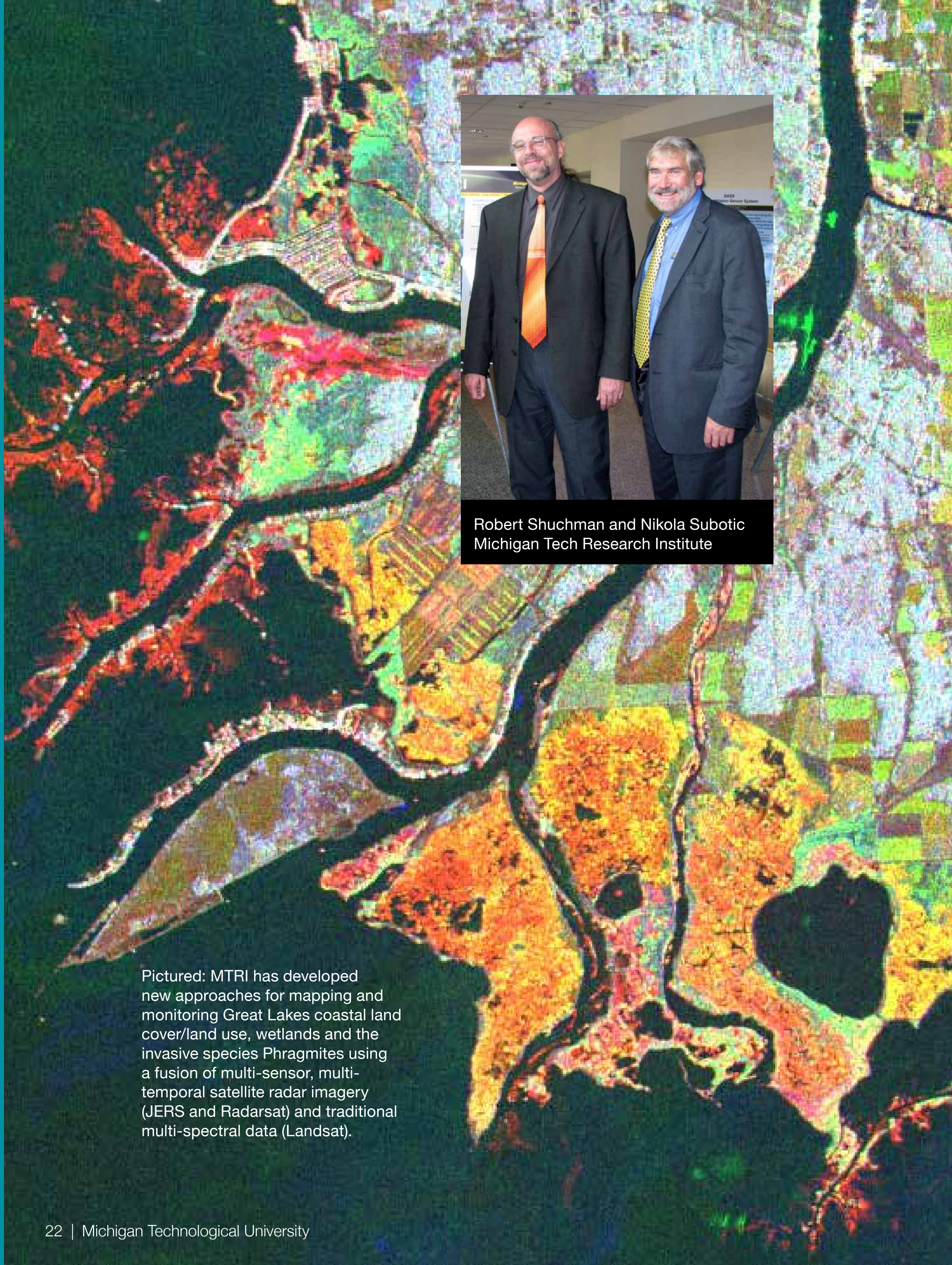
“We are developing chemical modifications of DHP that can dramatically improve interfacial binding, increase the rate of crosslinking while using reduced oxidant levels, and bind to tissue over a wide range of pH levels. Chemical bonding may also offer unique properties, such as light-mediated debonding and anti-microbial ability.”

Lee’s goal: to gain a systemic understanding as to how chemical modifications affect the two key chemistries of DHP (intermolecular crosslinking and interfacial binding) needed for adhesive curing and adhesion. “Biocompatibility still needs to be determined as well.”



Bruce P. Lee
Biomedical Engineering

Pictured: Cross-section of the shoulder joint



Robert Shuchman and Nikola Subotic
Michigan Tech Research Institute

Pictured: MTRI has developed new approaches for mapping and monitoring Great Lakes coastal land cover/land use, wetlands and the invasive species Phragmites using a fusion of multi-sensor, multi-temporal satellite radar imagery (JERS and Radarsat) and traditional multi-spectral data (Landsat).

Michigan Tech Research Institute

Sensing—and understanding—natural and man-made environments

The Michigan Tech Research Institute (MTRI) is a recognized leader in the research, development and practical application of sensor and information technology. MTRI utilizes a diverse staff of scientists and engineers to develop novel, multidisciplinary solutions to a wide variety of social, environmental and technical challenges—addressing critical problems in national security, protecting and evaluating critical infrastructure, bioinformatics, Earth sciences, and environmental processes.

One example: the increasing proliferation of radio frequency (RF) communication and sensing systems, which has led to increasingly crowded airways. MTRI is addressing that challenge by devising new signal processing approaches to allow efficient, joint utilization of precious RF spectrum by communication and sensing systems. The Institute's expertise in radar, communications and signal processing makes it ideally suited for this kind of effort. "In the old days, radars had their allocated spectra, communications had theirs," says Nikola Subotic, MTRI co-director. "We are looking at a much more complicated challenge: the simultaneous coexistence of a variety of uses of the same spectrum. In the future, all of these spectra will be mixed together. It won't be clear which function is intended or if, in fact, there are multiple functions, such as sensing, communications, navigation and control," Subotic explains.

Although based 500 miles from Michigan Tech's Houghton, Michigan campus, MTRI is an integral part of the University. Its scientists and technicians—over 60 at last count—are Michigan Tech faculty members and staff, and MTRI offers undergraduate and graduate research internships each summer. At any given time, researchers at MTRI are working on several dozen different projects for government agencies such as NASA, TARDEC, MDOT, EPA, USDA, USDOT, DARPA, USAF, AFRL, BLM, and more.

In the environmental arena, MTRI researchers use satellite imagery to track harmful algal blooms in the Great Lakes, working with the EPA's Great Lakes National Program Office, the Great Lakes Observing System, and the NOAA Great Lakes Environmental Research Laboratory. The resulting maps give unprecedented access to real-time data to assist stakeholders in making informed decisions.

In another effort, an MTRI researcher employs quantitative signal and data processing techniques in partnership with the University of Michigan Sleep Disorders Center in the first-ever attempt to use digital imagery of patients to assess the impact of sleep-disordered breathing.

The Institute's broad focus includes education, research, and the development of technology to sense and understand natural and man-made environments. "MTRI pairs new phenomenological understandings with the development of mathematical paradigms in order to extract new knowledge from existing and nontraditional data sources," co-director Robert Shuchman explains. "Our goal is to enable responsible parties to make better decisions in the real world."

Banking on innovation

Bringing technology to market with I-Corps

The National Science Foundation Innovation Corps (I-Corps) program offers academic researchers and students an opportunity to learn firsthand about technological innovation and entrepreneurship.

Over a period of six months, each I-Corps team, with a principal investigator/entrepreneurial lead and an industry mentor, learns what it will take to achieve an economic impact with their particular innovation, answering questions such as: What are the required resources? What are the competing technologies? What value will this innovation add? Who cares?

Michigan Tech's 2013 I-Corps team placed first among twenty-one teams in New York after a final presentation of their market analyses for new technologies. Principal investigator Adrienne Minerick led the team with postdoc Kaela Leonard, and Mary Raber served as team mentor. The technology they are looking to develop is a rapid, portable blood-typing device.

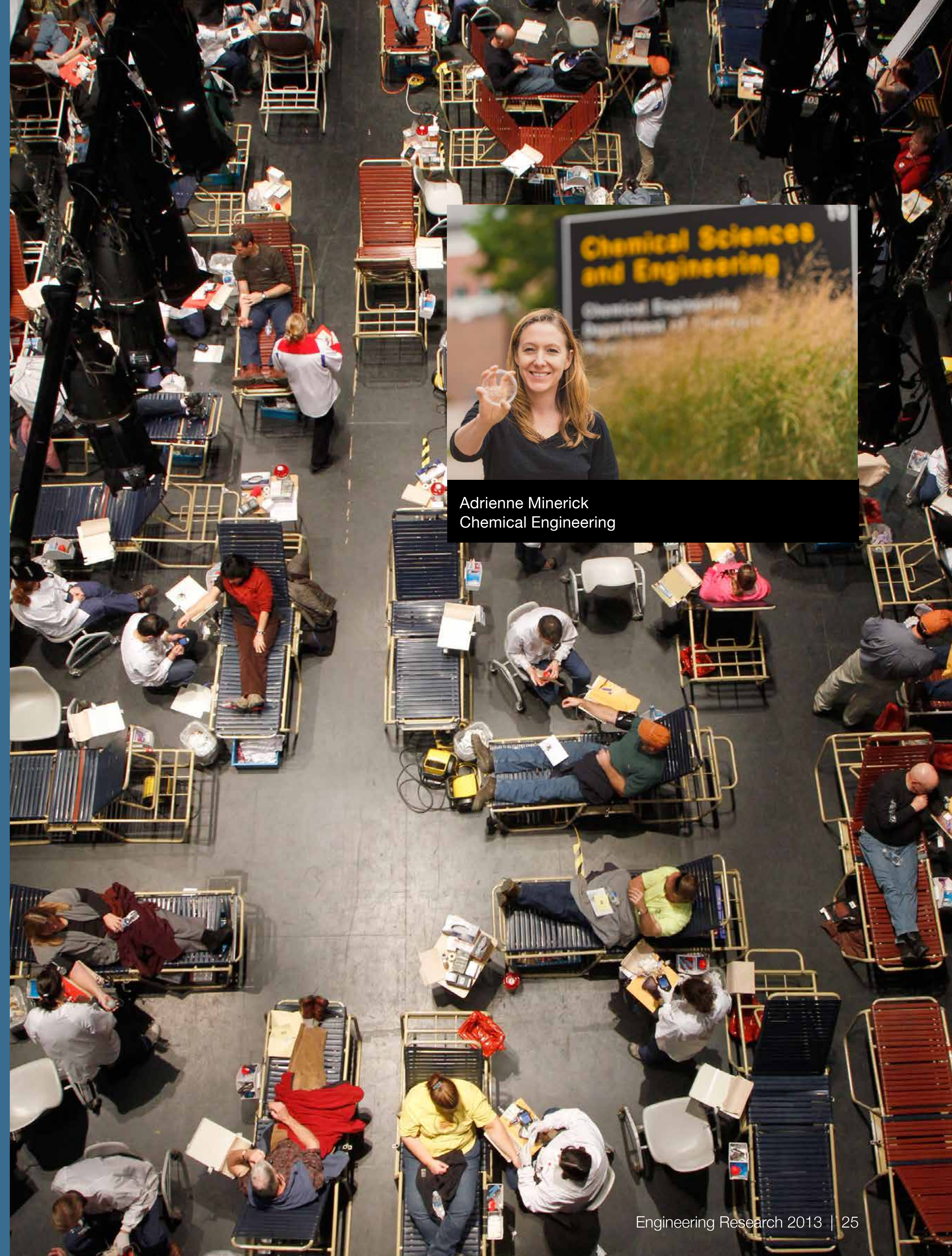
"The real powerful aspect of the device is that it can discern different molecules on biological cell surfaces," Minerick explains. "For example, it can recognize blood type without the use of any chemical reagents." Blood banks are most interested in utilizing the device, which is being combined with other technology in the Minerick lab to simultaneously determine hematocrit of the blood.

"In general, lab-on-a-chip technology has the potential to replace costly centralized medical laboratory analysis with point-of-care diagnostic tests that could provide the patient with positive or negative results—along with quantitative information on disease status—in only a few minutes," says Minerick. "This has already been accomplished with blood glucose meters. Imagine having point-of-care technology for common blood chemistry panels, or even for early detection of diseases such as cancer.

I-Corps enabled Minerick's team to interview potential customers and assess their needs. "We talked to numerous hospital personnel, emergency medical technicians, and various medical labs in urban and rural areas before discovering a sector highly interested in our technology. I-Corps taught us how to continuously gauge our market and adapt our business model in real time. We have defined our next steps and are moving forward with commercializing our lab-on-a chip device," she adds. Minerick and Raber started a company called Microdevice Engineering, LLC in collaboration with Superior Innovations, a for-profit company that nurtures Michigan Tech startups.

An I-Corps team led by Ezra Bar-Ziv also placed first among twenty-four teams from across the nation in 2012. Their focus is torrefaction—turning low-rank biomass into high added-value biocoal. Bar-Ziv has put his ideas into practice by establishing an Israeli company, EB Clean Energy, that is now partnering with a northwestern utility to commercialize the process. And Amlan Mukherjee recently founded a start-up company called Life Cycle Solutions, LLC after receiving support through the NSF I-Corps program. (See page 8).

John Diebel, assistant director of technology commercialization at Michigan Tech, has worked with the I-Corps program as an industry mentor. He calls I-Corps training "transformative," not just for the participating teams, but also for the entire field of technology transfer.



Adrienne Minerick
Chemical Engineering

Iron ore—and more

Seeking sustainability in mineral processing

The ASISC research center at Michigan Tech is a partnership of academic institutions and industry with interests in mineral processing. Members pool resources to address a diverse spectrum of interdisciplinary research questions. Their primary goal: to develop a new generation of sustainable, economical mineral processing technologies.

PhD student Howard Haselhuhn is an ASISC researcher focused on water chemistry. At an iron-processing facility, he recently studied the technology used to remove impurities from iron ore.

Depending on the time of year, almost all of the water used in an iron concentration plant is recycled. "This is not just important from an environmental standpoint; it is cost effective to conserve the thermal energy in the process water as well as the water quality within the plant," explains Haselhuhn. "Iron ore concentration facilities depend on surface chemical interactions for many concentration operations; therefore, strict control of water chemistry is necessary. Most tap water is of insufficient quality for direct use within iron ore concentration plants," he notes.

Iron ore is ground down into very small particles, which are mixed in water. Reagents are added to the mixture to flocculate iron oxide particles. These flocs, which contain more iron, settle quickly, leaving unflocculated particles, containing primarily silica, to remain suspended. However, Haselhuhn discovered, sometimes the raw ore and recycled water contain high levels of magnesium. In turn, that causes silica particles to cluster and settle out with the iron, rendering the separation process ineffective.

"By compensating for the excess magnesium, companies could reduce the loss of iron in their concentration process, something that could provide millions of dollars in potential savings," he says. "We are fortunate enough to have an abundance of fresh water in the Great Lakes area, which makes iron processing easier. In many other parts of the world, the process water must at least partially come from the ocean, which is very high in magnesium. They can still process; just with different, more expensive methods."

Once the ore is concentrated, it is in the form of an iron oxide. "Obviously, the oxygen must be removed before it becomes iron," he adds. "This is typically accomplished by reacting it with a carbon source, typically coal. One direction ASISC has been exploring is replacing coal with a biomass-derived reductant. This decreases dependency upon non-sustainable natural resources."

The mineral processing industry makes continuous improvements in technology, explains Haselhuhn. "Many of these improvements have been small and locale-specific, but once in a while there is a giant step forward that can bring about a new era in the industry. These dramatic improvements will be necessary to remain a sustainable industry. Unlike many industries, the feedstock (iron ore) is constantly degrading in quality. Eventually, it will not be feasible to process unless new methods are developed."

"Repurposing waste will be key to reclamation of mining sites once the ore is gone," he adds. "ASISC is committed to finding 'zero-waste' solutions to mineral processing."

Pictured: A crucible containing iron nuggets that were reduced from iron ore using biomass as a reductant.

Howard Haselhuhn
Chemical Engineering

Pictured: PCMI student Wade Aitken-Palmer is working with a small fishing community in Ghana to regain clean water access—something it lost eight years ago.

Largest in the nation

Peace Corps Master's International at Michigan Tech

Michigan Technological University ranks as the number one Peace Corps Master's International university nationwide for the eighth consecutive year, with 35 Master's International graduate students currently making a difference as Peace Corps Volunteers.

Peace Corps' Master's International (PCMI) students use projects completed during their Peace Corps service to satisfy some of their degree requirements. "PCMI volunteers return to the United States as global citizens, with leadership, cross-cultural understanding, and language and technical skills that position them for success in today's global job market," says Peace Corps Deputy Director Carrie Hessler-Radelet.

Since Michigan Tech became a PCMI partner in 1995, more than 120 graduates have earned degrees through the program, serving in 45 different countries. Offering eight distinct graduate programs affiliated with Peace Corps, Michigan Tech has the largest number of PCMI programs in the country. These graduate programs attract global-minded students to the university, while helping Peace Corps meet host country needs for skilled professionals to work in key areas of need, such as agriculture and food security, environmental conservation, water and sanitation, public health, and education.

PCMI degree programs at Michigan Tech include Civil and Environmental Engineering, Mechanical Engineering, and Mitigation of Geological Natural Hazards, as well as Applied Natural Resource Economics, Biological Sciences, Forest Resources and Environmental Sciences, Rhetoric and Technical Communication, and Science Education.

Wade Aitken-Palmer is currently helping a small fishing community in Ghana regain clean water access—something the community lost eight years ago. After he completes the PCMI program in mechanical engineering, he hopes to work with an international agency, company, or nongovernmental organization (NGO) on community-based, small-scale alternative energy. "I enjoy projects that can both benefit the environment and the local population," he says. "This is where I will make a difference."

Just before departing for Ghana, Aitken-Palmer and mechanical engineering PhD student and Peace Corps volunteer Ben Mitchell won a Michigan New Venture Competition award. The two captured a $30,000 first prize and another $10,000 for Best Social Venture. Their company, called Baisikeli Ugunduzi (Swahili for "modern bicycle"), is dedicated to creating better bicycle components for rural Africans who depend on bicycles for their livelihood. Their first invention: a tough inner tube that eliminates flat tires.

For more information about the Peace Corps Master's International program at Michigan Tech, visit www.mtu.edu/peacecorps

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Michigan Tech's AMJOCH Observatory—located four miles from campus at an excellent dark-sky site—offers a computer-controlled Meade 16-inch LS-200 telescope, complete with ST-8 CCD camera and UBVRI filters.

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