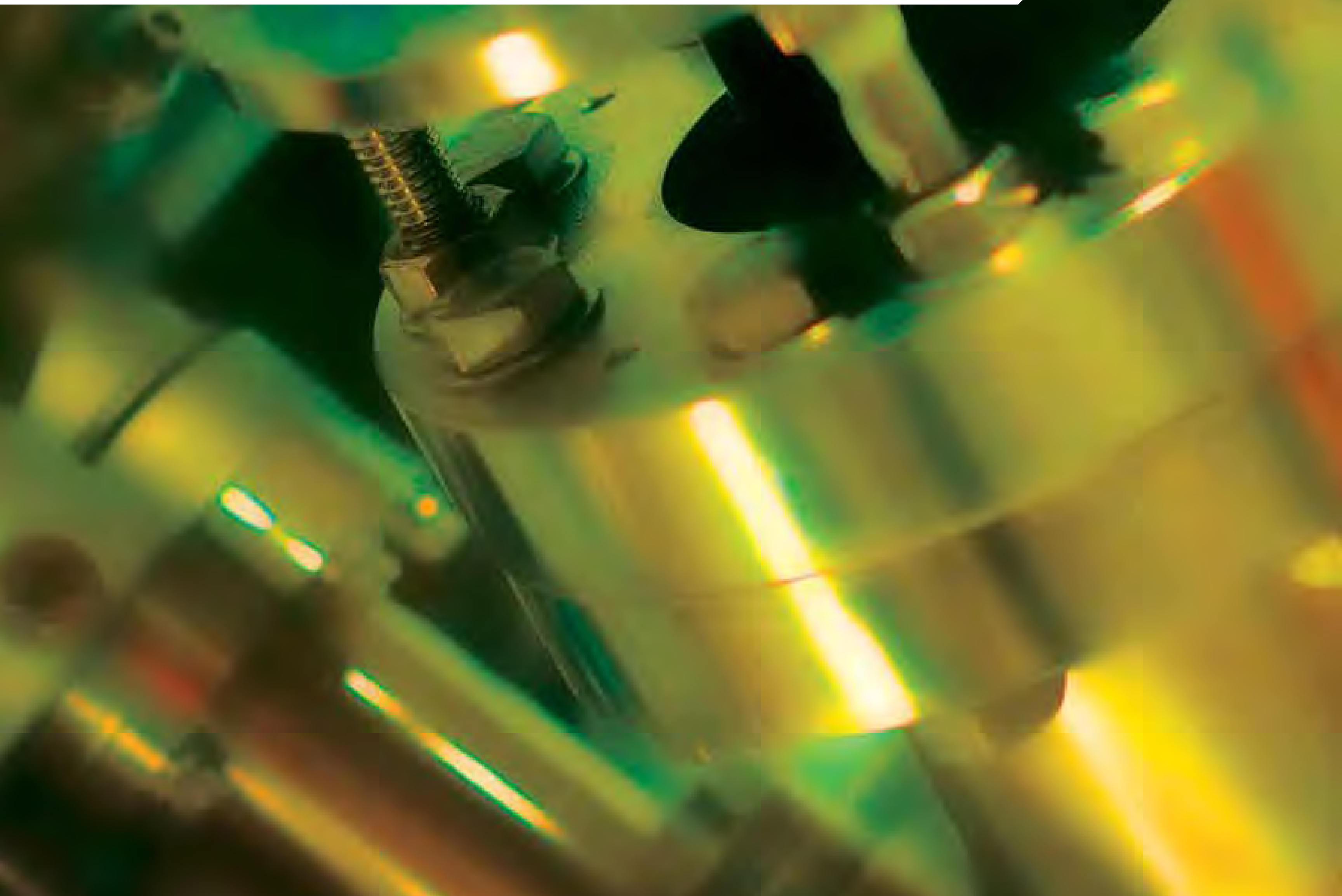
Fall 2009

re:search

An inside look at innovation and discovery at Missouri University of Science and Technology



Power 2.0

Performance vs. emissions

More backbone for bridges

Missouri S&T
University of Science & Technology

Dear Colleague,

THE TURN OF EVENTS during last year is certainly something we will remember for many years to come. On one hand, I watched with great concern the effect of the economic downturn on our nation and the world, but, on the other, excited about the one-time funding opportunities provided by the American Recovery and Reinvestment Act (ARRA) of 2009. Missouri S&T faculty responded to as many call for proposals as they could and continue to respond to new ones. Clearly there are not enough resources to support all the research that needs to be conducted to solve the problems facing us, but the ARRA funding will go a long way.

FY09 was another great year with all time highs for new awards and proposals submitted, and national recognition and performance of our faculty. Some Missouri S&T highlights include:

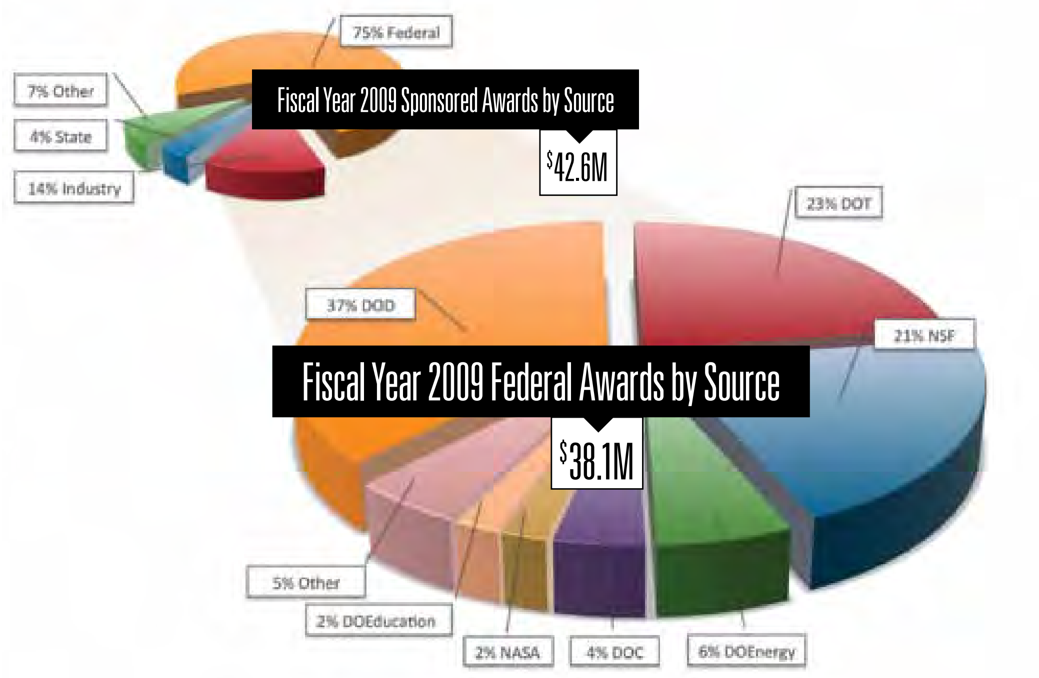
- Site for a new National Science Foundation's (NSF's) Engineering Research Center for Future Renewable Electric Energy Delivery and Management (FREEDM) Systems. Led by North Carolina State University, Missouri S&T is one of five U.S. universities aiming to transform the nation's power grid into an Internet for energy that will speed renewable electric-energy technologies into every home and business.
- Headquarters for a new NSF Industry/University Cooperative Research Center on Electromagnetic Compatibility. Collaborating with University of Houston, the center aims to develop analytical and experimental techniques for the analysis and solution of electromagnetic compatibility problems including electromagnetic interference, electromagnetic susceptibility, signal integrity, and power integrity.
- Development of two new transportation structures and geotechnical transportation research programs for Missouri Department of Transportation in collaboration with University of Missouri-Columbia and University of Missouri-Kansas City.
- An NSF CAREER award for Dr. Rosa Zheng to support her research on improving underwater wireless communications using a cross-layer design between physical and network layers to achieve the overall high performance of underwater communication networks, building a field programmable gate array hardware test bed for the designed transceivers, and conducting further ocean experiments.
- Chancellor Jack Carney chaired the first-ever University of Missouri System's Energy Summit that brought together faculty and researchers, businesses, entrepreneurs and venture capitalists from across the state and beyond, along with federal and state agencies, to explore and showcase Missouri's cutting-edge research and development efforts in energy, alternative fuel sources, power, storage, infrastructure and enabling technologies.

With great pleasure I am sending you the Fall 2009 issue of the Missouri S&T *re:Search* magazine highlighting some of the research being conducted at Missouri S&T. I invite you to read how our outstanding faculty are making a difference and I look forward to hearing about all the exciting news from your campus.

Sincerely,
K. Krishnamurthy, Vice Provost for Research

Fiscal Year 2009 Summary

Proposals Submitted	567
Dollars Requested	$180.1M
Proposals Awarded	364
Dollars Awarded	$42.6M
Total Expenditures	$38.1M
Faculty Involved with Sponsored Activities	243
Invention Disclosures	40
Patent Applications Filed	21
Patents Issued	4
License/Options Signed	27



re:Search is the annual report on research, innovation and discovery activities at Missouri University of Science and Technology, formerly University of Missouri-Rolla, in Rolla, Mo. Published by the Office of Sponsored Programs, *re:Search* highlights only a portion of Missouri S&T's vibrant, focused research program. For more information about Missouri S&T's research, contact:

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Missouri S&T Chancellor John F. Carney III chaired the first-ever Missouri Energy Summit, which featured keynote speaker T. Boone Pickens.

Power 2.0: Researchers are building the energy Internet

TODAY'S INTERNET, with its fast-loading videos and global connectivity, is a far cry from the Internet of a decade ago, when most households connected via dialup and service was sporadic. What broadband service did for the Internet, researchers at Missouri S&T hope to do for the American power grid.

Last fall, S&T joined a group of universities working to turn the nation's power grid into an efficient and reliable Internet for energy. Funded through National Science Foundation's Engineering Research Center, the goal of this consortium – called FREEDM (Future Renewable Electric Energy Delivery and Management Systems) – is to speed renewable electric-energy technologies into every home and business in America, and to ensure power is available when it's needed.

> "Our nation's utility infrastructure is aging and in disrepair. It only takes one well-placed power outage to bring us to our knees."
>
> —Mariesa Crow, the Fred W. Finley Distinguished Professor of Electrical and Computer Engineering at Missouri S&T

S&T and its partner universities are working with dozens of utility companies, electrical equipment manufacturers and alternative energy start-ups to create this new power grid. Built on the Internet concept, this future power grid will be a distributed network of networks that can re-route electricity around disruptions in the system. The network will connect traditional power sources, such as coal-fired or hydroelectric power plants, with new alternative energy options, such as wind and solar grids. Researchers envision a grid in which consumers will be able to generate their own power on a small scale and even sell excess energy back to the utility companies.

Mariesa Crow, the Fred W. Finley Distinguished Professor of Electrical and Computer Engineering at Missouri S&T and the campus's principal investigator on the FREEDM project, says the time is right for this new approach. "Our nation's utility infrastructure is aging and in disrepair," she says. "It only takes one well-placed power outage to bring us to our knees. We saw that in 2003, with the outage that hit the northeast."

She's referring to the big August 2003 grid failure that plunged some 50 million Americans and Canadians into darkness. That event was no fluke, says Crow, who is also director of the university's Energy Research and Development Center. Similar outages could

Transforming the nation's power grid will become more important as alternative-energy technologies prepare to flood the marketplace...

occur in the future if steps are not taken now to improve the North American power grid.

That's where the FREEDM project comes in. Supported by an initial five-year, $18.5 million grant from NSF with an additional $10 million in institutional support and industry membership fees, the project draws on America's best energy researchers to conceptualize a new kind of power grid – much the same way the Department of Defense created the Advanced Research Project Agency more than 50 years ago to create a new communications system. That system, ARPAnet, became the forerunner to the Internet.

Transforming the nation's power grid will become more important as alternative-energy technologies prepare to flood the marketplace, Crow says. She and her colleagues at S&T, North Carolina State University (the lead university for this project) and other collaborating institutions foresee widespread adoption of plug-in hybrid cars over the next several years. But today's power grid would not be able to handle the additional energy demand during peak charging times, such as when people return home from work in the evening. The smart grid developed at the center will also allow consumers to sell energy back to the power companies when demand is low, preparing the utilities for times when demand is greatest.

THE SMART GRID GETS BRAINY

How can researchers make a smart power grid even smarter? By using more brain power, of course.

That's the approach Missouri S&T researcher Ganesh Kumar Venayagamoorthy is taking. Working with Georgia Institute of Technology researchers, Venayagamoorthy is using living neural networks composed of thousands of brain cells from laboratory rats to control simulated power grids in the lab. From those studies, he hopes to create a "biologically inspired" computer program to manage and control complex power grids in Mexico, Brazil, Nigeria and elsewhere.

"We want to develop a totally new architecture than what exists today," says Venayagamoorthy, an associate professor of electrical and computer engineering at Missouri S&T. "Power systems control is very complex, and the brain is a very flexible, very adaptable network. The brain is really good at handling uncertainties."

The Missouri S&T team is working with researchers at Georgia Tech's Laboratory for Neuroengineering, where the living neural networks have been developed and are housed and studied. Some 600 miles northwest of Atlanta, Venayagamoorthy will transmit via the Internet signals to those networks from his Real-Time Power and Intelligent Systems Laboratory. Venayagamoorthy and his S&T colleagues will train those brain cells to recognize voltage signals and other information transmitted from Missouri S&T's real-time simulator. The research is funded through a $2 million grant from the National Science Foundation's Division of Emerging Frontiers in Research and Innovation.

Venayagamoorthy and his colleagues hope to develop BIANNs, or biologically inspired artificial neural networks. Based on the brain's adaptability, these networks could control future power systems, as well as other complex systems, such as traffic-control systems or global financial networks.

Unlike traditional artificial neural networks, Venayagamoorthy's BIANNs will be modeled after the brain and therefore more capable of dealing with complex systems. "As electric power and energy systems get larger and larger, the dynamics become more complicated, and the neural networks have to be scaled up," he says. "But as they scale up, they break down. It becomes more difficult for neural networks to learn and change in real time.

"They can learn online, but the learning is slow and sometimes the decision-making is very short-sighted," he says. For instance, if a transmission line is taken out during a severe storm, traditional artificial neural networks cannot react quickly enough to locate the problem and bring the system back online.

“We’re looking at one aspect — the change in emissions and what environmental impact that might have. Others will be looking at the consequences of using these fuels with respect to engine performance.”
—Phil Whitefield, chair and professor of chemistry at Missouri S&T

In 2008, Whitefield and his colleagues were recognized for making a substantial research contribution to the Intergovernmental Panel on Climate Change with work that was integral to the group’s receipt of the Nobel Peace Prize, which the IPCC shared with former Vice President Al Gore in 2007.

The air up there: Performance vs. emissions

ON ANY GIVEN FLIGHT, nearly 90 percent of a jet's fuel is consumed at high altitudes. The result is the release of greenhouse gases high in the atmosphere. Over the past decade, Phil Whitefield and his colleagues at Missouri S&T have worked to develop the new international standard for testing these aircraft emissions to help determine their impact on the environment. Now, the researchers are applying their expertise to help the aircraft industry find more environmentally sustainable fuels.

Whitefield's team developed a technique based on the fundamental properties of the particulate matter – the size of the particles, their composition, their number and their mass. Because their tests must work well with current-day engine testing, the methods must be quick and reliable.

Whitefield, chair and professor of chemistry, leads a group of researchers in the university's Center of Excellence for Aerospace Particulate Emissions Reduction Research, a multidisciplinary effort involving nine universities with funding from the Federal Aviation Administration. Whitefield's team has the lead emissions role in the consortium.

The researchers populate and maintain a national database of emission particulate information. The data they collect can be used to predict the impact of aircraft emissions on the environment and human health and to analyze fuel usage.

As concern grows about energy security, Whitefield's group has joined the search to find a renewable fuel source to replace fossil fuels for aircraft. Finding a greener fuel is a major goal of the aircraft industry, Whitefield says, but it must be compatible with the current engine systems – what the industry calls a "drop-in fuel."

"Reducing harmful emissions and having less of an environmental impact is becoming increasingly important in the global marketplace for aviation," Whitefield says. "We look to see if there are alternative fuels that would be usable to support our commercial and military fleet. There are a number of candidate fuels out there based on biofuels, coal or natural gas." It's up to Whitefield's team to determine their environmental impact.

Whitefield's team is preparing for an upcoming test at the University of Sheffield in England. This joint project with Shell Oil Co. will look at the small engines used to drive auxiliary power units – the systems that allow the plane to run its lights and air conditioners while on the ground. No data currently exists on this type of engine.

Shell will provide alternative fuels for the researchers to test. They will compare the results to those of the fuels currently in use.

"We're looking at one aspect – the change in emissions and what environmental impact that might have," Whitefield says. "Others will be looking at the consequences of using these fuels with respect to engine performance.

"Each of the new fuels to be tested is a complicated mixture," Whitefield says. "Each will have its own signature with respect to emissions and we have the state-of-the-art tools to characterize that so people can make reliable predictions about their environmental impact."

Whitefield hopes eventually to test emissions from newly developed high-bypass engines, which make up about 30 percent of the current fleet. If he obtains funding, the data he gathers will be the first of its kind.

Building better aircraft

From advanced materials used to coat F-15s to waterjet technology for cutting materials faster, researchers at Missouri S&T are finding ways to build better aircraft.

The Center for Aerospace Manufacturing Technologies at Missouri S&T was established in 2004 through a federal appropriation. CAMT researchers develop technology for aircraft fabrication and assembly with an emphasis on direct digital manufacturing, laser materials processing, high-speed machining, and composites manufacturing.

The tiny Missouri S&T Motes could be used in disaster situations when communication infrastructure fails.

Wireless: Miniature motes

DESPITE THEIR NAME, mobile phones aren't that mobile in at least once sense. Like land-based telecommunications systems, cell phones rely on fixed physical infrastructures such as cell towers. That means that in the event of a natural disaster or terrorist attack, mobile communication would come to an abrupt halt. Missouri S&T researchers, led by Jagannathan Sarangapani, the Rutledge-Emerson Distinguished Professor of Electrical and Computer Engineering, have devised a way to work around this possibility. They've developed a network of tiny, wireless devices – called Missouri S&T Motes – and energy-efficient networking protocols that work together to keep wireless systems operational.

The motes use sensors to detect environmental variables, such as wind direction or the presence of certain chemicals, and pass that information on to nearby motes via a wireless network.

The networking protocols developed by the S&T researchers ensure service quality, minimize energy usage and end-to-end delays, and maximize the transmission rate. In addition, the devices are smaller, cheaper and easier to program than anything on the market, Sarangapani explains.

Giving the nation's infrastructure more backbone

"The goal is to take innovations like this out of the laboratory, team up with partners, solve problems, and make an economic impact."
—Keith Strassner, director of technology transfer and economic development at Missouri S&T

The glass-based coating for reinforcement bars, developed by Chen (left) and Brow, could help build stronger bridges.

BORROWING AN IDEA from defense research to build blast-resistant walls, Missouri S&T researchers have developed a material that could result in stronger bridges and longer life for other steel-reinforced structures. The strong, corrosion-resistant substance comes from an unlikely material: glass.

The U.S. construction industry spends more than $4 billion annually for polymer-coated and galvanized reinforcement bar, or rebar. But research has shown that the traditional polymer coatings do not provide enough corrosion protection for the rebar that holds up the nation's aging infrastructure. The Missouri S&T coating – an engineered mixture of glass, clays and water – aims to solve that problem. Applied as a slurry to the rebar, then heated to more than 1,400 degrees Fahrenheit, the coating adheres to steel, promotes bonding with concrete and helps prevent corrosion due to water and salt.

Missouri S&T has filed for a patent on the technology, which was developed by a team of researchers led by Richard Brow, Curators' Professor of materials science and engineering, and Genda Chen, professor of civil, architectural and environmental engineering and interim director of the Center for Infrastructure Engineering Studies at S&T. The US Army funded the research through the Leonard Wood Institute.

The Department of Defense has used related technology to develop blast-resistant walls. Brow and Chen realized that some ideas originally conceived by the U.S. Army Corps of Engineers for that effort could be built upon to engineer the glass-ceramic rebar coating.

Missouri S&T recently licensed the new technology to Pro-Perma Engineered Coatings in St. Louis. "The goal is to take innovations like this out of the laboratory, team up with partners, solve problems, and make an economic impact," says Keith Strassner, director of technology transfer and economic development.

Mike Koenigstein, who earned a bachelor's degree in ceramic engineering at Missouri S&T in 1993, is managing partner of Pro-Perma. So far, he says, the company is using the coating in two projects: one to strengthen marine structures in Corpus Christi, Texas, and another to reinforce a sea wall near Pearl Harbor in Oahu. Both projects are sponsored by the Department of Defense.

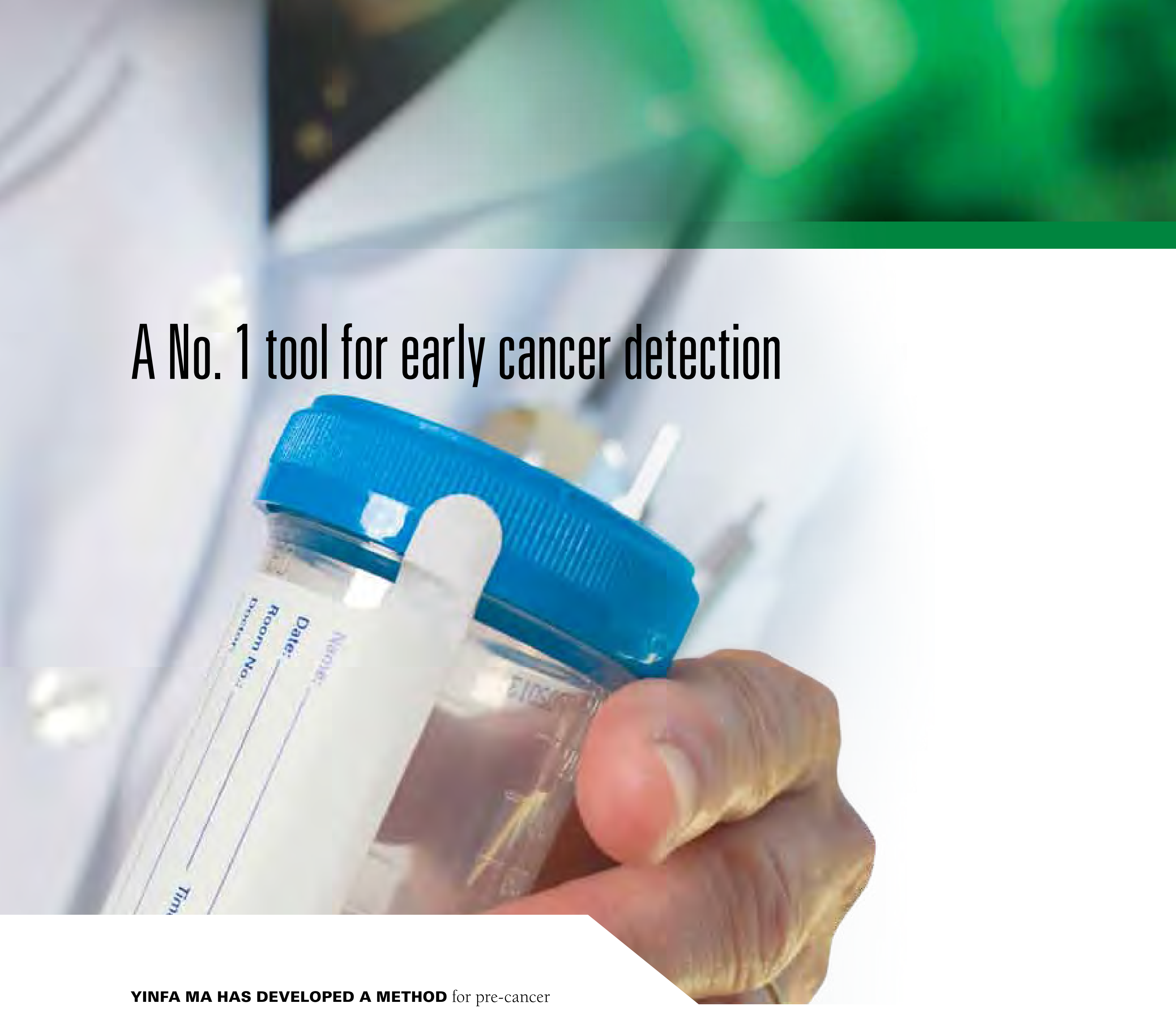
In addition to protecting structures from water and salt, Brow and Chen say the new coating would help make bridges and buildings stronger in earthquake-prone regions.

According to Chen, some 800 short-span bridges in Missouri need to be retrofitted or replaced. In addition, more than 200 longer-span bridges in Missouri are in urgent need of work.

Strassner and Koenigstein think demand will be high for the new rebar coating. They envision opening a pilot plant dedicated to producing the glass-based coating in Rolla, which is already home to high-tech glass manufacturer Mo-Sci Corp. as well as Missouri S&T.

Pro-Perma and Mo-Sci are working as partners to commercialize the coating technology. "We have all of the resources here to support technology-driven businesses," Strassner says. "We want to be an economic engine for the state of Missouri."

A No. 1 tool for early cancer detection



YINFA MA HAS DEVELOPED A METHOD for pre-cancer screening that uses urine samples for detection. Ma hopes to be able to predict types of cancer as well as severity.

"Cancer is the second-highest cause of death among all diseases," says Ma, a Curators' Teaching Professor of chemistry at Missouri S&T. "Early diagnosis of cancer is crucial, but not many people want to go to the hospital to undergo costly, invasive cancer screening."

The research builds on knowledge of pteridines, compounds that help regulate the metabolism of cells. Ma found that six pteridine derivatives can be detected in urine samples, and that levels of some pteridines increase significantly if there is a tumor inside the body. Most importantly, Ma has discovered that one molecule, called oncopterin, exists in the urine of cancer patients but not in healthy human samples.

Ma's prototype instrument, appropriately called a P-scan, is used to screen urine for oncopterine and six other pteridine bio markers. The oncopterin level in urine indicates whether cancer is likely to develop, and varying levels of the six pteridines can actually provide a "fingerprint" of the type of cancer.

"I won't give up," Ma says. "I will continue to work on this project until we have succeeded and can market the instrument to save people's lives."

Diabetes: No more painful pricks

Kim's device could replace glucose monitoring.

WAKE UP. Prick your finger. Repeat daily. For the rest of your life.

That's a way of life for thousands of diabetics. But a method being developed by Chang-Soo Kim will make testing your blood glucose level as easy as telling time.

With funding from the National Science Foundation and the National Institutes of Health, Kim, an associate professor of electrical and computer engineering, and David Henthorn, assistant professor of chemical and biological engineering, are developing a new sensor that can provide continuous blood sugar monitoring. Diabetics would wear the device like a wristwatch. The system is a more accurate and less painful method for checking levels than intermittent monitoring using disposable test strips. The researchers soon plan to demonstrate a "smart" autonomous sensor that operates with minimal human intervention.

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Take a closer look at Missouri S&T

FOUNDED IN 1870, Missouri University of Science and Technology is one of the nation's best technological research universities. In January 2008, we changed our name from the University of Missouri-Rolla to a name that better describes our focus as a leading technological research university.

At Missouri S&T, we're looking at the big picture when it comes to things like making buildings stronger and developing alternative energy technologies. But we also have the tools to take a closer look at the future of nanotechnology, including a focused ion beam (FIB) microscope. The FIB machine, the only one of its kind in the state of Missouri, is used to study everything from nano-scale changes in materials that have been stressed to ancient bacteria that are trapped in salt crystals.

We invite you to take a closer look at Missouri S&T. Start by reading the stories inside this report, then stay connected with us online at **research.mst.edu**.