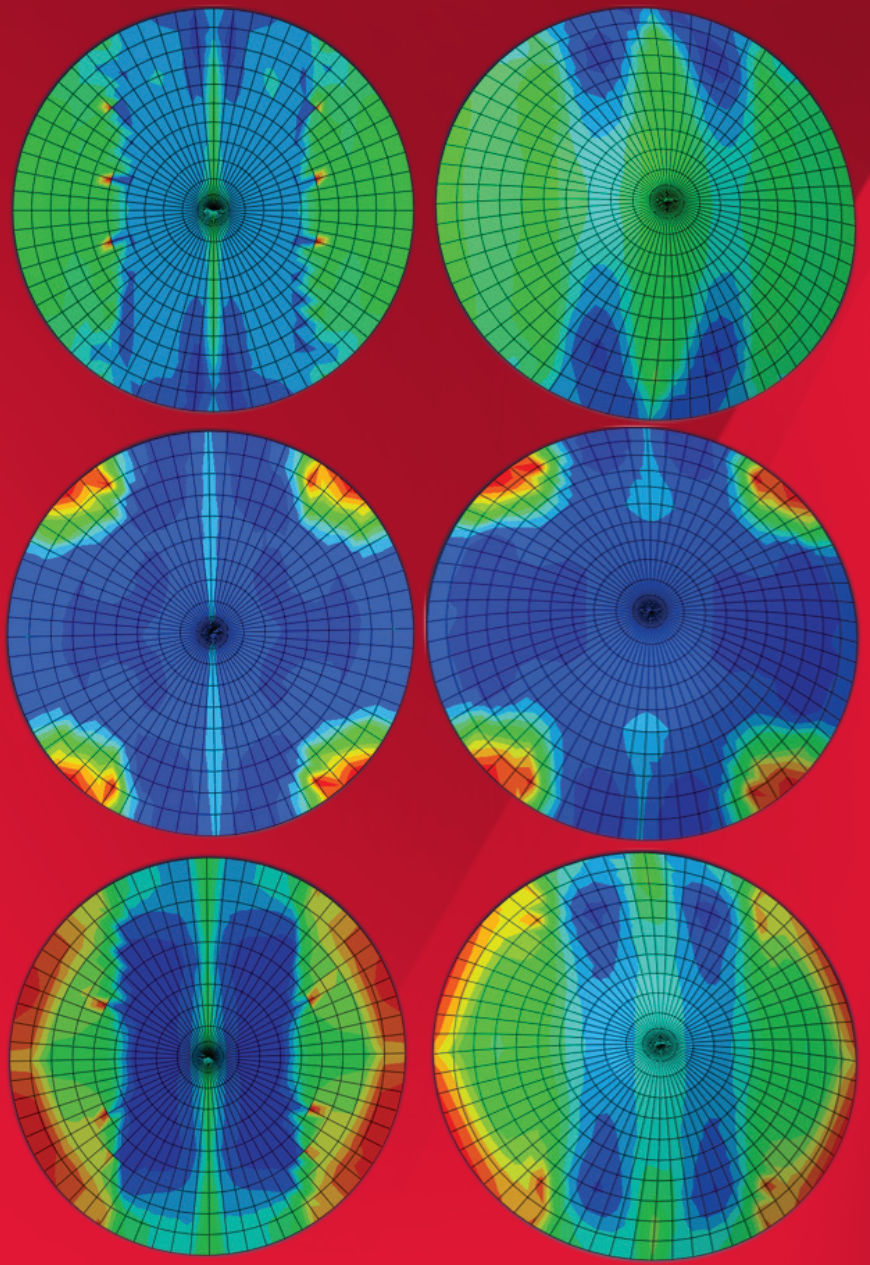
IOWA STATE UNIVERSITY
College of Engineering



CYCLONE ENGINEERING RESEARCH

SPRING 2017

Cyclone Engineering Research

Iowa State's College of Engineering brings together talented faculty, staff and students and gives them tools to demonstrate engineering accomplishments. Our research spans a spectrum of innovation, all with the goal to make a difference.

In this publication, we highlight one project that involves creating batteries that can self-destruct, while another that works on creating solid electrolytes for batteries to make them more durable. Electrically conductive concrete will improve winter weather operations at airports, and developments to electric steel will make motors for electric vehicles more efficient. Original technology helps researchers study microbial resistant gene reservoirs in the environment and makes manufacturing more dynamic.

We know it takes the right people to advance science. In January, the college welcomed **Ashfaq Khokhar** as the Palmer Department Chair in Electrical and Computer Engineering to further the department's strengths and create new opportunities. Researchers in the same department are launching a new program that will help underrepresented minorities, including women, in STEM fields develop their professional and career identity.

In bringing all these elements together, we have created a progressive space where every day we see ideas being turned into useful solutions.

Sarah A. Rajala
James L. and Katherine S. Melsa Dean of Engineering

Arun K. Somani
Associate Dean for Research
Philip and Virginia Sproul Professor
Anson Marston Distinguished Professor

Editor: **Jessi Strawn**
Graphic Designer: **William Beach**
E-mail: engineeringinfo@iastate.edu
Website: www.engineering.iastate.edu/research

Photography: **Chris Gannon** and **Dan McClanahan**

CONTENTS

***On the cover: Reza Montazami**, assistant professor of mechanical engineering, is working on a project to develop self-destructing batteries. Part of his research involves simulating stress distribution in soft electronics.*

SELF-DESTRUCTING BATTERIES

A practical solution for powering transient electronics

Researchers at Iowa State have made significant progress in an effort to make transient electronic devices completely autonomous.

Reza Montazami, an assistant professor of mechanical engineering and an associate of the U.S. Department of Energy's Ames Laboratory, is leading a team that has developed a transient lithium-ion (Li-ion) battery that offers nearly the same voltage as commercial products and can disintegrate in 30 minutes.

Reza Montazami, assistant professor of mechanical engineering

These transient batteries, and the materials research and structural design behind them, will be crucial as the field of transient electronics continues to grow.

"Devices that operate for short, defined periods of time and then self-destruct can be used in a range of applications, from healthcare to military and homeland security," Montazami explains. "They offer a great deal of promise, but they currently still rely on an outside, non-transient, power source. If we can change that, we can make the devices even more beneficial."

And that's exactly what Montazami has set out to accomplish.

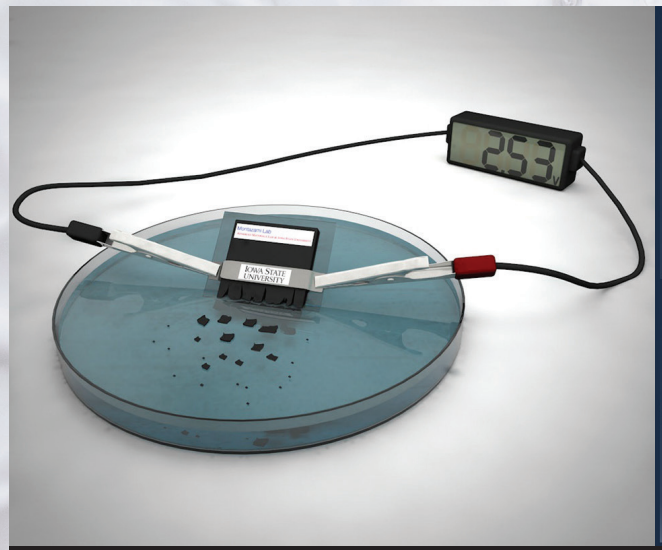
He and his team have combined Li-ion battery technology with a new physical–chemical hybrid transiency approach that breaks down a battery and dissolves its electrodes.

"The casing for the battery uses polymers that swell when immersed in a liquid, causing the nanocomposite electrodes to break and disperse," he explains. "Because the battery is designed to disintegrate both chemically and physically, it is very difficult to trace back to the owner even if the device were still physically present."

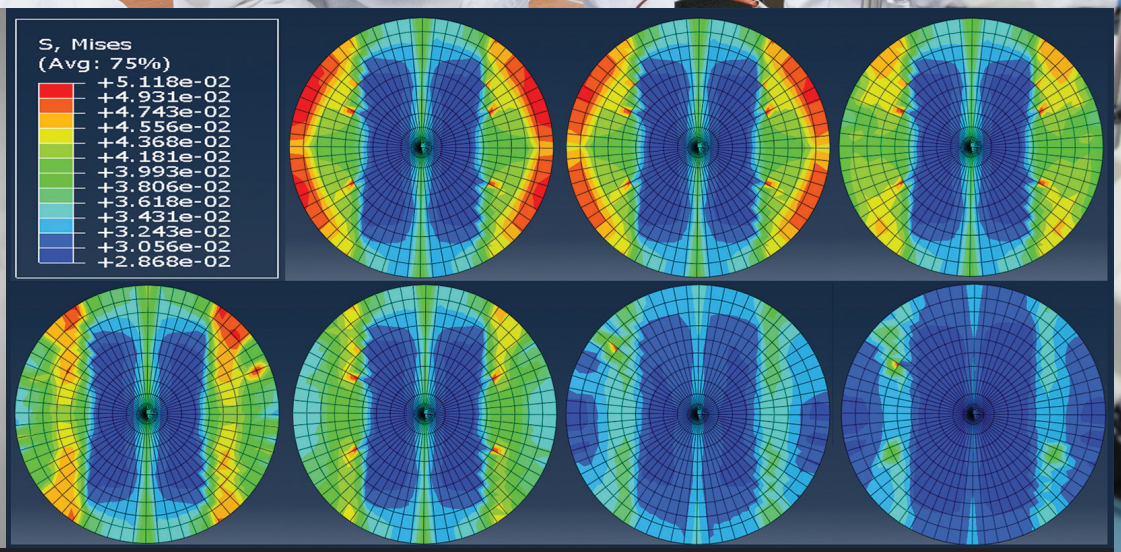
At this point, the batteries are 5 mm by 6 mm, and 1 mm thick and can power a desktop calculator for approximately 15 minutes. And while they don't completely disappear, Montazami says he will continue experimentation to advance the technology because of the value it could bring to even mainstream electronics.

"If we look at the bigger picture, we could see a consumer battery that could be dissolved once a person was done using it instead of that battery ending up in a landfill," he adds.

The team is continuing to study the physical–chemical hybrid transiency platform to improve understanding of what interactions are at play. The group is also working to improve the performance of the battery for devices that use more power. That could mean making electrodes with higher area density or finding ways to connect several batteries.



ISU scientists have developed a working battery that dissolves and disperses in water. Illustration by Ashley Christopherson.



Simulated stress distribution in soft electronics printed via advanced additive manufacturing techniques. Background: ***Reza Montazami*** *(center) with graduate students,* ***Reihaneh Jamshidi*** *(left) and* ***Yuanfen Chen****.*

INCREASING ELECTRIC STEEL PERFORMANCE

Materials research will make electric motors more efficient, cost effective

Can electric steel, a popular material that's already a key functional material for modern society, get better? **Jun Cui**, an associate professor of materials science and engineering and a senior scientist at the U.S. Department of Energy Ames Laboratory, says it can.

That's why he's leading a team of researchers who want to increase the amount of silicon in electric steel to 6.5 percent. If the group succeeds, the new steel can be used as the stator material to create an efficient, sustainable, non-rare-earth electric motor.

The team is currently working on a project that would advance electric steel to be used in the motors of electric vehicles. The work is supported by a three-year, $3.8 million grant from the DOE's Vehicle Technologies Program.

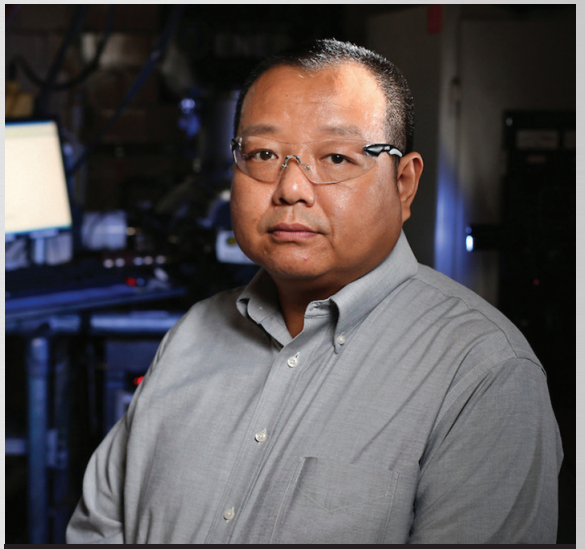
Cui says using electric steel to develop the magnetic stator core of a motor can reduce eddy currents and heat and power loss in the motor. The motor would then be able to run at higher frequencies and have a higher power density, resulting in a smaller, more efficient motor.

To get to this point, the team has to overcome an issue with electric steel – it becomes brittle once you reach more than 4 weight percent silicon.

"When iron atoms are being mixed with a large number of silicon atoms, the brittleness comes from the silicon atoms having time to find each other and pair up," Cui explains. "To bypass this brittleness, we are rapidly cooling the alloy so the silicon atoms have no time to pair."

The work combines modeling and experimentation, and brings in research partners from the United Technologies Research Center in East Hartford, Connecticut; and the University of Delaware in Newark.

Experts from Iowa State and the Ames Laboratory will also contribute to the project, including **Scott Chumbley**, a professor of materials science and engineering and scientist for the Ames Laboratory; **Peter Collins**, the Alan and Julie Renken associate professor of materials science and engineering and an associate scientist of the Ames Laboratory; **Iver Anderson**, a senior metallurgist for the Ames Laboratory and an adjunct professor of materials science and engineering; **Valery Levitas**, a Schafer 2050 Challenge Professor of aerospace engineering and an associate scientist of the Ames Laboratory; **Frank Peters**, an associate professor and associate chair of operations in industrial and manufacturing systems engineering; and **Matthew Kramer**, director of the Ames Laboratory's Division of Materials Sciences and Engineering and an adjunct professor of materials science and engineering.



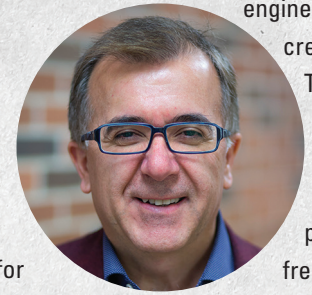
***Jun Cui**, associate professor of materials science and engineering and senior scientist at the Department of Energy Ames Laboratory*

SAFER, MORE SUSTAINABLE AVIATION

Iowa State's partnership in FAA program advances airport runways, operating technology

Engineers from Iowa State are part of a collaborative partnership to help navigate and improve the complex, ever-changing aviation industry with innovative ideas and new research projects.

"When you look at addressing any problem in the field, from the weather to security to operational efficiencies, you know it's going to take a community of minds coming together to create solutions," says **Halil Ceylan**, professor of civil, construction and environmental engineering and director of the Program for Sustainable Pavement Engineering and Research at Iowa State's Institute for Transportation.



***Halil Ceylan**, professor of civil, construction and environmental engineering*

Ceylan also serves as a site director for the Federal Aviation Administration's Center of Excellence Partnership to Enhance General Aviation Safety, Accessibility and Sustainability, or PEGASAS.

The partnership, which was established in 2012, is led by researchers at Purdue University and includes Iowa State, The Ohio State University, Georgia Institute of Technology, Florida Institute of Technology and Texas A&M University as core members.

Together, the researchers are working with the federal government and industry to study a variety of general aviation issues.

Ceylan is using his expertise in pavement engineering to lead a project that aims to create a hybrid heated pavement system. The system includes electrically conductive concrete, nanostructured superhydrophobic coatings and hydronic heated pavements that will keep airport pavement surface temperature above freezing during winter weather operations and reduce airport incidents related to unfavorable conditions.

Iowa State researchers are contributing to several other projects, including developing an FAA pavement marking presence tool, analyzing and processing data regarding airport safety, and testing how LED lighting performs under extreme conditions.

Ceylan says he's also excited about the student outreach component of PEGASAS. Two Ph.D. students from Iowa State were able to travel to FAA's William J. Hughes Technical Center for two months to learn and apply their skills in a real-world setting.

"I participated in a similar fellowship as a graduate student, and I can honestly say it changed the trajectory of my career in such a positive way. It's programs like these that will help shape the future of the aviation field. We have so many brilliant minds with so much to offer, we just need a way to get them involved, and PEGASAS is a great way to do just that."

***Halil Ceylan**'s research team has built the world's first electrically conductive heated pavement test site at an airport. This photo shows the technology performing well during a snow event on Dec. 10, 2016, at the Des Moines International Airport.*

CHARACTERIZING ANTIMICROBIAL RESISTANCE

Interdisciplinary team uses systems approach to sequence microbial genes

Historically, treatments for disease-causing microorganisms have relied heavily on the use of antimicrobial drugs.

Adina Howe says this very practice (both when it's used properly and when it's misused), along with naturally occurring phenomena, has accelerated how quickly microorganisms are evolving into resistant strains.

"If we continue to see bacteria, fungi, viruses and parasites increasingly becoming resistant to antimicrobial drugs, common treatments for infections and minor injuries will become ineffective," explains Howe, an assistant professor of agricultural and biosystems engineering.

She adds that other factors, like poor infection control practices, inadequate sanitary conditions and inappropriate food handling, can encourage the spread of antimicrobial resistance.

To better understand antimicrobial resistance and how it enters the environment and food chain, Howe is leading a research team that is studying the phenomenon in agricultural environments.

The multidisciplinary group, which includes **Michelle Soupir**, an associate professor of agricultural and biosystems engineering at Iowa State, **Heather Allen** and **Tom Moorman** from USDA's Agricultural Research Service, and **Shannon Hinsa**, an associate professor of biology at Grinnell College, recently received a nearly $1 million, three-year grant from the U.S. Department of Agriculture's National Institute of Food and Agriculture.

The group will be using a systems approach in its research, adding insight from engineering, microbiology, soil science and health experts.

Iowa State's team is working to improve a technology that Howe designed to efficiently sequence the genes of microbes. The tool, called DARTE-QM, will allow the group to hone in microbial resistant gene reservoirs in the environment.

To begin its work, the team is studying manure, soil and water samples gathered from swine operations.

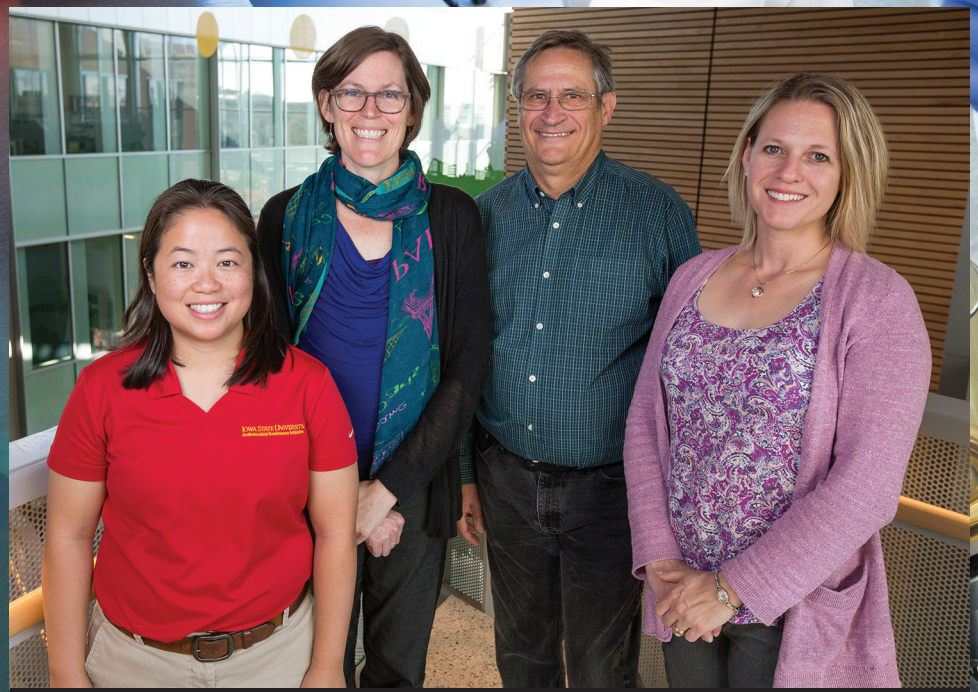
"Using DARTE-QM, we can take DNA from the environment and look at its fingerprint to identify bacteria and which genes might allow antimicrobial resistance to develop. We can target hundreds of resistant genes at the same time," Howe explains.

The group will also consider environmental factors, like production practices or weather-related occurrences, as it studies where antimicrobial resistance occurs and why it continues.

Howe says the group also studies various strategies to mitigate the emergence, spread and persistence of antimicrobial pathogens, and that this endeavor absolutely requires input from multiple disciplines and perspectives. Currently, the team is evaluating the effectiveness of various manure storage strategies and their impact on reducing resistant bacteria.

"If everyone on this team wasn't participating in this project, there's no way we would be able to accomplish our goals," Howe says. "It's a whole team of dedicated, hardworking people who bring their expertise to solve a very challenging problem. The end result will be a better understanding of how resistance develops and how we might reduce it."

DARTE QM



Pictured left to right: ***Adina Howe****, assistant professor of agricultural and biosystems engineering,* ***Heather Allen*** *and* ***Tom Moorman*** *from USDA's Agricultural Research Service, and* ***Michelle Soupir****, associate professor of agricultural and biosystems engineering.*

ECOSYSTEMS OF SUPPORT

Promoting an accessible, responsive approach to engineering education

A new initiative in the Department of Electrical and Computer Engineering will help a pool of talented students pursue a degree in engineering.

The project, called ECSEL: Electrical, Computer, and Software Engineers as Leaders, is part of the National Science Foundation's Scholarships in Science, Technology, Engineering, and Mathematics (S-STEM) program, which provides financial support to help low-income, academically talented students obtain STEM degrees and enter the workforce or graduate study.

The program will fund 582 scholarships over the next five years for students majoring (or preparing to transfer) in electrical engineering, computer engineering and software engineering.

"We're also creating what we are calling an ecosystem of academic and co-curricular support for these students, providing them with an experience that will not only encourage them to stay in their STEM field of choice but also give them the tools to excel," says **Joe Zambreno**, associate professor of electrical and computer engineering and principal investigator of the project.

The program is a multi-institutional, collaborative partnership between the Department of Electrical and Computer Engineering, Program for Women in Science and Engineering, Des Moines Area Community College and Kirkwood Community College, and Zambreno says the group will leverage the individual successes of each partner as the program grows.

"We are looking at the entire process of earning a degree in STEM and identifying ways to make it better, whether it's making sure classes transfer from community college to Iowa State or offering leadership development opportunities that keep the students engaged in their learning and growth," he adds.

An important aspect of the project will be the team's research studies of the ecosystem of supports that will accompany the project. Zambreno says the group will investigate how underrepresented minorities, including women, in STEM fields develop their professional and career identity using both qualitative and quantitative metrics.

"Knowing what motivates individuals can help us make adjustments to the learning environment we offer," he adds. "The more we can do to encourage diversity in thought and culture in STEM, the better the fields will be."

ASHFAQ KHOKHAR

The new chair of Iowa State's Department of Electrical and Computer Engineering

Iowa State University welcomed **Ashfaq Khokhar** as the Palmer Department Chair in Electrical and Computer Engineering (ECpE) on Jan. 1, 2017.

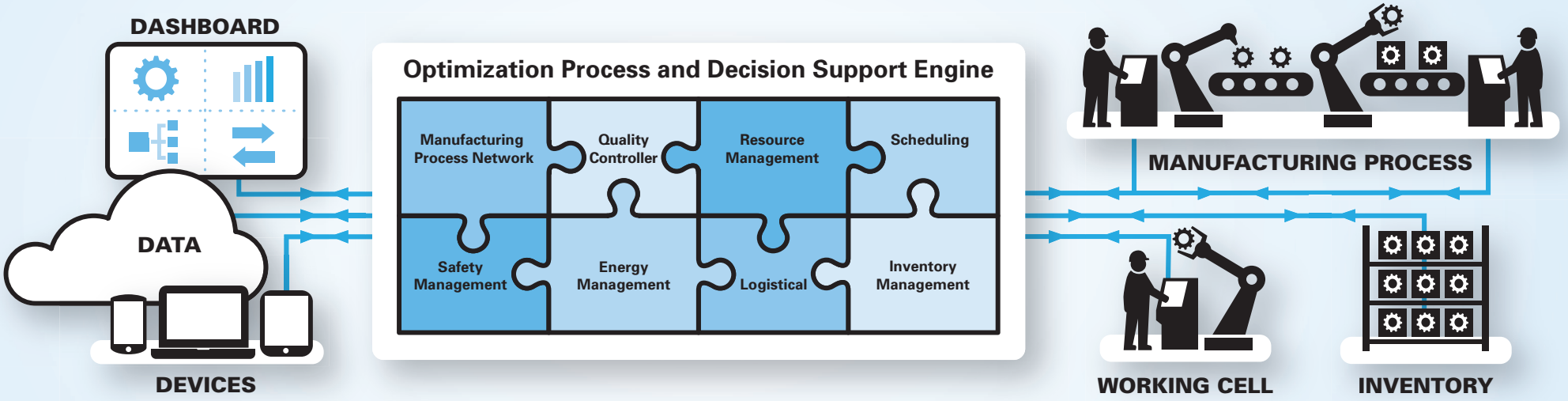
Before joining Iowa State, Khokhar was chair of the Department of Electrical and Computer Engineering at Illinois Institute of Technology, and he previously served as professor and director of graduate studies in the Department of Electrical and Computer Engineering at the University of Illinois at Chicago. Khokhar is an Institute of Electrical and Electronics Engineers (IEEE) Fellow.

"Dr. Khokhar is passionate about providing students the highest quality education, and we look forward to his contributions in this leadership role," said **Sarah Rajala**, James L. and Katherine S. Melsa Dean of Engineering. "He will continue the positive and collaborative atmosphere in the department and has strong support from the faculty and staff."

Khokhar says he is excited about this new opportunity. "One of the main goals I have is to help move electrical and computer engineering to the next tier in terms of academic stature, and to increase overall visibility for the department and our core strengths," he said. "The ECpE department is doing great things, and we want to build on this and develop an aggressive outreach to further strengthen its connection with constituents, including students, parents, alumni and peers."

The new department chair will also continue to pursue his research that explores the role of engineering in improving healthcare, with particular focus on big data analytics. Khokhar envisions a system where tiny smart devices and implants capable of monitoring vitals and other phenomena of interest can be utilized to improve quality of care. He says enabling these devices to automatically connect with each other based on common characteristics can create smart connected communities of like-minded healthcare objects and people associated with these objects.

Khokhar earned his bachelor's degree in electrical engineering from the University of Engineering and Technology in Lahore, Pakistan, his master's degree in computer engineering from Syracuse University and his Ph.D. in computer engineering from the University of Southern California.



FACTBOARD: VISUALIZING DATA

Creating a real-time data-driven visual decision support system for the factory floor

Guiping Hu has set out to make manufacturing production more efficient. The associate professor of industrial and manufacturing systems engineering is working on a project for the Digital Manufacturing and Design Innovation Institute (DMDII) to develop a shop floor decision support system called FactBoard.

DMDII is a federally-funded research and development organization of UI LABS focused on projects that demonstrate and apply digital manufacturing technologies to increase the competitiveness of American manufacturing. Hu says FactBoard fits the bill because it will help manufacturers respond to changes in real time.

The project aims to convert thousands of existing, real-time data inputs into a collection of visual dashboards, creating a record of transactional data that can be used to make informed decisions about production.

***Guiping Hu**, associate professor of industrial and manufacturing systems engineering*

"Each manufacturing floor is different – there may be a logistics problem or a production process that needs adjusted," Hu says. "With FactBoard, we can use information based on data that is already available, set up parameters and organize data based on the needs of each shop."

At Iowa State, four faculty members, five graduate students and several undergraduate research assistants are helping Hu with the project. Hu's also working with Boeing, John Deere, Proplanner and Factory Right to develop the technology.

The group has been surveying manufacturing floors to identify 5-10 key problems that are common across industries. Narrowing that list down hasn't been an easy task, but it's why Hu says having a range of companies involved at the beginning of the project is so important.

She adds that because she has such a wide audience for FactBoard, the team is creating a system that can be incorporated within individual IT frameworks through XML integration methods.

Once FactBoard is implemented, Hu says manufacturing facilities can use it to improve how they manage inventory and on-time delivery methods as well as the efficiency and effectiveness of production equipment.

JUMP-STARTING BATTERY ADVANCEMENTS

Solid electrolytes are key to making batteries more powerful and safer

For more than 30 years, **Steve Martin** has been studying and characterizing different materials to identify properties that would allow for optimal energy transfer and storage in batteries. He says ceramic-like sulfide glasses may hold the solution, and now he's working on a project to scale up his fundamental research and ultimately assemble and test batteries with this technology.

Martin, an Anson Marston Distinguished Professor in Engineering in Iowa State University's Department of Materials Science and Engineering and an associate of the U.S. Department of Energy's Ames Laboratory, says his life's work is inspired by the need to reduce the world's reliance on fossil fuels.

"We've realized the negative consequences of burning oil, and we need to find ways to improve batteries to better support alternative energy sources and applications, like wind energy and electric automobiles," he adds.

***Steve Martin**, Anson Marston Distinguished Professor in Engineering*

Martin's latest project aims to create a new type of electrolyte based on solids instead of the liquid electrolyte we see in today's lithium-ion batteries.

"The electrolyte's job is to separate a battery's electron-producing anode from its electron-accepting cathode. Because liquid electrolytes are highly flammable, batteries have been purposely designed with 10 times less energy density than is actually possible to avoid catching fire," he explains.

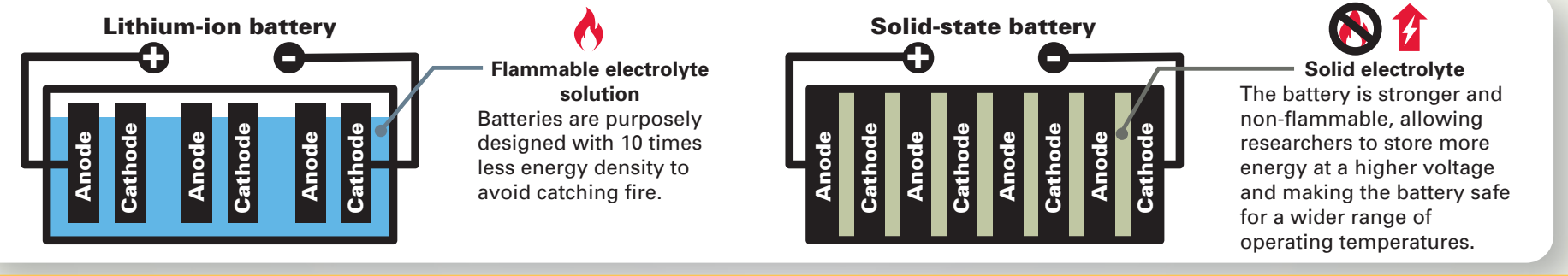
The solid electrolyte Martin is developing is stronger and non-flammable compared to liquid electrolytes. These two factors alone will allow the researchers to create a battery that can store more energy at a higher voltage and that is safer for a wider range of temperatures, both hot and cold.

Finding the right chemistry for these electrolytes has taken Martin and several other researchers years to discover, but it's been worth the wait. The new batteries will essentially be thin film, manufactured in such a way that they will be denser and more durable, and they will help improve a range of alternative energy technologies.

Martin's work is most recently supported by a three-year, $2.5 million grant from the U.S. Department of Energy's Advanced Research Projects Agency – Energy and its new Integration and Optimization of Novel Ion-Conducting Solids (IONICS) program. There's additional, cost-share funding from Iowa State and the Iowa Energy Center.

The funding also supports the work of **Jing Xu**, a newly hired assistant professor of materials science and engineering, three postdoctoral researchers, two doctoral students and three undergraduates.

"With Dr. Xu's expertise in assembling and testing batteries and my understanding of making electrolytes, we're going to see some significant advancements through this project," Martin says. "It's great to see momentum picking up around battery research, because I know progress in this area will bring tremendous value to society."



NEWS BITES

THREE ENGINEERS RECEIVE AIR FORCE RESEARCH GRANTS

The Air Force Office of Scientific Research recently awarded $20.8m in grants to 58 scientists and engineers through the Air Force's Young Investigator Research Program (YIP). Three engineering faculty from Iowa State were among those selected:

- **Matthew Panthani**, an assistant professor of chemical and biological engineering and Herbert R. Stiles Faculty Fellow, "Group IV quantum dots for integrated photonics"
- **Soumik Sarkar**, assistant professor of mechanical engineering, "A neural-symbolic approach to real-time decision-making in complex aerospace systems"
- **Travis Sippel**, assistant professor of mechanical engineering, "Microwave enhancement of composite solid propellant flames"

The program's objective is to foster creative basic research in science and engineering, enhance early career development of outstanding young investigators, and increase opportunities for the young investigators to recognize the Air Force mission and the related challenges in science and engineering.

INVESTIGATING ICING PHYSICS

When ice builds up on aircraft wings and wind turbine blades, it can change how the structures are balanced and shaped. These changes, even in subtle instances, can cause serious damage, and at times may result in devastating accidents. That's why a team of researchers in aerospace engineering is studying the fundamental processes involved in icing physics.

Rye M. Waldman and **Yang Liu**, both postdoc research associates, and graduate students **Linkai Li** and **Linyue Gao** are working with **Hui Hu**, Martin C. Jischke Professor in Aerospace Engineering, to better understand the complex interactions between heat and mass transport, thermodynamics, and aerodynamics that happen as ice accumulates over different surfaces.

The group is using Iowa State's Icing Research Tunnel, which is the only university-based, multi-functional icing research tunnel in the U.S. The facility can duplicate/simulate icing phenomena over a range of conditions.

The team says as it develops improved models of ice accretion, it will be better able to predict ice formation and accretion processes. The work will result in more effective and robust anti-/de-icing strategies that can make operating aircraft and wind turbines in cold weather both safer and more efficient.

Faculty use Iowa State's Icing Research Tunnel to study how ice builds up on an aero-engine fan model.

MALLAPRAGADA NAMED 2016 NATIONAL ACADEMY OF INVENTORS FELLOW

Surya Mallapragada, Anson Marston Distinguished Professor and the Carol Vohs Johnson Chair in Chemical and Biological Engineering, will be inducted into the National Academy of Inventors as a 2016 NAI Fellow on April 6, 2017.

Election to NAI fellow status is a high professional distinction accorded to academic inventors who have demonstrated prolific innovation in creating or facilitating outstanding inventions that have made a tangible impact on quality of life, economic development and the welfare of society.

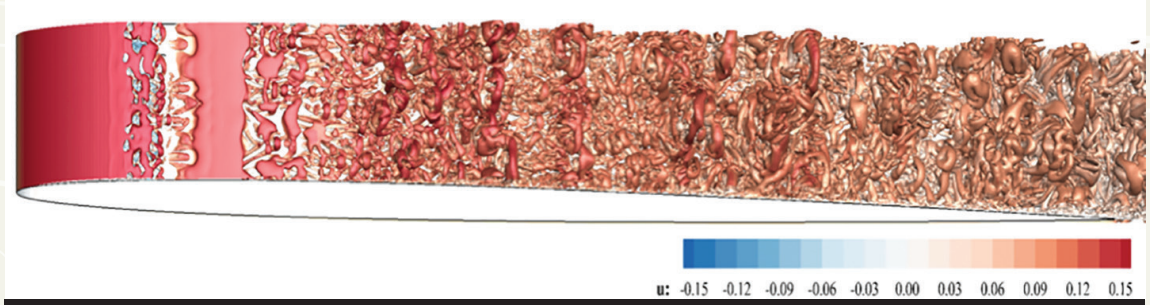
Mallapragada, who also has appointments with materials science and engineering and the U.S. Department of Energy Ames Laboratory, has worked for about two decades to invent bio-materials and bio-inspired materials with the goal of improving human health.

Her research group has six patents with more in the pipeline. In addition to patents for bio-materials and bio-inspired materials, others are related to the development of biodegradable polymer substrates that help nerves bridge gaps and regenerate.

COLLEGE INSPIRES INNOVATION

The Exploratory Research Projects program at Iowa State's College of Engineering is supporting faculty members as they gather preliminary data for high-risk, high-impact, novel research ideas. This spring, seven projects will receive grants to explore new research areas:

- **Vikram Dalal**, Anson Marston Distinguished Professor and Whitney Professor of electrical and computer engineering, "Novel material for efficient and stable multi-junction solar cell device"
- **Stephen Gilbert**, assistant professor of industrial and manufacturing systems engineering, "Transportation stress modeling to design innovative controls and information"
- **Simon Laflamme**, associate professor of civil, construction and environmental engineering, "Flying sensors for structural health monitoring"
- **Leifur Leifsson**, assistant professor of aerospace engineering, "Optimal blade design for dynamic stall mitigation of unmanned aerial systems"
- **Meng Lu**, assistant professor of electrical and computer engineering and mechanical engineering, "A wearable patient monitoring system based on noninvasive epidermal biosensors, multi-sensor data fusion, and predictive decision making"
- **Zengyi Shao**, assistant professor of chemical and biological engineering, "Integrated photoelectromicrobial cell for efficient artificial photosynthesis"
- **Qun Wang**, adjunct assistant professor of chemical and biological engineering, "Intestinal cartography of space, time and environment impacts through miniguts"



***Leifur Leifsson**, assistant professor of aerospace engineering, is working on a project to mitigate the dynamic stall that occurs in unmanned aerial vehicles, making them safer and more reliable. His project explores optimal blade design and biomimicry of the tubercles of humpback whale flippers. To study the unsteady air flow around blades, he's using highly accurate partial differential equation simulations.*

IOWA STATE UNIVERSITY
College of Engineering
4100 Marston Hall
533 Morrill Road
Ames, Iowa 50011-2103

Marston Hall, which has served as home to the College of Engineering at Iowa State University for more than a century, was recently rededicated after the building received a comprehensive, two-year renovation that preserved the college's distinguished history and focused on educating future Cyclone engineers.