2012

Engineering Research 2012

College of Engineering, Michigan Technological University

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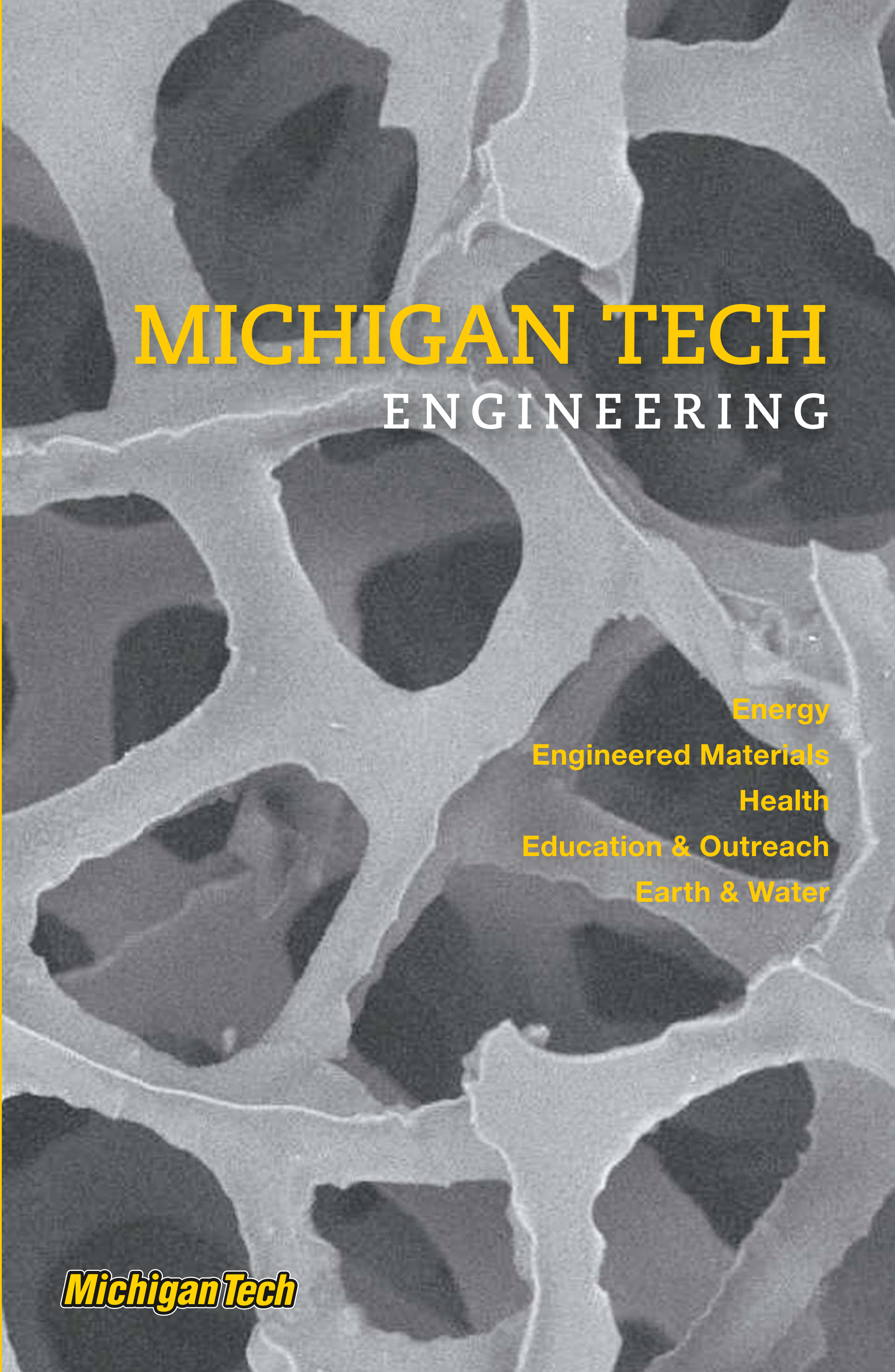

MICHIGAN TECH
ENGINEERING

Energy

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Michigan Tech

Letter from the Dean

Welcome to Michigan Technological University. As some of you may know, I am a recent arrival to this great campus. From my first visit and several others during the spring and summer before my arrival, I was impressed with the high caliber of students.

Coming from the University of Illinois at Chicago, where I was head of the Department of Mechanical and Industrial Engineering and director of the Energy Resources Center, I look forward to tackling the opportunities and challenges at Michigan Tech, bragging about the great research and teaching being done here, and further enhancing our reputation. As a byline, my research is in energy systems and thermal sciences—in other words, I'm an Energy person. I'm a fellow of the American Society of Mechanical Engineers and ASHRAE. I'll be joining the ASME Board of Governors in June 2013.

As Dean I will be working to enable faculty and staff in our College of Engineering to forge new connections and strengthen our external visibility. I believe multi-institutional collaboration is the future. Further expanding our undergraduate programs and expanding our graduate and research programs are top goals.

One thing is certain—I will be building on the tremendous accomplishments of the past and of those who have gone before me here at Michigan Tech.

Please don't hesitate to contact me with any of your questions or ideas.

I look forward to hearing from you.

Sincerely,

William M. Worek
Dean of Engineering
Dave House Professor

On the cover:
Carbon foam SEM magnification 100x. Tony Rogers and Bahne Cornilsen have developed an asymmetric capacitor with a lightweight, rechargeable cathode based on carbon foam. See page 3.

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Tony Rogers
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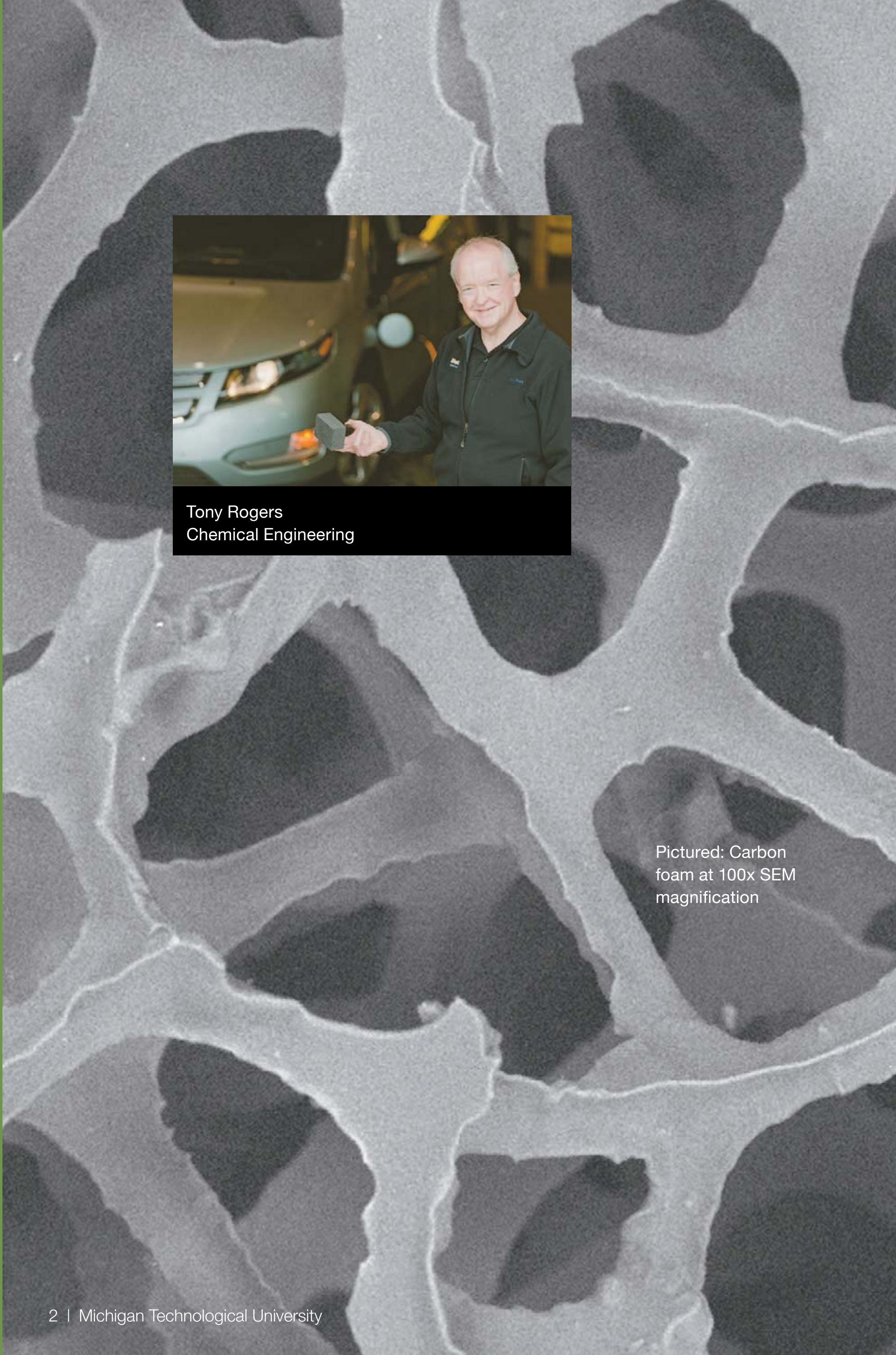
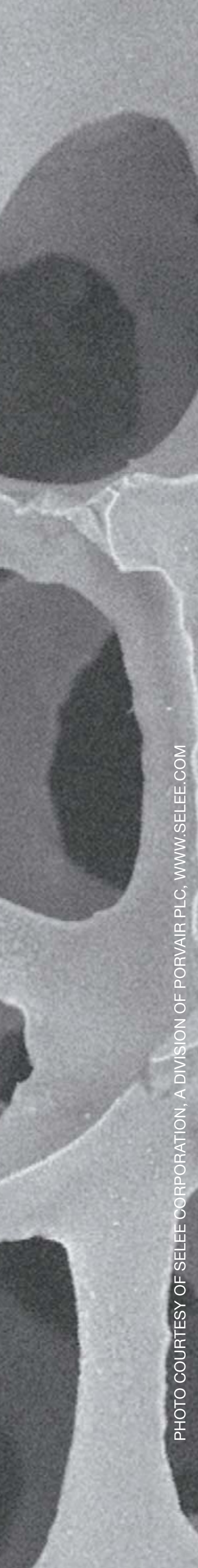


Pictured: Carbon foam at 100x SEM magnification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Asymmetric capacitors

Utilizing a lightweight, rechargeable cathode based on carbon foam

A lighter, greener, cheaper, longer lasting battery. Who wouldn't want that? Michigan Tech researchers Tony Rogers (chemical engineering) and Bahne Cornilsen (chemistry) are working on it. Their collaboration brings together Rogers' interest in porous, electrically-conductive carbon foams and Cornilsen's extensive nickel battery expertise. The result is a twist on what's called an asymmetric capacitor, a new type of electrical storage device that's half capacitor, half battery.

It may be a marriage made in heaven. Capacitors store an electrical charge physically and have important advantages: they are lightweight and can be recharged (and discharged) rapidly and almost indefinitely. Plus, they generate very little heat, an important issue for electronic devices. However, they can only make use of about half of their stored charge.

Batteries, on the other hand, store electrical energy chemically and can release it over longer periods at a steady voltage. And they can usually store more energy than a capacitor. But batteries are heavy and take time to charge, and even the best can't be recharged forever.

Enter asymmetric capacitors, which bring together the best of both worlds. On the capacitor side, energy is stored by electrolyte ions that are physically attracted to the charged surface of a carbon anode. Combined with a battery-style cathode, this design delivers nearly double the energy of a standard capacitor.

Now, Rogers and Cornilsen have incorporated a novel material on the battery side to make an even better asymmetric capacitor. Their cathode relies on nickel oxyhydroxide, the same material used in rechargeable nickel-cadmium or nickel-metal hydride batteries. In most batteries that contain nickel oxyhydroxide, metallic nickel serves as a mechanical support and a current collector. The team has replaced the nickel with carbon foam. Carbon foam has advantages over nickel. "It's lighter and cheaper, so we thought maybe we could use it as a scaffold, filling its holes with nickel oxyhydroxide," said Rogers. Carbon foam has a lot of holes to fill. "The carbon foam we are using has 72 percent porosity. That means 72 percent of its volume is empty space, so there's plenty of room for the nickel oxyhydroxide. The carbon foam could also be made of renewable biomass, and that's attractive."

But how many times can you recharge their novel asymmetric capacitor? Nobody knows; so far, they haven't been able to wear it out. "We've achieved over 127,000 cycles," Rogers said. Other asymmetric capacitors have similar numbers, but none have the carbon-foam edge that could make them even more desirable to consumers. "Being lighter would give it a real advantage in handheld power tools and consumer electronics," said Rogers. Hybrid electric vehicles are another potential market, since an asymmetric capacitor can charge and discharge more rapidly than a normal battery, making it useful for regenerative braking. The group is pursuing commercialization of its new technology under a grant from the State of Michigan.

Biocoal

Torrefaction—turning low-rank biomass into high added-value biocoal

Working for the Israel Electric Corporation (IEC), which imports all of the 13 million tons of coal consumed by the country of Israel each year from 200 different sources, enabled Ezra Bar-Ziv to accumulate vast experience in evaluating a large variety of coal types, including those used by the US power industry.

Building on that experience, Bar-Ziv invented new techniques that mimic nature by converting plants (biomass) into a new fuel, referred to as torrefied-biomass, or simply biocoal.

Biocoal is a synthetic material similar to coal but without all its hurdles and limitations. Bar-Ziv has gained the ability to identify a synergy between the production of the most suitable biocoal for a given boiler and the accurate assessment of its performance—a unique expertise that is retained by only a few experts in the world. His goals: to lower emissions in coal-fired boilers and provide optimized operational conditions of the entire coal power plant to achieve maximum performance.

"Coal is highly polluting, with emissions including NOx, SOx, particles, PAH, mercury, CO_2 greenhouse gas, and others. There is a very large variability and inconsistency in coal that causes tremendous operational difficulties," notes Bar-Ziv. The new biocoal fuel he has developed is basically identical to coal and thus can be used as a drop-in fuel without retrofitting the power plant, yet produce very clean and green electricity from a sustainable and renewable source of energy.

Bar-Ziv's work in torrefaction includes three main achievements: (1) the ability to produce a biocoal with properties identical to the coal that yields the optimal performance in a given coal-fired power plant; (2) the use of municipal solid waste as a feedstock in the torrefaction process, which eliminates hazardous dioxins and furans; and (3) an accurate predictive assessment of performance of the tailored biocoal in a given boiler. "The synergy between the chemical structure of a biocoal and its optimal firing conditions is a unique combination that only a handful of people around the globe have acquired," he says.

Bar-Ziv has put his ideas into practice by establishing an Israeli company, EB Clean Energy, to test new technologies for biomass torrefaction to produce biocoal. The company has already developed one cost-effective technology that is currently being commercialized in Israel for production of 1.5 million tons of biocoal for Israel Electric Corporation. "There is no torrefaction technology in the US at such a level of maturity," notes Bar-Ziv. He is proposing to establish a torrefaction facility that would operate at a production rate of one to two tons per hour—only a factor of ten smaller than a full-scale industrial plant. He will use this facility to produce biocoal for firing tests in US coal-fired boilers. Bar-Ziv's next goal is to build a semi-industrial scale torrefaction facility located at an industrial biomass facility to serve local power plants.

Another torrefaction project under proposal, this one at Portland General Energy (PGE), would produce 12,000 tons of biocoal for firing tests to prove the feasibility of using biocoal in an industrial-scale boiler—the first large feasibility study in the US in this area.

"All of these projects will significantly enhance the ability to produce clean electricity with biocoal, a renewable source, at an affordable price," says Bar-Ziv. "This, in turn, we hope, will enable US power companies to attain renewable energy portfolios."

PHOTO COURTESY OF AVA-CO2

Ezra Bar-Ziv
Mechanical Engineering-Engineering Mechanics

Reza Shahbazian-Yassar
Mechanical Engineering-Engineering Mechanics


PHOTO CREDIT © CHRISTIAN VON HOSSLIN, WWW.TURN-E.DE; *BUILD YOUR OWN ELECTRIC VEHICLE*, 3RD EDITION, BY SETH LEITMAN AND BOB BRANT, WWW.ENERGYGUY.COM

A window to energy structures

Probing battery systems at the nanoscale level

Nanomaterials, with dimensions almost 1/1,000 the diameter of a human hair, offer many unique properties in contrast to their bulk scale. Many classical equations governing the electrical, mechanical, or thermal properties of materials are no longer valid or able to predict the behavior of nanomaterials.

This unique behavior has opened a new field in the science of materials. In order to produce reliable and durable products, the origin and mechanisms involved with the behavior of nanomaterials must be understood.

Researchers at Michigan Tech have access to one of the most state-of-the-art nanoscale characterization techniques, which allows them not only to probe the electrical, mechanical, electromechanical, and electrochemical behavior of a single nanomaterial, but also to image their atomic structure in real time and space. The integration of this nanoprobing technique with a high-resolution transmission electron microscope (TEM) has added another dimension to their analysis: a window to observe the atomic structure of nanomaterial while it responds to electric or mechanical fields, known as 'in-situ' electron microscopy—analysis conducted by only a handful of universities and national labs.

Reza Shahbazian-Yassar is focused on energy storage and conversion technologies. His research team is working on battery technologies, and in particular Li-ion batteries in an ongoing collaboration with Savannah River National Laboratory and Argonne National Laboratory. The team has been successful in making a nanobattery made of a single nanowire that serves as an anode electrode. "For many years, it was a dream to manipulate and image the behavior of a single nanomaterial subjected to a various range of temperature, load, environment, and electric fields," notes Shabazian-Yassar. "With recent progress in the fabrication of miniature devices and nanotechnology this has finally become a reality. Now, with the help of TEM, we can observe what is happening inside a Li-ion battery during the charging/discharging process." The team is set to start a new collaboration on Si-based anodes with the National Institute of Materials Science (NIMS) in Japan.

Shabazian-Yassar also uses nanoprobing techniques to understand the failure and aging of fuel cell materials. "A current challenge in making hydrogen-based vehicles is that the fuel cell (a device that converts the chemical energy of H_2 and O_2 combination to electricity and water) loses its functionality over period of service. When we open the fuel cell device and take a piece of it under microscope, we notice huge changes in the structures of the anode, cathode, and the membrane." Shabazian-Yassar's team is studying the mechanical and electrical degradation fuel cell materials along with several universities and national labs. "If we make a connection between the structural degradation and the mechanical/electrical properties at nanoscale, we can shed light on many questions in this field."

Real materials, virtual experiments

Using supercomputers to simulate materials

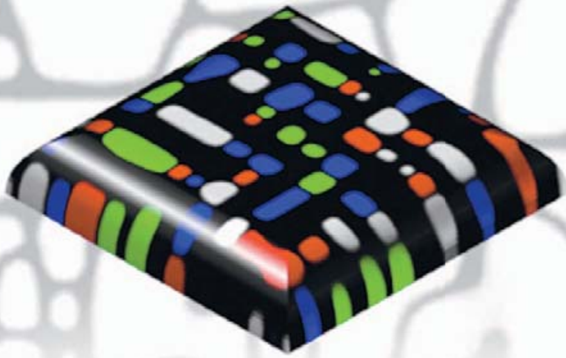
A material's macroscopic behaviors, as we see in our everyday experiences, are the result of the collective behaviors of an enormous number of atoms that compose the material. Many distinct processes take place over vastly different length and time scales. When simulating material behaviors, even today's most powerful supercomputers do not have the capability to handle all these scales from the atomic up to the macroscopic level. Nevertheless, computational materials science has been playing an increasingly important role in materials research, complementing real experiments, and in many cases, proving to be indispensable.

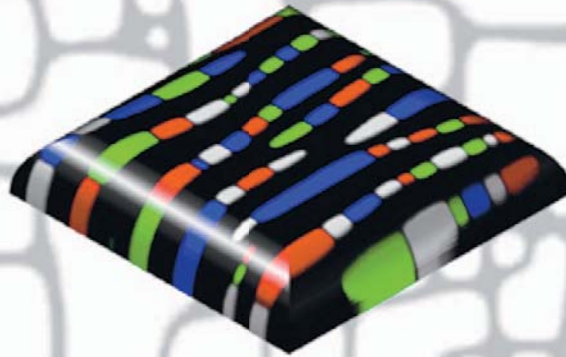
Yongmei Jin uses supercomputers to resolve puzzling issues in materials science. Jin uses materials modeling and simulation to generate digital characterizations of real materials and perform virtual experiments in the digital world of computers.

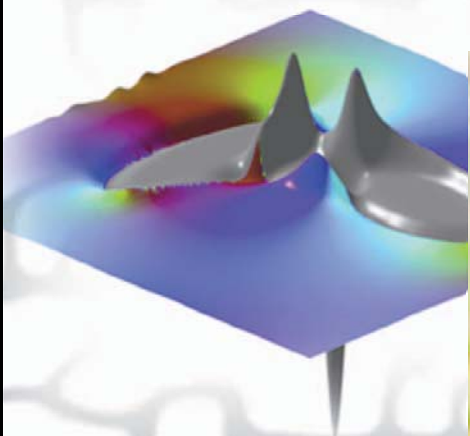
"Fortunately, atoms do not behave randomly due to their interactions," notes Jin. "In some materials, atoms arrange themselves in an orderly manner over distances much longer than atomic spacing, which is called long-range order. The macroscopic behaviors of such materials are mainly determined by the morphology and evolution of different ordered regions, called domains, often a few nanometers to micrometers in size." Over the past decade, Jin's research has focused on modeling and simulation studies of the processes taking place in various materials—structural, electrical and magnetic. Her goal: improved properties and functionalities for high-tech applications.

In some other materials, atoms arrange themselves in a less orderly manner and the atomic order only extends over a few atomic spacings, called short-range order. "Exotic properties are found in some short-range-ordered materials, signifying new opportunities for materials design. The challenge is the lack of knowledge of these detailed atomic arrangements, which are difficult to detect."

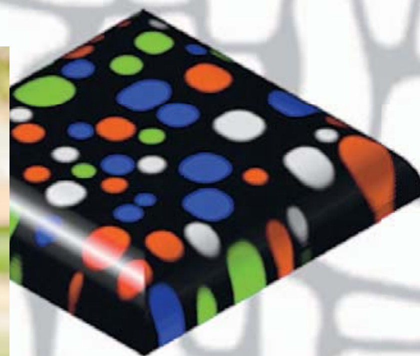
Jin began her journey into this exciting research field by combining high-energy synchrotron X-ray diffraction experiments and advanced data analysis through computer simulations. Her experiments provide high-quality diffuse scattering data in which the information of short-range atomic ordering is hidden and can only be extracted by large-scale data processing. "Collection of experimental data is a small part of the job," she says. "It is the data analysis that is the great challenge. My major work—and the source of my enthusiasm—are always the computations."



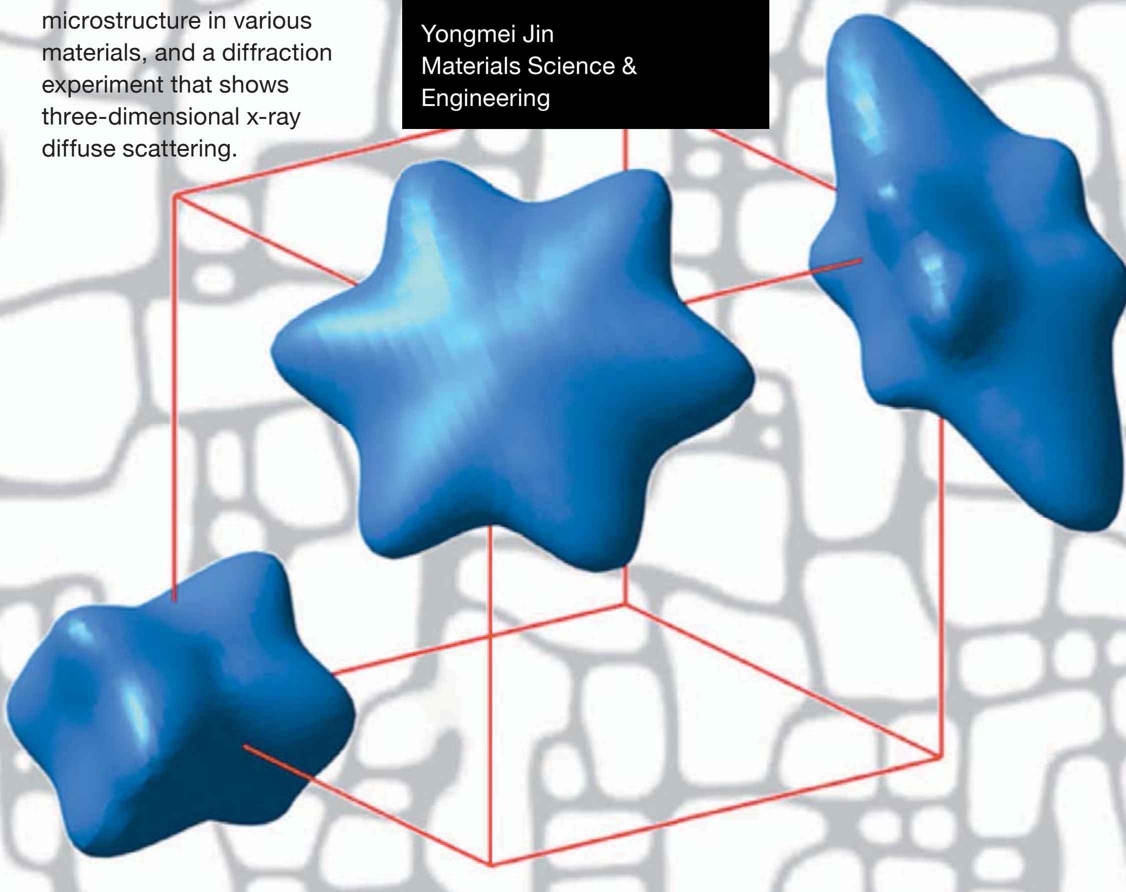




Yongmei Jin
Materials Science & Engineering



Pictured: Simulations that show precipitates, charge accumulation, and microstructure in various materials, and a diffraction experiment that shows three-dimensional x-ray diffuse scattering.



Paul Sanders
Materials Science & Engineering

Lighten up

Developing high-strength, low-alloy aluminum

The US Navy hopes to transition from steel-hulled ships to a lightweight aluminum fleet that will be faster and more energy efficient. To be successful, the Navy needs a variety of aluminum alloys capable of meeting a wide breadth of specific performance needs—strength, stiffness, joinability, fatigue resistance, corrosion resistance, and suitability for niche customization.

Paul Sanders is working with the Office of Naval Research on an efficient, focused strategy for new aluminum alloy design. His approach, termed high-strength, low-alloy aluminum (HSLA-Al), was conceived, and is being developed, at Michigan Tech. He seeks to replicate the high-strength, low-alloy paradigm that was developed to design steels in the 1960s; HSLA steels are still in use today.

To achieve this goal, Sanders and his team employ a minimalist design solution that starts with pure aluminum and adds only elements required to deliver the required strength. “We are replacing typical Si, Cu, and Mg alloying elements with a small concentration of transition and rare earths elements, most notably scandium, to engineer a nano-precipitate microstructure with good strength and ductility,” he explains. “Small concentrations are necessary as most metallic elements have low solubility in aluminum.” The main challenge? At this point, cost. “Scandium—at $4,000 per pound—is a more potent strengthener of aluminum than any other element.”

Sanders seeks to understand the thermodynamics (stability) and kinetics (how fast things happen) in aluminum-scandium alloy systems. “This will help us identify the optimum alloy composition and thermomechanical (e.g. heating and rolling) processing that will deliver peak properties at the lowest cost,” Sanders explains. “Specifically, we are looking at the aluminum-scandium-zirconium system. Think of this system as forming small M&Ms in a sea of aluminum. First the scandium gets together to form small, well-dispersed nano clusters of Al_3Sc (the chocolate center). Later, due to the slower diffusion of zirconium, a shell of Al_3Zr (the candy shell) forms around the Al_3Sc. This zirconium serves several valuable purposes. First, it makes the precipitates bigger, giving more strength without adding expensive scandium. Second, it is even more stable than scandium at high temperatures, so this shell traps the Sc inside, increasing possible use temperatures from 300 to 400° C.”

Other applications could take advantage of HSLA-Al’s high temperature stability—including internal combustion engines (pistons), brake rotors, and armor.

Coherent optics

Shining light on cell and tissue dynamics

The electromagnetic spectrum is an observable phenomenon that carries the fingerprints of its interactions with matter. Investigating the characteristic features of light is one of the primary means by which we understand the universe of which we are a part. Recently, this includes gaining an improved understanding of dynamic biological systems that are of importance to human health.

Sean Kirkpatrick studies the way light interacts with dynamic biological systems of all scale sizes, from subcellular and cellular structures, through tissues, fluid transport systems, organs, and even entire organ systems. Using laser speckle-based techniques he has developed, Kirkpatrick has successfully used laser speckle analysis to non-invasively evaluate potential skin cancers, monitor cranial blood flow in animal models, quantify the viscoelastic properties of healthy and pathological human tissues, monitor the curing kinetics of synthetic biopolymers, and more.

"In a very general sense, light is either absorbed or scattered when it interacts with biological structures," says Kirkpatrick. His research team focuses on scattering phenomena. In particular, they examine the spatio-temporal dynamics of scattered coherent light, and from this infer the properties of the scattering media. These properties include such things as cellular metabolism, blood and other fluid flow, and even mechanical properties of human tissues.

Of particular interest to Kirkpatrick is the theory and application of laser speckle phenomena. "Speckle is a ubiquitous phenomenon observed whenever coherent radiation, such as ultrasound, coherent x-ray, radio waves, or laser light is scattered by a rough surface or by a scattering volume," he explains. "Laser speckle is observed when light from a coherent laser source is scattered by such objects. Speckle appears as a granular intensity pattern. It is the result of mutual interference of a set of coherent wavefronts of different amplitude and phase. These speckle patterns, while considered noise for many applications, carry with them information about the scattering medium." The key, he says, lies in discovering methods to analyze the speckle patterns and gain access to this information.

Kirkpatrick and his team combine numerical simulations with experimental approaches to investigate the nature of speckle patterns and to develop analytical techniques to evaluate speckle patterns in a manner that yields information about the scattering medium. For instance, the team is using laser speckle techniques to help quantify blood perfusion in suspected cancerous tissue. Blood perfusion should be higher in cancerous tumors than in benign tumors.

"While our focus has been primarily on medical applications, the work we do has direct applications to other fields as well," notes Kirkpatrick. "That includes atmospheric optics, free-space communication systems, and materials science, as well as contributing to the science of light scattering."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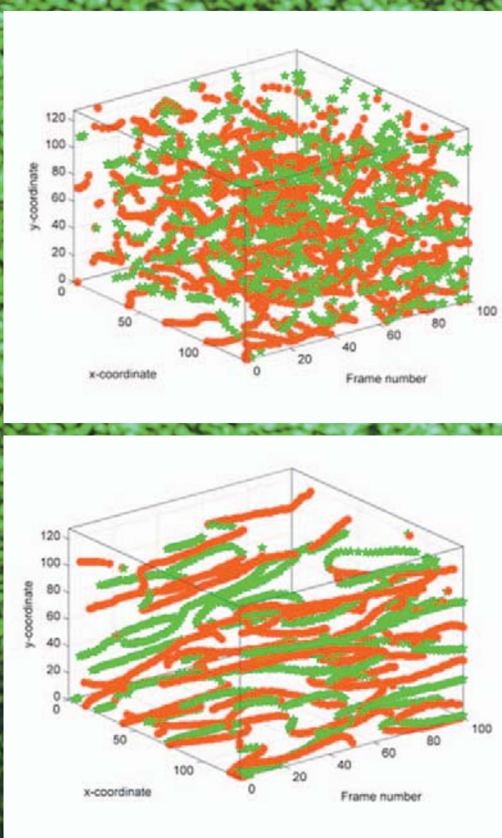
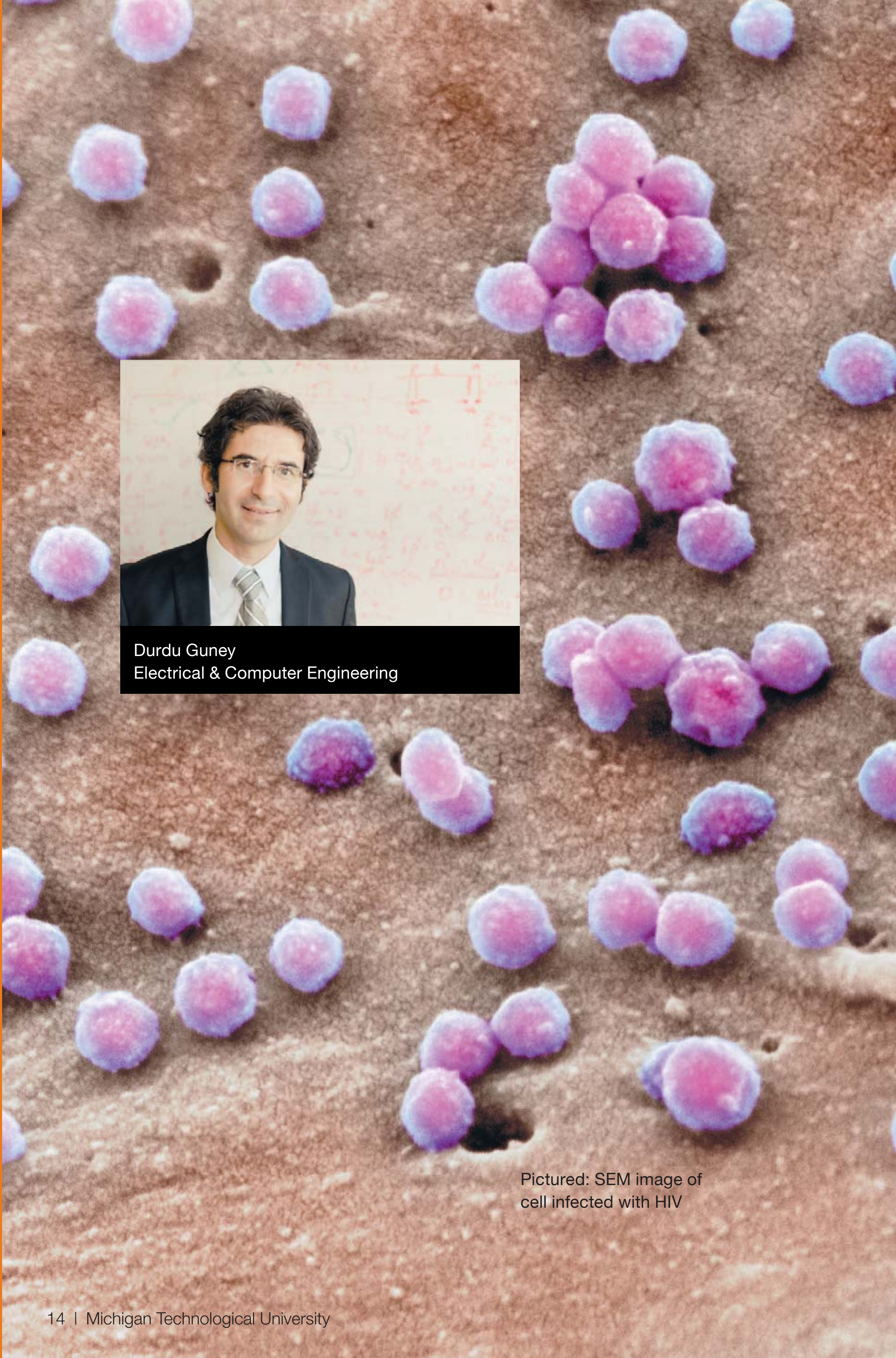
Sean Kirkpatrick
Biomedical Engineering

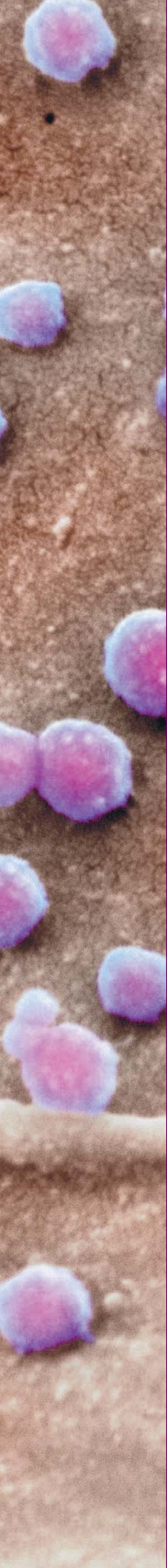


Pictured: Motion paths of singular locations, or optical vortices, in the phase of scattered light fields coming from solutions of rapidly and slowly moving polystyrene microparticles.



Durdu Guney
Electrical & Computer Engineering

Pictured: SEM image of cell infected with HIV



Superlens

Nearing the creation of the perfect lens

A biomedical superlens would let you see a virus in a drop of blood. It could open the door to better and cheaper electronics. It might make ultra-high-resolution microscopes as commonplace as cameras in our cell phones.

No one has yet made an optical superlens, also known as a perfect lens, though people are trying. Optical lenses are limited by the nature of light, the so-called diffraction limit, so even the best won't usually let us see objects smaller than 200 nanometers across, about the size of the smallest bacterium. The sizes of viruses—the smallest infectious agents—can be as small as 20 nanometers. Scanning electron microscopes can capture objects that are much smaller, about a nanometer wide, but they are expensive, heavy, and, at the size of a large desk, not very portable.

Durdu Guney has taken a major step toward creating a superlens that could extend our ability to use visible light to see objects as small as 100 nanometers across.

"To build a superlens, you need metamaterials: artificial materials with properties not seen in nature," Guney explains.

The secret lies in plasmons, charge oscillations near the surface of thin metal films that combine with special nanostructures. When excited by an electromagnetic field, they gather light waves from an object and refract it in a way not observed in nature called negative refraction. This allows the lens to overcome the diffraction limit. In the case of Guney's model, it could allow us to see objects smaller than 1/1,000 the width of a human hair.

Other researchers have also been able to sidestep the diffraction limit, but not throughout the entire spectrum of visible light. Guney's model shows how metamaterials might be "stretched" to refract light waves from the infrared: through visible light and into the ultraviolet spectrum.

Making these superlenses would be relatively inexpensive, which is why they might find their way into cell phones. But there would be other uses as well, says Guney. "It could also be applied to lithography," the microfabrication process used in electronics manufacturing. "The lens determines the feature size you can make, and by replacing an old lens with this superlens, you could make smaller features at a lower cost. You could make devices as small as you like."

What excites Guney the most, however, is that a cheap, accessible superlens could open our collective eyes to worlds previously known only to a very few. "Most viruses can only be seen by electron microscopes," he says. "For example, the viruses such as HIV, Hepatitis B, and Hepatitis C have average sizes of about 120nm, 40nm, 60nm, respectively." If a superlens is built, these viruses could be viewed by a simple optical microscope, which could be integrated with a smartphone. Due to its compact size, it could be then conveniently used in remote areas with no problem on either humans or animals. Such a superlens could also be used in biotechnology and genetic engineering during the production of vaccines to prevent diseases caused by viruses.

"Currently the public's access to high-powered microscopes is negligible," he says. "With superlenses, everybody could be a scientist. People could put their cells on Facebook. It might just inspire society's scientific soul."

Hands-on ability

Does it matter? Yes it does.

Students are changing. The experiences they bring to college have changed vastly, and their futures will be much different than the futures of past graduates. Whereas past students engaged in many practical hands-on activities while growing up, today's youth spend many hours using electronic games and computers. Even though today's engineers rarely get to manipulate objects (besides pencils and computer keys), is mechanical "hands-on ability" still important? If so, why?

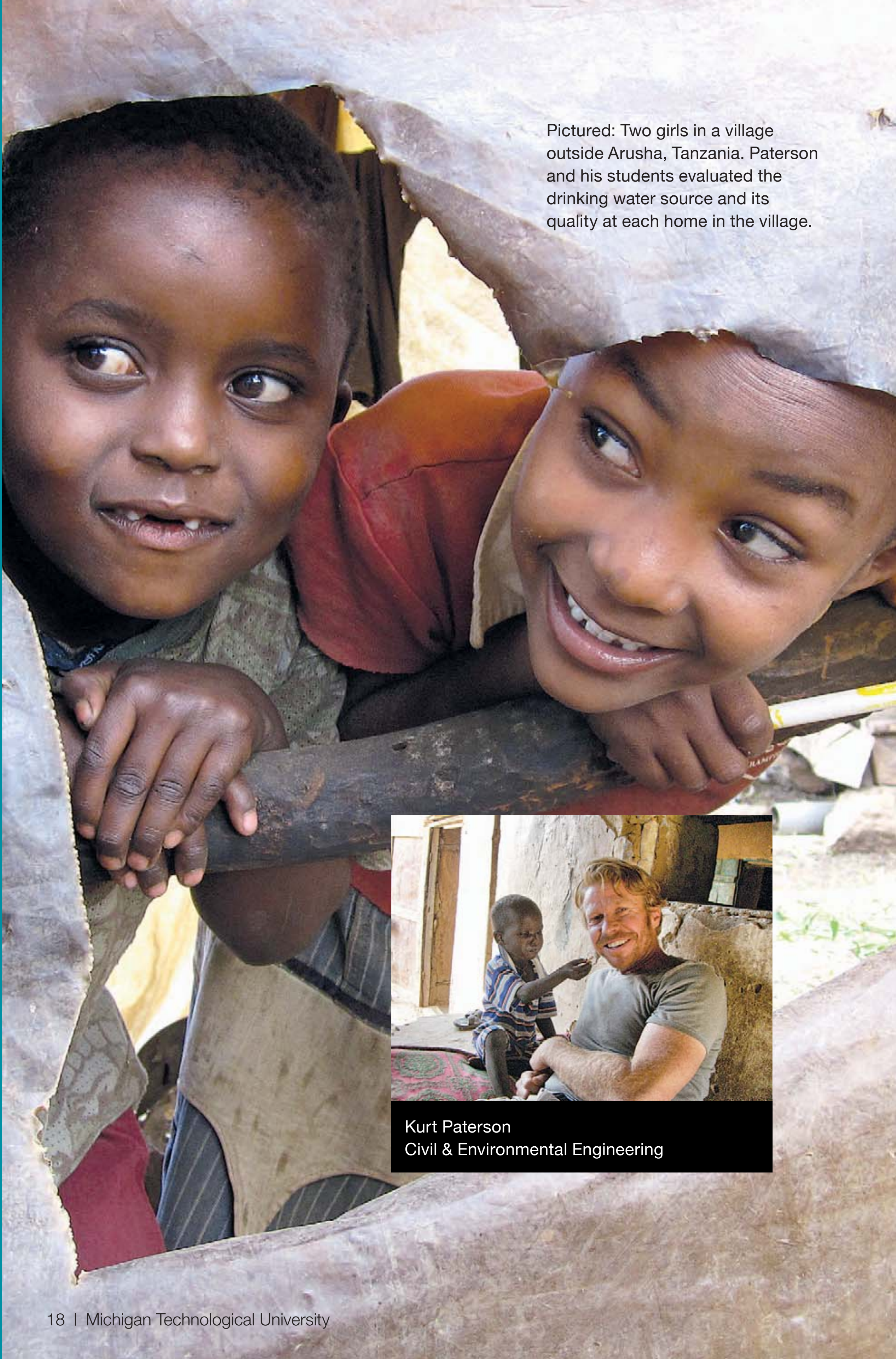
Michele Miller has been interested in these questions for a number of years. Drawn to mechanical engineering through a love of math and physics, she felt ill-prepared for an entry level manufacturing engineering job after college. Extensive use of machines and instrumentation in graduate school removed the intimidation factor and gave a sense of empowerment. Early work with graduate students in the laboratory revealed that they also lacked hands-on ability, and Miller became more firmly convinced: the undergraduate curriculum does not provide adequate preparation.

Miller's recent research has investigated whether hands-on ability is important and why. Surveys of employers show that hands-on ability is almost as highly rated as teaming and communication skills as the top priority for new graduates, well ahead of academic ability, creativity, and prior work experience. "Employers also indicate that hands-on experience is important because it develops the ability to visualize how something will work, to design, and to troubleshoot," she notes. For prototyping a design concept, an engineer will use their hands-on ability to make creative use of available materials and tools. The ability helps them to imagine and tinker with multiple approaches to realize a functioning physical system.

Miller and collaborators have investigated several ways to measure hands-on ability, including a paper and pencil test, observations of students doing hands-on laboratory tasks, and performance on physics-based computer games. The research team has also investigated where the ability comes from—use of tools, outdoors skills, and vocational skills classes. Male students are more likely than female students to develop this ability through informal hobby activities while female students are more likely than male students to develop the ability from vocational skills classes. Hands-on ability that students develop prior to college also seems to play a role in their decision to study mechanical engineering. Students who possess the ability tend to view engineering more favorably. Other researchers have found that hands-on activities are one of the strongest reasons for choosing mechanical engineering (over financial, parental, interest in math and science, and other reasons).

Why does all of this matter? For Miller, two reasons come to mind. "First, to better attract students to mechanical engineering, they need a chance to develop hands-on skills before college. Working with mechanisms builds relevant thinking skills, and just as importantly, it builds interest, enjoyment, and appreciation of engineering work," she says. "In addition to changing the conversation about the good work that engineers do, students need firsthand experiences of mechanical systems. The present-day curriculum may have been effective for a student with lots of prior hands-on experience, but it may be inadequate for the typical student of today."

Michele Miller
Mechanical Engineering-Engineering Mechanics



Pictured: Two girls in a village outside Arusha, Tanzania. Paterson and his students evaluated the drinking water source and its quality at each home in the village.

Kurt Paterson
Civil & Environmental Engineering


PHOTO CREDIT KURT PATERSON

Contribution-based learning

Integrating Grand Challenge engagement into engineering education

Early last decade, the United Nations issued its Millennium Development Goals, shortly after The National Academy of Engineering convened a blue ribbon committee to craft a list of Grand Challenges for the 21st Century. Together these lists underscore the critical needs and great opportunities confronting humanity and the planet: eliminating poverty, feeding the world without environmental collapse, providing clean water and sanitation to all, access to modern health care, mitigating global environmental change, creating clean energy, and improving our cities, among many others. Absent from the lists was the one challenge that rules them all: How do we create the kind and number of professionals to solve these challenges? Kurt Paterson has been investigating this issue in earnest over the past decade.

"Traditional approaches helped create these Grand Challenges, but they aren't likely to solve them," notes Paterson. "We have missed something completely in education, namely an unmet thirst for contribution," he says. "The explosive growth of Engineers Without Borders nationwide, zero to 200 university chapters in eight years, is compelling evidence for me. There is universal interest across engineering colleges." Although personal stories shared by participants of those programs were moving, Paterson knew a research-based approach was needed to translate anecdote to evidence.

Paterson and colleagues convened their own expert panel to identify opportunities, challenges, benefits, and resources needed for integrating Grand Challenge engagement in engineering education. That work rapidly led to research in order to better understand what students gain, or sacrifice, from their involvement. His team has assessed several hundred engineering students at a variety of universities across the country over the past three years.

"The evidence for what I call 'contribution-based learning', or CBL, is compelling," Paterson reveals. Paterson's work finds these students have what modern organizations seek: technical competence, leadership, creativity, global agility, plus a deep concern for their work. "CBL combines two powerful learning catalysts, project work and empathy," he notes. "We are finding technical competence is the same in students involved in CBL or not, but CBL ignites a passion for excellence, and meaning."

Paterson leads several CBL options at Michigan Tech: a Peace Corps program, the University's EWB chapter, an international senior design program, a certificate program in international sustainable development, a social entrepreneurship class, a research program in Africa, and an umbrella group to connect the entire Michigan Tech contribution tribe—the D80 Center (discovery/design/delight for the poorest 80 percent). Last year, Paterson was elected to start a new division focused on community engagement for the American Society for Engineering Education—the fastest growing division ever. "Within a year 300 engineering faculty joined, blowing the lid off our expectations."

"At Michigan Tech, students contribute, and in turn reap powerful motivation for learning while gaining project-based experience during their studies. They become civic-minded, develop meaningful recommendations from faculty and other partners, and graduate knowing they can continue to make significant differences. Ultimately the solutions to the Grand Challenges are found in us," Paterson suggests. "It's time to start contributing."

Groundwater cleanup

Breaking down pollutants with bacteria

The chlorinated solvent tetrachloroethene (PCE), a suspected carcinogen, is widely used for metal degreasing and dry cleaning. Because of improper disposal and spills, PCE and a related chlorinated solvent, trichloroethene (TCE), are two of the most common groundwater pollutants in the US.

Unlike petroleum products, which float on top of the water table when spills occur, PCE is more dense than water and accumulates at the bottom of aquifers, forming a separate phase that can dissolve PCE into groundwater as it flows on by—a process that can continue for hundreds of years.

Jennifer Becker's research exploits the ability of certain anaerobic bacteria to respire PCE (and TCE) in the same way that humans respire oxygen.

Supplied with a suitable energy source, often hydrogen, bacteria will grow on and transform PCE. This process is known as dehalorespiration. "Detoxification occurs if the bacteria remove all of the chlorines, and in this way dehalorespiration can be used to clean-up—or bioremediate—contaminated groundwater," adds Becker. "But many dehalorespiring bacteria only remove a few of the chlorines, and also generate dichloroethene or vinyl chloride—both of which are unacceptable due to their toxicity."

Several years ago Becker wondered if competition among dehalorespiring bacteria for either the contaminants or energy sources could affect the outcome of bioremediation. She used mathematical modeling to simulate potential ecological interactions between dehalorespiring bacteria in typical bioremediation scenarios. Her simulations suggested that interactions among dehalorespiring bacteria could significantly impact the outcome of bioremediation, and her research was recognized and funded with a National Science Foundation Presidential Early Career Award for Scientists and Engineers.

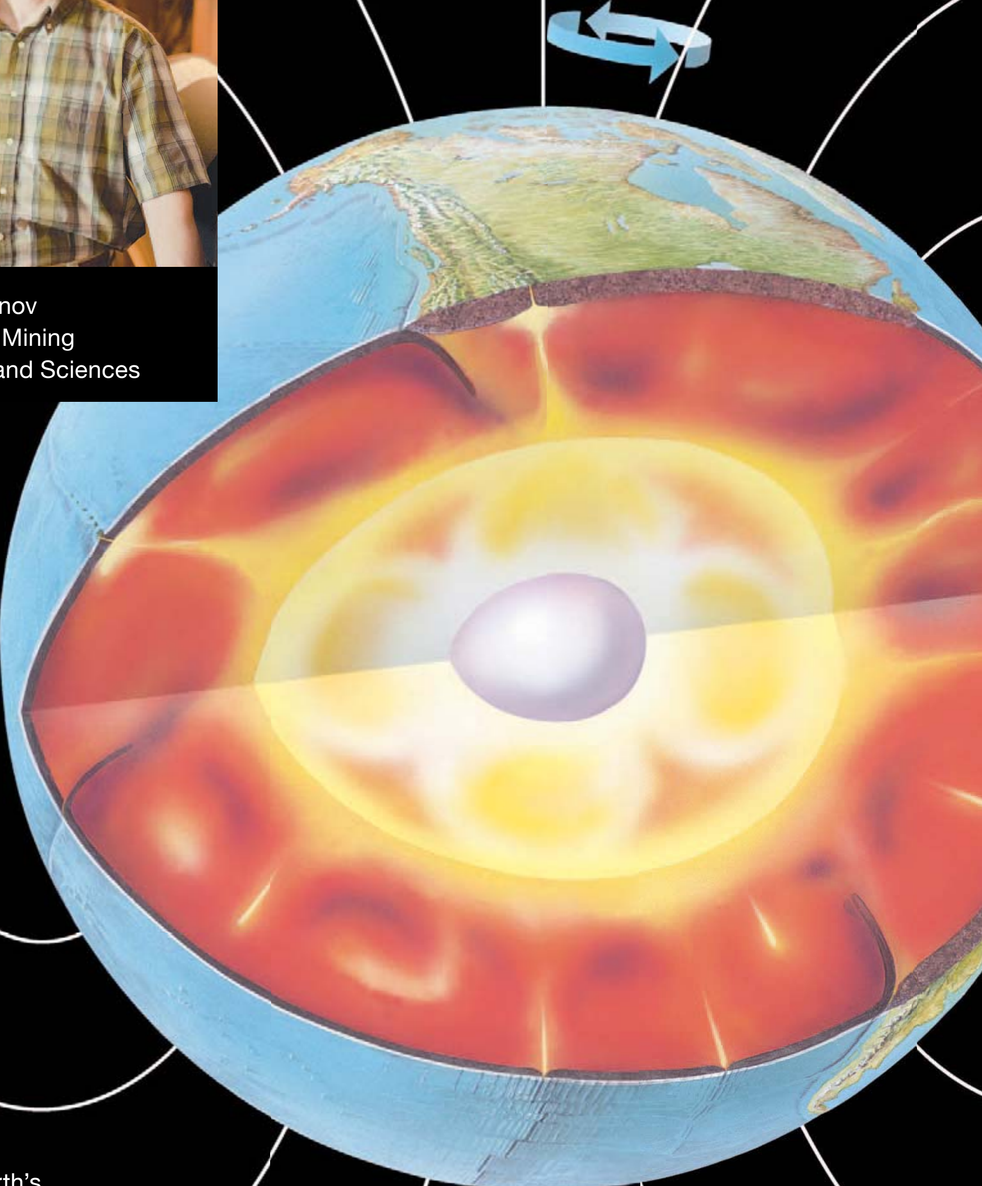
Currently Becker and her research team integrate both mathematical modeling and laboratory experimentation into their approach. "Experimental results that differ from model predictions often inform our conceptual and mathematical models," she says. "For example, in several laboratory experiments involving dissolved-phase PCE, one of the dehalorespiring bacteria populations did not grow as well as predicted by our model, and in some cases, transformation of PCE was also lower than expected. This led to the discovery that when multiple dehalorespiring strains are present at a site, the interactions between populations are not always competitive." In some cases, Becker and her team observed complementary interactions among the populations in which the product of dehalorespiration generated by one strain served as a growth substrate for the other strain. Antagonistic interactions were also observed. In this case, a product of dehalorespiration generated by one strain strongly inhibited and effectively eliminated the other population.

"PCE and TCE bioremediation projects generally focus on engineering the contaminated site to promote the survival and activity of dehalorespiring bacteria," Becker explains. "Information on the ecology of these bacteria will be extremely useful."

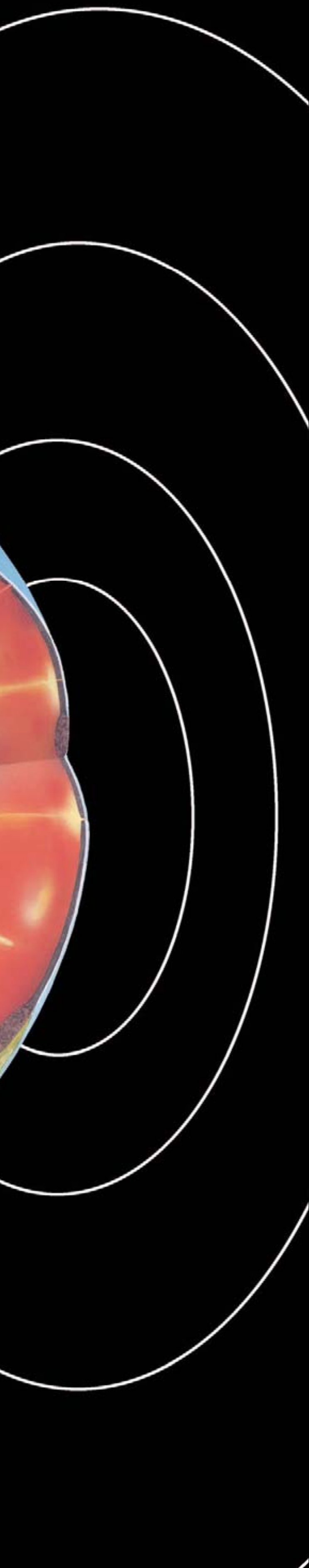
Jennifer Becker
Civil & Environmental Engineering

Pictured: Nebraska cornfield, irrigated from aquifer via center-pivot sprinklers

Aleksey Smirnov
Geological & Mining
Engineering and Sciences



Pictured: Earth's
magnetic field
and deep interior



Paleomagnetism

Deciphering the early history of the Earth

The first four billion years of Earth history (otherwise known as the Precambrian) was a time of many critical transitions in the Earth system, including the oxygenation of the atmosphere and the emergence of life. However, many of these processes and the links between them remain poorly understood. Deciphering the early history of our planet—including the early history of its geomagnetic field—represents one of the great challenges in Earth science. Available data are scarce, and key questions remain unanswered: When and how did the geomagnetic field start? How did it evolve at early stages, and how did it interact with the biosphere and other Earth system components?

Data on the ancient field can be obtained from fossil magnetism—some rocks record the Earth's magnetic field that existed at the time of their formation. However, for very old rocks, the conventional methods do not work well. Aleksey Smirnov seeks to at least double the amount of reliable data on the Precambrian field by applying new experimental approaches to investigate the fossil magnetism of well-dated igneous rocks around the globe.

Smirnov's research has broad implications for Earth science including a better understanding of the workings and age of the geodynamo. "There is currently disagreement on the age of the solid inner core, ranging between 1 and 3.5 billion years," notes Smirnov. His research may provide the first robust observational constraint to resolve this contradiction. "Crystallization of the inner core may have resulted in a dramatic increase of the geomagnetic field strength," he explains. "If we observe this increase in the paleomagnetic record, we will have a much better estimate of the inner core age and hence a better constrained thermal history of our planet."

Knowing the strength and stability of the early geomagnetic field is also crucial to understanding the causative links between the magnetic field and modulating the evolution of atmosphere and biosphere. "Before the inner core formation, the geodynamo could have produced much weaker and less stable magnetic field," adds Smirnov. "An attendant weaker magnetic shielding would allow a much stronger effect of solar radiation on the life evolution and atmospheric chemistry."

Smirnov's work on the early magnetic field history has been supported by several NSF grants including a 2012 CAREER award. His research is not limited to the ancient field. Other interests include the application of magnetic methods for hydrocarbon exploration, magnetic mineralogy, biomagnetism, and plate tectonics.

Paul Rogers ’04

Director, US Army Tank Automotive, Research, Development and Engineering Center

The Secretary of the Army recently appointed a new Senior Executive Service civilian to lead the Tank Automotive Research, Development and Engineering Center (TARDEC) in Warren, Michigan.

Paul Rogers, who earned a PhD in Mechanical Engineering-Engineering Mechanics from Michigan Tech in 2004, officially became TARDEC’s Technical Director on August 13, 2012. In this new role, he manages a workforce of more than 1,700 engineers, scientists, researchers and support staff, and sets strategic direction for a full range of investments that affect more than 270 Army systems worldwide. With an annual budget of more than $475 million, Rogers oversees TARDEC’s vigilance and resourcefulness to deliver rapid technology solutions that ensure American Soldiers dominate the battlefield.

Rogers brings a wealth of systems engineering integration experience and expertise to TARDEC. Since April 2010, Rogers served as the Deputy Program Executive Officer for Ground Combat Systems. Prior to that, he served as TARDEC’s Executive Director for Research and Technology Integration (2007).

In addition to his doctorate in Mechanical Engineering-Engineering Mechanics, Rogers earned a Master’s degree in Strategic Studies from the US Army War College, a Master of Science degree in Engineering-Mechanical Engineering from the University of Michigan-Dearborn and a Bachelor of Science degree in Mechanical Engineering from Michigan Tech. He is a graduate of the Army Engineer Officer Basic and Advanced Courses, Combined Arms Services Staff School, Army Command and General Staff College and the US Army War College.

Doug L. Parks '84

Vice President, Product Programs, General Motors

Doug Parks, who graduated from Michigan Tech in 1984 with a Bachelor of Science in Mechanical Engineering, has been promoted to Vice President, Product Programs at General Motors.

GM recently changed the vehicle line team structure within its Global Product Development organization, consolidating current vehicle development executive roles and streamlining global vehicle development.

In the previous structure, a product program was developed under the direction of a vehicle line executive, vehicle line director and vehicle chief engineer. In the new structure, product programs will be consolidated under one executive chief engineer for each program, all of whom will report to Parks.

The new structure eliminates redundancy and reduces complexity—enabling faster decision making and instilling clear accountability in the vehicle development process.

Parks was previously executive director and group vehicle line executive for electric cars at GM, a position he held since March 2012. He had also earlier served as global vehicle line executive and global vehicle chief executive for electric cars, including the Chevrolet Volt.

Parks has translated a lifelong love for cars and motorcycles into a career engineering some of the most technically advanced vehicles GM has ever produced. He rose through the ranks to become the global vehicle chief engineer for GM's compact vehicles, including the Chevy Cruze, Opel Astra and Buick Excelle. He was responsible for the delivery and execution of the Chevrolet Volt and other future electric vehicles—including engineering, manufacturing, quality and finance.

Guy Meadows

Director, Great Lakes Research Initiatives

The Great Lakes represent almost 90 percent of the US surface freshwater, with almost one-half of that in Lake Superior alone.

Never before has the Great Lakes basin faced the magnitude of issues and stresses currently in operation—challenges that cut across all branches of science and engineering, from biology to physics, and from social science to management and policy.

Enter Professor Guy Meadows, who recently joined Michigan Tech after 35 years at the University of Michigan Ann Arbor. As Director of Great Lakes Initiatives at Michigan Tech's new Great Lakes Research Center, Meadows' primary goal is to blend scientific understanding and technological advancements into environmentally sound engineering solutions for the Great Lakes. "Tackling these difficult and multi-disciplinary issues requires an organization that brings together dedicated researchers, from all areas, to focus their collective energies and expertise on problems never before faced," says Meadows. "The opportunity is now before us; it is up to us to seize the moment.

"Freshwater is perhaps our most valuable natural resource," adds Meadows. "Research directed at understanding and preserving all aspects of this enormous natural resource is critical to the well being of our nation, our neighbors, and the world. We've needed a state-of-the-art, integrated facility where researchers, students, technicians, policy makers and the general public can come together to not only share ideas, but to share laboratory space, advanced equipment and a common goal. The Great Lakes Research Center is that 21st century space."

Meadows' own research involves the development of a wide range of environmental monitoring platforms, which operate in the Great Lakes and coastal ocean. These range from a network of automated wind and wave measurement buoys distributed through the upper Great Lakes to underwater vehicles for bottom mapping. His team has even developed a fully autonomous ocean-monitoring buoy that flies as a robotic Pelican.

The next step, in collaboration with colleagues at Michigan Tech, is to accurately take the internal temperature of Lake Superior by propagating sound waves the entire length of the basin and very accurately measuring the travel time. "We will do this at many different frequencies, causing the sound waves to take many different paths through the lake, from surface to bottom. This will answer the question: 'Is Lake Superior warming up? And if so, by how much?'"

Michigan Tech's Great Lakes Research Center provides the ideal location to further develop the next generation of advanced sensors and numerical models for the marine environment. "The University's new super computer, which will be housed in the GRLC, make this possible," says Meadows. The Center's location on the deep Keweenaw Waterway will allow the team to begin to monitor the Lakes though the harsh northern winters. "Presently, we must remove our network of surface buoys before ice develops. This leaves us blind to understanding Lake dynamics during the worst (and most interesting) part of the year," he adds. "We are now able to develop a network of underwater buoys each with a node cabled back to the GLRC—an evolving effort with partner universities on the Canadian side."

Meadows' distinguished career of teaching, research and service includes numerous awards for outstanding teaching, which reaches beyond the University setting to less formal environments, including five nationally-televised documentaries for the History Channel and the Discovery Channel.

For more information on the new Great Lakes Research Center at Michigan Tech, visit www.greatlakes.mtu.edu.

Great Lakes Research Center,
Michigan Tech

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