IOWA STATE UNIVERSITY College of Engineering

CYCLONE ENGINEERING ENGERERING RESEARCH

Stronger when stressed: New smart, flexible material transforms to hard composite

FALL 2018 CONTENTS

PHILANTHROPY JUMP-STARTS RESEARCH
INNOVATION32018 NSF CAREER AWARD WINNERS4STRONGER, CHEAPER, GREENER FOUNDATIONS FOR
OFFSHORE RENEWABLE ENERGY GENERATION6SMART MATERIAL GETS STRONGER WHEN
STRESSED8ADVANCING BIORENEWABLES PROCESSING FOR A
SUSTAINABLE, AGRICULTURAL-POWERED FUTURE10BOOSTING DIVERSITY IN ENGINEERING WITH
EVIDENCE-BASED STRATEGIES12NEWS BITES14

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

Arun K. Somani

Associate Dean for Research Anson Marston Distinguished Professor Philip and Virginia Sproul Professor

Editor: Breehan Gerleman

Contributing Editor: **Mike Krapfl** Photography: **Christopher Gannon** and **Bob Elbert** Graphic Designer: **William Beach** collegerelations@iastate.edu www.engineering.iastate.edu/research

On the cover:

Cyclone Engineers have developed a new smart material that transforms itself into a hard composite when bent, twisted or squeezed. The new material could be used in medicine to support delicate tissue or in industry to protect valuable sensors. Story on page 8.

Copyright © 2018, Iowa State University of Science and Technology. All rights reserved.

Iowa State University does not discriminate on the basis of race, color, age, ethnicity, religion, national origin, pregnancy, sexual orientation, gender identity, genetic information, sex, marital status, disability, or status as a U.S. veteran. Inquiries regarding non-discrimination policies may be directed to Office of Equal Opportunity, 3410 Beardshear Hall, 515 Morrill Road, Ames, Iowa 50011, Tel. 515 294-7612, Hotline: 515-294-1222, email: eooffice@iastate.edu.

PHILANTHROPY JUMP-STARTS RESEARCH INNOVATION

"Philanthropy propels early-stage, innovative research at Iowa State, making discoveries possible that simply wouldn't have happened without donors' gifts," said **Sarah Rajala**, James L. and Katherine S. Melsa Dean of Engineering. "The outstanding level of support from our donors also helps us attract the best faculty to work on groundbreaking research questions and train the next generation of researchers."

The College of Engineering has more than 50 named professors and chair positions, supporting faculty who are conducting research in life-improving areas from renewable energy to fighting disease to cybersecurity.

"Donors to the College of Engineering are incredibly committed to making a difference, and they are making an investment in a better future for us all by supporting faculty at lowa State," said Rajala.

In this issue, you can read more about the pioneering research conducted by faculty supported by philanthropy. Learn more on page 4 about our National Science Foundation CAREER winners, many of whom have been supported by Black & Veatch Building a World of Difference Faculty Fellowships in Engineering. And on page 10, see how **Robert Brown**, Gary and Donna Hoover Chair in Mechanical Engineering, is leading the nation in biorenewables processing research.

More than 50 named professors and chair positions

- College of Engineering, Iowa State University



Frank Peters, third from left, an associate professor, was recently named to the C. G. "Turk" and Joyce A. Therkildsen Professorship in Industrial and Manufacturing Systems Engineering

2018 NSF CAREER Award Winners

Alice Alipour

Assistant professor of civil, construction and environmental engineering

"Resiliency of Electric Power Networks Under Wind Loads and Aging Effects through Risk-Informed Design and Assessment Strategies"

Alipour will use a systems approach to create new design methodologies for electric power networks that will increase power grid resiliency in hurricanes, blizzards and other severe storms.

She will also develop interactive educational opportunities for high school students, curricula focused on interdisciplinary research, industry partnerships, and a mentoring program to interest and educate the next generation of natural hazard engineers.



Shan Hu

Assistant professor of mechanical engineering

"Scalable Manufacturing of Hierarchical Nanostructures by Acoustically Modulated Emulsion Technique for Next Generation Renewable Energy Applications"

> Hu will design techniques for self-assembly "nanomanufacturing" that will make the process more easily scalable, cheaper and faster to create 3-D nanostructures for next-generation clean energy technologies.

She is also creating multidisciplinary research opportunities for undergraduate, graduate and community college students from underrepresented minorities.



Adarsh Krishnamurthy

Assistant professor of mechanical engineering

"GPU-Accelerated Framework for Integrated Modeling and Biomechanics Simulations of Cardiac Systems"

Krishnamurthy will integrate patient data with cardiovascular modeling to create simulation, analysis and visualization tools that enable personalized treatment of heart diseases.

He is also developing educational and virtual reality tools that illustrate heart health concepts to both K-12 students and adults.

Neil Gong

Assistant professor of electrical and computer engineering

"Graph-based Security Analytics: New Algorithms, Robustness Under Adversarial Settings, and Robustness Enhancements"

Gong is developing graph-inference algorithms that quickly and reliably detect and combat cyberattacks.

He will also integrate his findings into a graduate course on data-driven security and contribute to K-12 cybersecurity outreach and competitions.



Chinmay Hegde

Assistant professor of electrical and computer engineering

"Advances in Graph Learning and Inference"

Hegde is developing faster and more accurate graph-learning and inference algorithms that will improve decision-making in transportation networks, social networks and personalized learning systems.

He will also create data science curricula and workforce development programs designed to increase the participation of women and underrepresented minorities in computational sciences.



Juan Ren

Assistant professor of mechanical engineering

'Modeling and Control of Cellular Response to Dynamic Mechanical Manipulation Using a Dual-Input Platform"

Ren is creating dynamics models and control algorithms for how cells change structure in response to external force, providing cell biologists with a new tool to control biochemical and mechanical cell changes.

She will also develop a new undergraduate course in nanobiomechanics and an outreach program on using biomechanical methods in agriculture.

As "E

Zengyi Shao

Assistant professor of chemical and biological engineering

"Exploring nucleosome-depleted sequences for novel applications in synthetic biology"

Shao will study the influence of a subgroup of DNA that was recently discovered to be important to cell metabolism, opening a door to new biotechnology and improvements in human health.

She is also developing unique undergraduate research programs, mentoring next-generation STEM teachers and promoting the participation of underrepresented groups in STEM.

NSF CAREER PROJECT IN PROGRESS STRONGER, CHEAPER, **GREENER FOUNDATIONS** FOR OFFSHORE RENEWABLE ENERGY GENERATION "A challenge of foundation research is that you can't see through soil, so you often can't see exactly what's happening in an experiment. We used a transparent soil - a gelatin that acts like soft clay - to make observations not possible any other way." Cassandra Rutherford, assistant professor of civil, construction and environmental engineering

Cassandra Rutherford is studying how to improve foundation design of tidal current turbines – with an aim of helping offshore renewable energy generation go mainstream. Her project examining suction caissons as an economical and green option for tidal turbines is supported by an NSF CAREER award.

"Tidal current turbines have huge energy generation potential, and they overcome some challenges of wind turbines: Tidal turbines run continuously and are out of sight," said Rutherford, assistant professor of civil, construction and environmental engineering.

But research is limited on
how best to create tidal turbine
foundations. Suction caissons
have been used for some timeour
Cassandra Rutherford, assistant
professor of civil, construction and
environmental engineeringto anchor large offshore oil and gas
tidal turbines.inspire kids' i

"Suction caissons offer the additional benefit of being easy to place – you simply drop into position, pump out the extra water, and the pressure of the ocean pushes the caisson the rest of the way in," said Rutherford. "When the life of the tidal turbine is done, the suction caisson can be removed, making it a green alternative that leaves no waste behind in the ocean." Rutherford's research team used smallscale laboratory tests in transparent soil and centrifuge testing to evaluate the performance of suction caissons to resist high lateral loads and resist the cyclic loading caused by the oscillating blades of the turbine. The researchers, including international collaborators, are now creating 3-D numerical models that replicate experimental results and make more conclusions about caisson performance possible.

> "Right now, there's a lot of room for growth in offshore renewable energy generation, and as we transition to these types of energy in the future, I'm hoping our research will make tidal

current turbines a more viable option," said Rutherford. Rutherford is also working to

inspire kids' interest in civil engineering and renewable energy. As part of her CAREER project, she did hands-on wind, solar and wave energy experiments with second and fourth graders. And she did a week-long camp with high school girls.

"I'm trying to expose kids to a broader picture of what civil engineering is, as well as introduce them to a more diverse picture of who works as a civil engineer, so more students can see themselves in this field," said Rutherford.

Four more CAREER projects in progress



Kristin Rozier, aerospace engineering, "Theoretical Foundations of the UAS in the NAS Problem"

Jeramy Ashlock, civil, construction and environmental engineering, "A Framework for Integrated Computational and Physical Simulation of Dynamic Soil-Pile Group Interaction"





Meng Lu, electrical and computer engineering, "Integration of Photonic Crystals and Paper-Based Microfluidics for Biosensing"

Anupam Sharma, aerospace engineering, "Ultra-Quiet Aircraft Propulsion Inspired by the Unique Plumage of the Owl"



ACTIVE **CAREER** PROJECTS in the college of engineering



SMART MATERIAL GETS STRONGER WHEN STRESSED

Cyclone Engineers have developed a new smart and responsive material that stiffens up like a worked-out muscle.

Stress a muscle and it gets stronger. Mechanically stress the rubbery material – say with a twist or a bend – and the material automatically stiffens by up to 300 percent, the engineers said. In lab tests, mechanical stresses transformed a flexible strip of the material into a hard composite that can support 50 times its own weight.

This new composite material doesn't need outside energy sources, such as heat, light or electricity to change its properties. And it could be used in a variety of ways, including applications in medicine and industry.

Lead researchers are **Martin Thuo** and **Michael Bartlett**, both assistant professors of materials science and engineering, who combined Thuo's expertise in micro-sized, liquidmetal particles with Bartlett's expertise in soft materials such as rubbers, plastics and gels.

The researchers found a simple, low-cost way to produce particles of undercooled metal – that's metal that remains liquid even below its melting temperature. The tiny particles (they're just 1 to 20 millionths of a meter across) are created by exposing droplets of melted metal to oxygen, creating an oxidation layer that coats the droplets and stops the liquid metal from turning solid. They also found ways to mix the liquid-metal particles with a rubbery elastomer material without breaking the particles.

When this hybrid material is subject to mechanical stresses – pushing, twisting, bending, squeezing – the liquid-metal particles break open. The liquid-metal flows out of the oxide shell, fuses together and solidifies.

"You can squeeze these particles just like a balloon," Thuo said. "When they pop, that's what makes the metal flow and solidify."

The result, Bartlett said, is a "metal mesh that forms inside the material."

Thuo and Bartlett said the popping point can be tuned to make the liquid metal flow after varying amounts of mechanical stress. Tuning could involve changing the metal used, changing the particle sizes or changing the soft material.

In this case, the liquid-metal particles contain Field's metal, an alloy of bismuth, indium and tin. But Thuo said other metals will work, too.

"The idea is that no matter what metal you can get to undercool, you'll get the same behavior," he said. The engineers say the new material could be used in medicine to support delicate tissues or in industry to protect valuable sensors. There could also be uses in soft and bioinspired robotics or reconfigurable and wearable electronics.

"A device with this material can flex up to a certain amount of load," Bartlett said. "But if you continue stressing it, the elastomer will stiffen and stop or slow down these forces."



Examples of the new smart material, left to right: A flexible strip; a flexible strip that stiffened when twisted; a flexible strip transformed into a hard composite that can hold up a weight.



Left to right: Boyce Chang, Martin Thuo, Michael Bartlett and Ravi Tutika.

ŵ,

63

10 2 25 3 4 5 6 MM

6

0

05

ADVANCING BIORENEWABLES PROCESSING FOR A SUSTAINABLE, AGRICULTURE-POWERED FUTURE

Cyclone Engineer Robert Brown is pioneering the use of thermochemical processes

to efficiently and inexpensively turn biomass into biofuels and biobased chemicals.

Brown, Anson Marston **Distinguished Professor** in Engineering, has built a nation-leading research program in scaling biomass processing discoveries from the bench to pilot and demonstration scales.

Robert Brown. Anson Marston Distinguished Professor in Engineering

He directs Iowa State's Bioeconomy Institute, which researches processes that use heat, pressure and catalysts to produce significant advantages in yields, require less inputs, reduce capital costs and makes simpler, modular reactor designs possible.

"Our program's uniqueness is the depth and breadth of experience in the major thermochemical processes applied to biomass pyrolysis, gasification and solvent liquefaction - and our support of commercialization of these processes through scale-up and technoeconomic analysis," said Brown, who is also the Gary and Donna Hoover Chair in Mechanical Engineering and a professor

in chemical and biological engineering and agricultural and biosystems engineering. Brown's colleague Mark Mba-Wright, associate professor of mechanical engineering, takes data from laboratory and pilot plant experiments and determines costs to scale up to industrial production and how much the products will cost consumers. "The engineer in me is always

thinking 'OK, contributing to new knowledge in the thermochemical sciences is gratifying, but how do we use these findings?' Getting scale up and economics right is key to transitioning technology out of the lab and into the market," said Brown.

Brown's research has drawn the interest of major players in the energy industry. ConocoPhillips established an \$18.5 million research program at Iowa State that made critical advancements in thermochemical conversion of biomass, especially pyrolysis. Later, Chevron partnered with Brown's research team on solvent liquefaction research.

"Chevron valued our expertise in thermochemical processing and, most importantly, our capability to conduct research at pilot plant scale," said Brown.

The processing facility is now located at Iowa State's first-in-the-nation BioCentury Research Farm, which integrates biomass production and processing.

Brown is now lending his expertise to the Rapid Advancement in Process Intensification Deployment (RAPID) Institute, a Manufacturing USA project funded by the Department of Energy and led by the American Institute of Chemical Engineers. RAPID aims to improve the productivity of chemical manufacturing.

"Iowa State is co-leading RAPID's renewable bioproducts efforts on the strength of our past contributions in bioenergy and biobased products. The institute is supporting our efforts to scale autothermal pyrolysis into modular energy production systems, a collaboration with our commercialization partner Easy Energy Systems," said Brown. "We want to build subsystems the size of standard shipping containers, allowing these modular systems to be easily moved to biomass resources."





Robert Brown (right), Anson Marston Distinguished Professor in Engineering, is a nationwide leader in developing thermochemical processes to turn biomass into biofuels and biobased chemicals.

5

OLTAGE, INC.

BOOSTING DIVERSITY IN ENGINEERING WITH EVIDENCE-BASED STRATEGIES

Diane Rover, University Professor of electrical and computer engineering, is alliance director for the \$5 million Louis Stokes Alliances for Minority Iowa-Illinois-Nebraska STEM Partnership for Research and Education and co-principal investigator for the Reinventing the Instructional and Departmental Enterprise project, both of which seek to boost diversity in STEM fields.

IINSPIRE LSAMP: THRIVING IN STEM DISCIPLINES

Iowa State leads the \$5 million Louis Stokes Alliances for Minority Participation (LSAMP) Iowa-Illinois-Nebraska STEM Partnership for Research and Education (IINSPIRE) project that aims to increase the number and improve the experience of underrepresented students completing STEM degrees in the Midwest.

IINSPIRE offers students evidencebased academic, professional and social support, including mentoring, hands-on research experiences, transfer partnerships between two- and four-year institutions, and other programming.

Researchers, guided by social cognitive career theory, are studying both micro- and macrolevel influences to understand how

IINSPIRE students thrive and persist in STEM disciplines. Sixteen public and private colleges and universities and community colleges across three states are participating in IINSPIRE, providing a rich collaboration to study shared challenges alliance-wide.

IINSPIRE is led by principal investigator Jonathan Wickert, Iowa State senior vice president and provost and professor of mechanical engineering, and alliance director Diane Rover, University Professor of electrical and computer engineering. IINSPIRE is funded by the National Science Foundation.

RIDE: COLLABORATIVE, INCLUSIVE INSTRUCTIONAL MODELS

An interdisciplinary team of Iowa State researchers are developing new instructional models for course design in electrical and computer engineering, with a goal of better preparing the next generation of engineers for working in ever complex systems and broadening the participation of underrepresented students, especially women.

> The Reinventing the Instructional and Departmental Enterprise (RIDE) project is funded by \$2 million from the NSF to develop new approaches to teaching and learning in electrical and computer engineering, especially in relation to design and systems thinking, professional skills, such as leadership and inclusion, contextual concepts

and creative technologies. Researchers are developing and evaluating human-centered, collaborative and interactive teaching practices in new courses each semester, continually evaluating and improving strategies.

RIDE co-principal investigators are **Diane** Rover, University Professor of electrical and computer engineering, and Joe Zambreno, professor of electrical and computer engineering.

ECSEL: ECOSYSTEMS OF SUPPORT

Cyclone Engineers, together with colleagues at two community colleges, are examining the entire process of earning electrical, computer and software engineering degrees to help improve diversity and inclusion in the fields.

The Electrical, Computer and Software Engineers as Leaders (ECSEL) project research team, led by professor of electrical and

Research questions address how women

and other diverse students develop and sustain

their engineering identities and what motivates

underrepresented students to persist and thrive

in electrical, computer and software engineering

degree programs. ECSEL is funded by the NSF.

computer engineering Joe Zambreno, is adapting, implementing and studying an evidence-based student experience model that forms an entire ecosystem of supports, ranging from scholarships for low-income, high-potential students, to professional development activities and study abroad opportunities - all with a goal of doubling the number of women enrolled in the degree programs.

Joe Zambreno, professor of electrical and computer engineering





Jonathan Wickert.

Iowa State senior vice

president and provost

NEWS

TOUGH CANCER NANOSIZED TREATMENT

Anson Marston Distinguished Professor in Engineering **Balaji Narasimhan** is developing nanovaccines to fight the difficult-to-treat pancreatic cancer. The idea is to load fragments of certain proteins associated with pancreatic cancer into nanoparticles that can be introduced into the body. The proteins would arm a patient's immune system to target and kill cancer cells.



DATA-DRIVEN PLANT BREEDING

Associate professor of industrial and manufacturing systems engineering **Guiping Hu** is harnessing the power of big data to improve plant breeding and production. Hu, an Iowa State Plant Sciences Institute Faculty Scholar, is working with agronomists, economists and plant scientists to develop predictive models that optimize plant genomic selection, experimental field design and farm management.

NEW LEADER FOR DEPT. OF CIVIL, CONSTRUCTION AND ENVIRONMENTAL ENGINEERING

David Sanders has been named the Greenwood Department Chair in Civil, Construction and Environmental Engineering. Sanders comes to Iowa State from the University of Nevada, Reno, and he is a fellow of the American Concrete Institute, the Structural Engineering Institute and the American Society of Civil Engineers. His research has centered on the behavior and design of structural concrete with an emphasis in the seismic design of bridges.

BUILDING TO REBUILD LIVES

Cristina Poleacovschi, assistant professor of civil, construction and environmental engineering, is part of an interdisciplinary team working to answer the question of how the built environment of refugee camps affects community resilience. Researchers will use the concept of human-centered design, which addresses the needs, rights and perspectives of vulnerable communities, throughout the entire design process.

TODAY'S KIDS TOMORROW'S ENGINEERS

Suzanne Leonard, a Ph.D. student in agricultural and biosystems engineering, was a "resident engineer" in elementary school classrooms, helping encourage kids to apply critical thinking skills and creativity to STEM concepts. Leonard's work was supported by a Trinect Fellowship, an National Science Foundation program that pairs teachers with engineering graduate students to develop and deliver experiential STEM activities.

CATALYTIC PROMISE UNEXPECTED MATERIAL

Yue Wu, Herbert L. Stiles Professor of Chemical Engineering, developed a chemical process that improved the catalytic potential in two-dimensional metal carbide materials, opening the door for watergas shift reactions. The process, known as reactive metal-support interaction, used an unconventional nanostructured carbide-based support to design and obtain functional bimetallic catalysts.

IOWA STATE UNIVERSITY

College of Engineering

4100 Marston Hall 533 Morrill Road Ames, Iowa 50011-2103

Building Collaboration and Innovation

Iowa State is building an \$84-million, 140,000 square foot Student Innovation Center designed to inspire experimentation, interdisciplinary collaboration and free exchange of ideas in an inclusive environment. Scheduled to open in 2020, the facility reflects Iowa State's brand of hands-on, experiential learning and will feature unique fabrication equipment ranging from electronics to textiles, flexible meeting areas for project-based learning, and retail space to pilot entrepreneurial ideas.