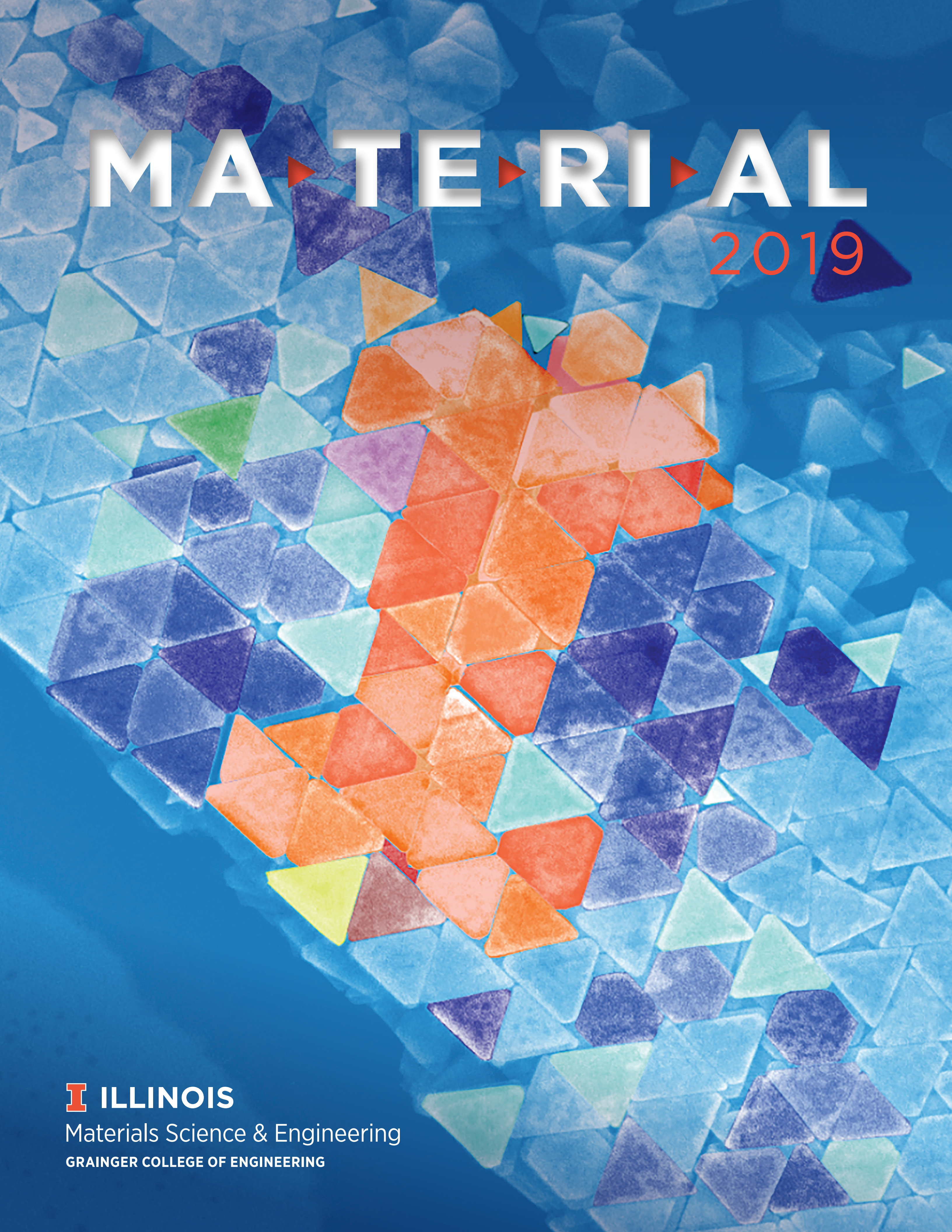

# MA▸TE▸RI▸AL

2019

ILLINOIS
Materials Science & Engineering
GRAINGER COLLEGE OF ENGINEERING

# Contents



**ILLINOIS**
Materials Science & Engineering
**GRAINGER COLLEGE OF ENGINEERING**

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Greetings Friends of MatSE:

MatSE at Illinois has much to celebrate this year! We are very proud of our new US News and World Report rankings, placing both our undergraduate and graduate programs at #3. The high-caliber of our faculty and students is evident in the research highlights and alumni updates that we share with you in this magazine.

You will also learn about our outreach efforts through summer camps to captivate the curiosity and imagination of female students from middle schools to high schools - we hope to see some of them here in a few years.

Support from our alumni and initiatives like the Grainger Matching Challenge (donations to undergraduate scholarships matched 1:1 through December 2019) has enabled MatSE to increase the number of scholarships and fellowships we offer to our students, making MatSE at Illinois an even greater attraction.

We are also thankful to Professor Emeritus Jim Economy and his family for their gift establishing the new James Economy Professorship in support of our faculty.

Last but not least, the Department is looking forward to transitioning to a new leadership in January 2020, when Professor Nancy Sottos, recently inducted as Swanlund Endowed Chair, will start as permanent Head.

Pascal Bellon
Interim Head


*Cover art: A scanning electron microscopy image of micron-sized silver plates packed into three-dimensional layers, like "tiles." In the paper (featured on page 6), using this type of plates as building blocks, the authors revealed a hierarchical ordering process out of polydisperse plates. Ahyoung Kim, a MatSE graduate student, colored the image to resemble the Illinois 'I'. (Qian Chen Group)*

**#3**
ranked graduate program

**#3**
ranked undergraduate program

**2nd**
largest number of undergraduates

**11,000**
square feet of undergraduate labs with cutting-edge equipment

**$250K**
in scholarships awarded in 2018-19

Left to right: Philippe Geubelle, Scott White, Nancy Sottos, Jeff Moore

# New polymer manufacturing process

## SAVES 10 ORDERS OF MAGNITUDE OF ENERGY

> "THIS DEVELOPMENT MARKS WHAT COULD BE THE FIRST MAJOR ADVANCEMENT TO THE HIGH-PERFORMANCE POLYMER AND COMPOSITE MANUFACTURING INDUSTRY IN ALMOST HALF A CENTURY."

Makers of cars, planes, buses – anything that needs strong, lightweight and heat resistant parts – are poised to benefit from a new manufacturing process that requires only a quick touch from a small heat source to send a cascading hardening wave through a polymer. Researchers at the University of Illinois have developed a new polymer-curing process that could reduce the cost, time and energy needed, compared with the current manufacturing process.

The findings, reported in *Nature*, state that the new polymerization process uses 10 orders of magnitude less energy and can cut two orders of magnitudes of time over the current manufacturing process. "This development marks what could be the first major advancement to the high-performance polymer and composite manufacturing industry in almost half a century," said the late aerospace engineering professor and lead author Scott White.

"The materials used to create aircraft and automobiles have excellent thermal and mechanical performance, but the fabrication process is costly in terms of time, energy and environmental impact," White said. "One of our goals is to decrease expense and increase production."

Take, for example, aircraft assembly. For one major U.S. producer, the process of curing just one section of a large commercial airliner can consume over 96,000 kilowatt-hours of energy and produce more than 80 tons of $CO_2$, depending on the energy source, White said. That is roughly the amount of electricity it takes to supply nine average homes for one year, according to the U.S. Energy Information Administration.

"The airliner manufacturers use a curing oven that is about 60 feet in diameter and about 40 feet long – it is an incredibly massive structure filled with heating elements, fans, cooling pipes and all sorts of other complex machinery," White said. "The temperature is raised to about 350 degrees Fahrenheit in a series of very precise steps over a roughly 24-hour cycle. It is an incredibly energy-intensive process."

The team is part of the Beckman Institute for Advanced Science and Technology at the University of Illinois at Urbana-Champaign and includes White, chemistry professor and Beckman Institute director Jeffrey Moore, aerospace engineering professor and department head Philippe Geubelle, and materials science and engineering professor Nancy Sottos. They proposed that they could control chemical reactivity to economize the polymer-curing process. "There is plenty of energy stored in the resin's chemical bonds to fuel the process," Moore said. "Learning to unleash this energy at just the right rate – not too fast, but not too slow – was key to the discovery."

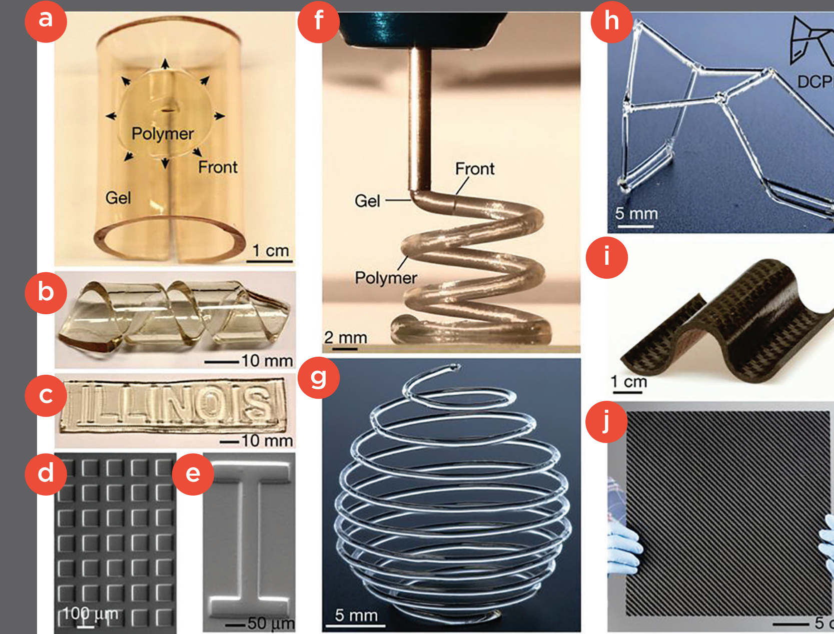
"By touching what is essentially a soldering iron to one corner of the polymer surface, we can start a cascading chemical-reaction wave that propagates throughout the material," White said. "Once triggered, the reaction uses enthalpy, or the internal energy of the polymerization reaction, to push the reaction forward and cure the material, rather than an external energy source."

"You can save energy and time, but that does not matter if the quality of the final product is substandard," Sottos said. "We can increase the speed of manufacturing by triggering the hardening reaction from more than one point, but that needs to be very carefully controlled. Otherwise, the meeting spot of the two reaction waves could form a thermal spike, causing imperfections that could degrade the material over time."

The team has demonstrated that this reaction can produce safe, high-quality polymers in a well-controlled laboratory environment. They envision the process accommodating large-scale production due to its compatibility with commonly used fabrication techniques like molding, imprinting, 3-D printing and resin infusion.

*The U.S. Air Force Office of Scientific Research supported this research.*

*Story: Lois Yoksoulian*
*Photo: L. Brian Stauffer*

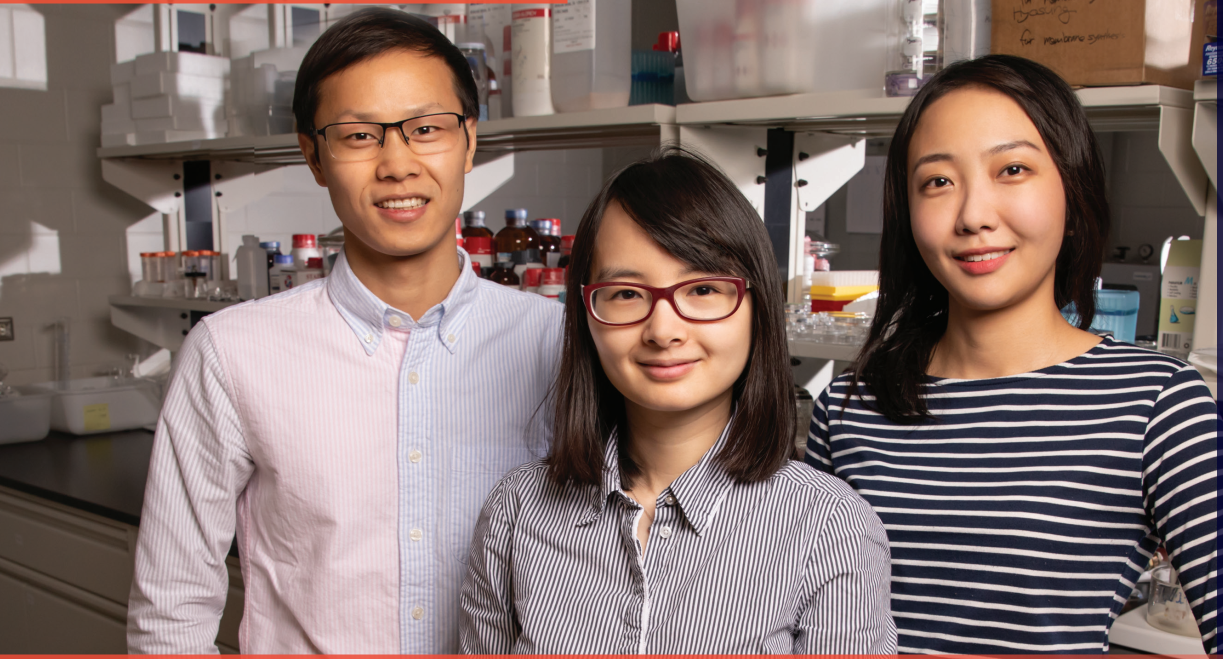



***Examples of advanced manufacturing with the new technique. a,*** *frontal polymerization (FP) in a free-standing polymer gel, propagating radially from a single initiation-point source.* ***b–e,*** *macropatterned/micropatterned thermo-set polymer produced by FP. In* ***b****, a flat gel sheet is rolled into a helix structure before FP. In* ***c****, a flat gel sheet is imprinted with an ILLINOIS stamp before FP. In* ***d*** *and* ***e****, gel sheets are produced by moulding at room temperature for 18 hours and followed by FP to solidify the micropattern.* ***f,*** *3D printing of gel that is solidified by FP immediately following extrusion from the print head.* ***g, h,*** *free-form 3D-printed structures produced via FP.* ***i,*** *a corrugated carbon fiber composite part fabricated by FP using vacuum-assisted resin-transfer moulding.* ***j,*** *a 900 cm2 carbon fiber composite panel (with 51% fibre volume fraction) cured by FP in 5 minutes using about 750 J of energy.*

## NSF LEAP HI GRANT: Energy Efficient Processing of Thermosetting Polymers and Composite Materials

Nancy Sottos, Jeff Moore, Philippe Geubelle and Naryana Aluru have been awarded new $2M grant from the National Science Foundation (NSF) LEAP HI, Manufacturing USA Program for "Energy Efficient Processing of Thermosetting Polymers and Composite Materials."

The proposed research will develop a new method for the manufacture of plastics and fiber reinforced composite materials, which are critical elements in structures like aircraft, automobiles, and wind turbine blades, where light weight and high-strength are required. Current methods for manufacturing these materials are costly and energy intensive due to the large amounts of heat required and long processing times. Drawing inspiration from how living system develop, this multidisciplinary research project will result in new plastic materials that require only small initial energy input to rapidly trigger the entire manufacturing process and dramatically reduce environmental impact. This new, more efficient method has significant potential to dramatically improve U.S. economic competitiveness in the critical area of composite manufacturing. The energy efficient concepts under development also provide an ideal platform to motivate and educate the next generation of students, postdoctoral researchers, entrepreneurs, industry, and the general public on the importance of sustainable manufacturing.



"THE FINDINGS OF THIS STUDY MAY ALLOW FOR THE DEVELOPMENT OF RECONFIGURABLE SELF-ASSEMBLY MATERIALS."

MULTISTEP SELF-ASSEMBLY OPENS DOOR TO BUILD

# new reconfigurable materials

*Materials science and engineering professor Qian Chen, center, and graduate students Binbin Luo, left, and Ahyoung Kim, right, find inspiration in biology to help investigate how order emerges from self-assembling building blocks of varying size and shape.*

Self-assembling synthetic materials come together when tiny, uniform building blocks interact and form a structure. However, nature lets materials like proteins of varying size and shape assemble, allowing for complex architectures that can handle multiple tasks.

University of Illinois engineers took a closer look at how nonuniform synthetic particles assemble and were surprised to find that it happens in multiple phases, opening the door for new reconfigurable materials for use in technologies such as solar cells and catalysis.

The findings are reported in the journal *Nature Communications*.

"Traditional self-assembly can be thought of like a grocery store stacking apples for a display in the produce section," said Qian Chen, a professor of materials science and engineering and lead author of the new study. "They would need to work with similarly sized and shaped apples – or particles in the case of self-assembly – to make the structure sturdy."

In the new study, Chen's group observed the behavior of microscale silver plates of varied size and nanoscale thickness in liquids. Because the particles used in self-assembling materials are so small, they behave like atoms and molecules, which allow researchers to use classical chemistry and physics theories to understand their behavior, the researchers said.

The nonuniform particles repel and attract according to laws of nature in plain, deionized water. However, when the researchers add salt to the water, changing electrostatic forces trigger a multistep assembly process. The nonuniform particles begin to assemble to form columns of stacked silver plates and further assemble into increasingly complex, ordered 3D hexagonal lattices, the team found.

"We can actually witness the particles assemble in this hierarchy using a light microscope," said Binbin Luo, a materials science and engineering graduate student and study co-author. "This way, we can track particle motions one by one and study the assembly dynamics in real time."

"The findings of this study may allow for the development of reconfigurable self-assembly materials," said Ahyoung Kim, a materials science and engineering graduate student and study co-author. "These materials can change from one type of solid crystal to another type with different properties for a variety of applications."

"Another benefit of this finding is that it can be generalized to other types of systems," Chen said. "If you have another type of nanoparticle, be it magnetic or semiconducting, this hierarchal assembly principle still applies, allowing for even more types of reconfigurable materials."

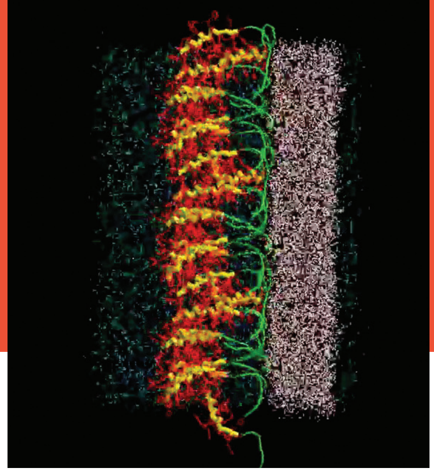
Graduate students John W. Smith and Zihao Ou, former postdoctoral researcher Juyeong Kim, and undergraduate student Zixuan Wu also contributed to this study.

*The National Science Foundation supported this research.*

*Story: Lois Yoksoulian*
*Photo: L. Brian Stauffer*

RESEARCHERS DEVELOP FAST, EFFICIENT WAY TO BUILD

# amino acid chains



*Still shot from a movie illustrating the spontaneous partitioning of PEG–PBLG macroinitiators towards the interface due to PEG segments touching the interface in molecular dynamics simulation. The interface was set as z = 0 nm, 9 PEG–PBLGs were placed at z = -3 nm initially at t = 0 ns, with the PEG segments touching the interface. The molecules were then simulated for 30 ns. The PEG chains initially touching the interface rapidly dragged the PEG–PBLGs from the DCM phase to the interface corresponding to the minimum of the PMF and most favorable location of the molecule. Two replicas of the fundamental simulation cell are shown connected through the periodic boundary.*

Scientists often build new protein molecules by stringing groups of amino acids together. These amino acid chains, called polypeptides, are the building blocks needed in drug development and the creation of new biomaterials.

The process for building polypeptides is difficult, however. Researchers report that they have developed a faster, easier and cheaper method for making new polypeptides than was previously available. The new approach uses a streamlined process that purifies the amino acid precursors and builds the polypeptides at the same time, unlike previous methods in which the processes were separate, laborious and time-consuming.

"Traditionally, making polypeptide chains has been a very complicated process," said University of Illinois materials science and engineering professor Jianjun Cheng, who led the new research. Synthesizing and purifying the amino acid precursors, namely N-carboxyanhydride, or NCA, requires days of tedious effort, and building the polypeptide chains takes hours to days, he said.

"The field has never grown big, in part because synthesizing polypeptides is so complicated," Cheng said. "NCA has a lot of impurities that are difficult to remove. Until now, the synthesis of high-quality polypeptides required ultrapure NCAs."

In biological cells, enzymes called ribozymes join amino acids together to form proteins, Cheng said. This process takes place in the presence of water, salt and numerous other molecules. Replicating this process in the laboratory is very difficult, however. Current methods require researchers to use purified NCA molecules and to build the chains in a water-free environment.

Cheng and his colleagues drew inspiration from ribozymes, which excel at making amino acid chains quickly while isolating them from the cellular environment. The team developed a system that mimics the ribozyme function, building the amino acid chains quickly while removing any molecules that could contaminate the system. This allows the researchers to build the desired chains with NCAs that are not pure.

"This is the first time since the discovery of the NCA molecule in 1906 that we have been able to build long chains using non-purified NCA," Cheng said.

"I worked on NCA purification for several years and found it very painful, because the process required water-free conditions and was technically challenging," said postdoctoral researcher Ziyuan Song, a member of Cheng's lab. "That's why there aren't many research groups working in this field. With this method, we can get more people to join and find more applications."

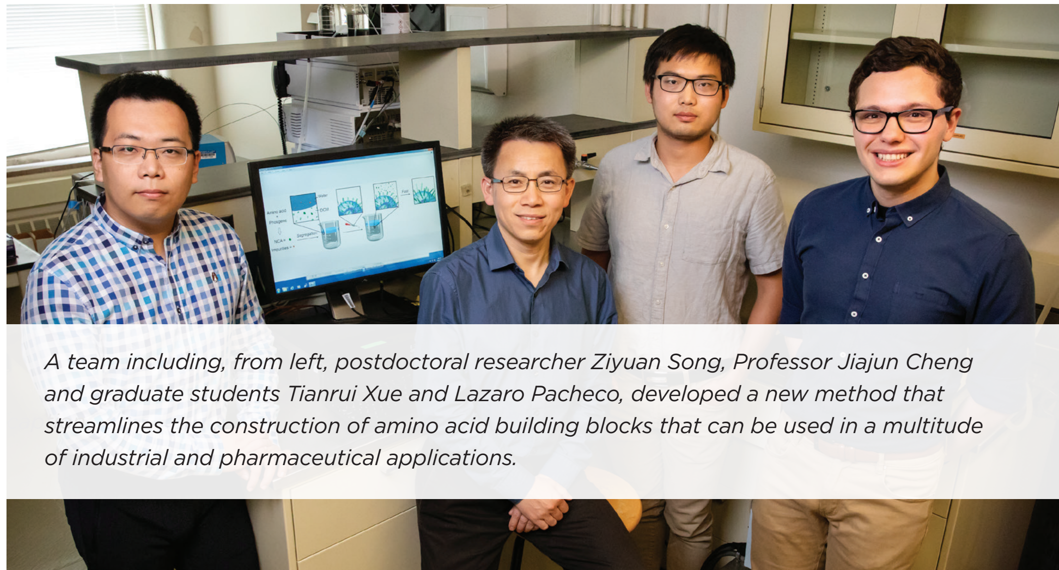
The method can be used in chemistry, biology and industry, where protein chains are routinely used as building blocks for the assembly of useful molecules, the researcher said.

"Previously, the field required specialized chemists like us to make these building blocks," Cheng said. "Our new protocol allows anyone with basic chemistry skills to build the desired polypeptides in a few hours."

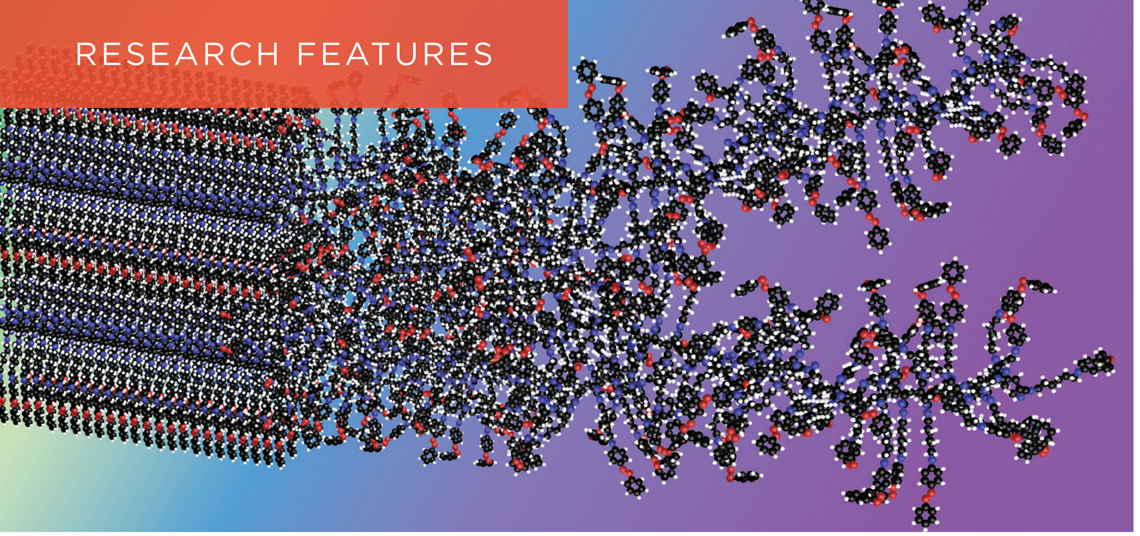
The researchers are investigating how to scale up the process and explore the full range of chemical and biological applications the new approach allows.

*The National Science Foundation and National Institutes of Health supported this work.*

*Story: Ananya Sen*
*Photo: L. Brian Stauffer*



*A team including, from left, postdoctoral researcher Ziyuan Song, Professor Jiajun Cheng and graduate students Tianrui Xue and Lazaro Pacheco, developed a new method that streamlines the construction of amino acid building blocks that can be used in a multitude of industrial and pharmaceutical applications.*



*Left: Polymers undergo a structural change when irradiated with light switching from low to high thermal conductivity.*

# Controlling thermal conductivity

## OF POLYMERS WITH LIGHT

In a new study, researchers at the University of Illinois at Urbana-Champaign have designed and demonstrated a novel type of polymer demonstrating a switchable thermal conductivity controlled by light. The material has the potential to route the conduction of heat on-demand and enable new, smarter, ways to manage heat.

The findings are reported in *Proceedings of the National Academy of Sciences.*

"Polymers are used extensively in engineered systems, but these materials have almost always been considered thermally static. Discovery of polymers that can be optically triggered to quickly switch between thermally conducting and insulating states will open up entirely new opportunities in thermal engineering," explained Paul Braun, a materials science and engineering (MatSE) professor and director of the Illinois Materials Research Laboratory.

"To the best of our knowledge, this is the first observation of a light-triggered reversible crystal-liquid transition in any polymeric material. The particularly notable finding in this study is the fast, reversible 3-fold change in thermal conductivity associated with the phase transition," explained Jungwoo Shin, a MatSE Ph.D. student.

The thermal switching polymer developed by the research team demonstrates a powerful control of the thermophysical properties of a polymer in response to light. This ability originates from a photo-responsive molecule, azobenzene, which can be optically excited by ultraviolet (UV) and visible light.

"We synthesized a complex polymer functionalized with light-responsive azobenzene groups. By illuminating with UV and visible light, we could change the shape of the azobenzene group, modulate interchain bonding strength and drive a reversible transition between crystal and liquid," said Jaeuk Sung, a MatSE Ph.D. student.

To capture the thermal conductivity transitions of azobenzene polymers under light illumination, the Illinois research team used a technique called time-domain thermoreflectance (TDTR) developed by David Cahill, a MatSE professor.

"The way heat is carried in polymers is related to the diffusion of vibrational modes. In ordered crystals, these vibrational modes travel much farther than what is observed in disordered liquids. As a result, an extreme change in molecular ordering of the polymer can significantly alter the thermal conductivity," Cahill said.

This extreme change in macromolecular ordering, e.g., crystal-to-liquid, is rare in nature, and has not been reported previously for any polymer system in response to light. Thus, unravelling the mechanism of the light-triggered phase transition was critical to understand the polymer's unique behavior.

"We could observe that, upon light exposure, this material quickly switches from one state to another with dramatically distinct heat transport properties. We used synchrotron-based x-ray scattering to elucidate the structure associated with each state during the transformation, closing the synthesis-characterization-function loop for this sophisticated polymer," added MatSE professor Cecilia Leal.

"Keeping an electrical device warm is as equally important as keeping it cold. Materials with such switchable thermal conductivity would enable ways to keep electrified systems safe, reliable and efficient even under extreme conditions." explained Andrew Alleyne, the director of the National Science Foundation (NSF) sponsored Engineering Research Center for Power Optimization of Electro-Thermal Systems (POETS), which supported this work, and a professor in Mechanical Science and Engineering at Illinois.

"The ability to rapidly switch the thermal properties of a polymer by exposure to light opens up exciting new routes for control of thermal transport and energy conversion at the molecular level," added Nancy Sottos, a MatSE professor.

This finding provides a striking example of how light can be used to control the thermal conductivity of polymers. A better understanding of the physical relationship between thermal conductivity and macromolecular ordering would also help push the limits of traditional polymers.

*Additional co-authors of this article include Minjee Kang and Xu Xie (Illinois), Byeongdu Lee (Argonne National Laboratory), and Kyung Min Lee and Timothy White (Air Force Research Laboratory).*

*This work was supported by the NSF and the Air Force Office of Scientific Research.*





# MATERIAL **Differences**

Since her childhood in rural Portugal, Cecilia Leal has been driven by a deep sense of curiosity about the world.

In her chosen field of materials science, this curiosity about the fundamental nature of things continues to serve Leal well: earlier this year, she received a Campus Distinguished Promotion Award in recognition of her accomplishments and was promoted to associate professor of materials science and engineering.

While some in this field study hard alloys or ceramics, Leal focuses on soft, biological matter. The Leal lab aims to understand how biological and biomimetic materials self-assemble on an atomic and molecular level.

"What we really like to do is to investigate the materials' properties. What I mean with that is how flexible something is, what kind of configuration the molecules take, where the atoms are, what the molecules are doing," explained Leal, who is also a Racheff Faculty Scholar. "If we know what a material is doing in terms of structure, that directly correlates to its function."

Her work involves pure science, but also bridges chemistry, physics and engineering. Recent publications stemming from the Leal Lab offer a glimpse into what materials science encompasses. The team studied lipid cell membranes, the thin sheets that surround cells and help control both the cells' function and the way they interact with other materials.

"The membrane's thickness and the atoms and molecules that go into it, its mechanical properties and its ability to be perforated or to expand and to contract or change structure—it's those properties that determine the many functions that the cells have," Leal explained.

Using microscopy, X-ray and spectroscopy techniques, the team characterized the intermolecular interactions happening within these membranes and then recreated biomimetic versions in a lab setting.

"We're sort of mimicking naturally occurring materials and trying to copy their properties," explained Leal. A better understanding of biological phenomena is key in materials science, she added.

"If you want to design better filtration membranes, look at a cell membrane, because they are really selective. If you want some make a material that will harvest the energy of the sun and convert it into another type of energy, well maybe you want to look at plants or mitochondria, because that's exactly what they do."

Though she does not work with patients or pharmaceutical companies directly, Leal is interested in the biotechnological and medical applications of her work. For example, if you want to fight a virus, first you have to examine the biomaterials that constitute that virus.

"A virus has the ability to enter our body, replicate really quickly and inject its DNA into our healthy cells," Leal said. If we could design a material that emulates that process but that carries a benign DNA, "we might be able to inject material that can repair a cell that has been compromised with some genetic disease, for example."

This is just one example of how multidisciplinary materials science can be.

"If I want to do something that has to do with cells, then I need to be talking to cell biologists; if you want to do flexible electronics, which is an emerging field in materials science, you really need to learn your electronic materials then you need to be talking to polymer scientists."

Leal is as passionate about teaching as she is about her research, and her love of the classroom dates back to her own college experience.

New teaching challenges also bring learning opportunities for Leal, who has received several campus teaching awards in recent years. During her Biomolecular Materials Science course in the spring, she spends a lot of time explaining complex molecular concepts in understandable ways.

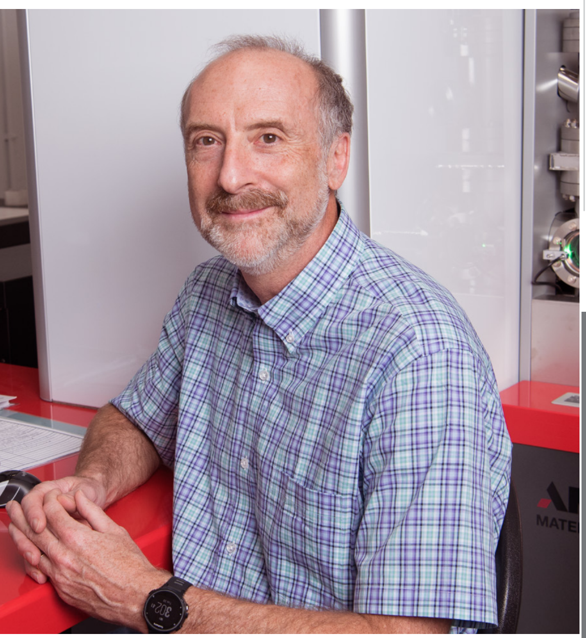
A classic example: "DNA is a very long molecule. If we add up all the DNA pieces in our bodies, it would reach to the moon and back in terms of length, and yet it fits inside really tiny cell nuclei," Leal said. Once a class has grasped a concept, she shows them an example of how that concept was used to create or adapt a material, whether that is soft matter like DNA or something a little more tangible—like a space shuttle.

Whether it's building a better rocket ship or creating biomaterials that can help cure disease on a cellular level, materials science remains central to our understanding of the world.

*Story: Daniel F. Le Ray*
*Photo: Steph Adams*

## ▼ Bellon Group

The Bellon research group focuses on materials driven into non-equilibrium by external forcing such as charged particle irradiation and plastic deformation. These systems display an intrinsic ability to self-organize at the nanoscale. The research makes uses of experiment, advanced characterization by electron microscopy and atom probe tomography, theory, modeling and atomistic simulations to understand and predict these microstructure evolutions. We are specifically studying how self-organization can lead to self-adapting materials with dramatically improved performances.

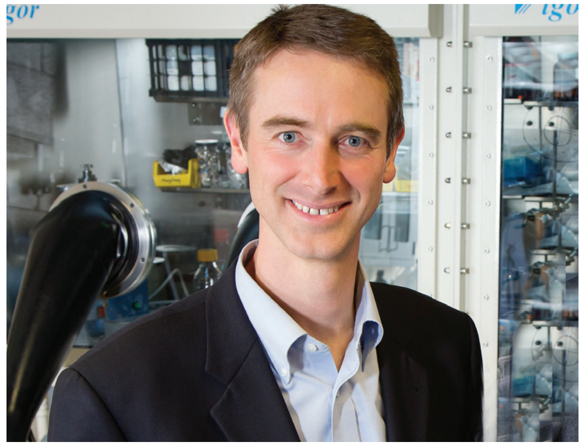


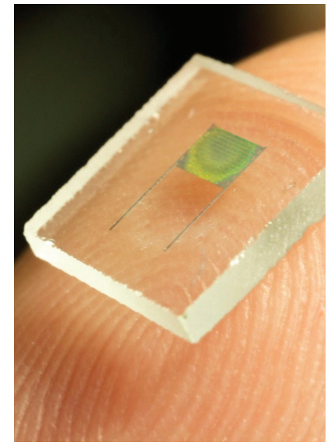
**Publications**

"Design Principles for radiation-resistant solid solutions." *Phys. Rev. B* doi.org/10.1103/PhysRevB.95.174102

"Novel mechanism for order patterning in alloys driven by irradiation." *Phys. Rev. B* doi.org/10.1103/PhysRevB.96.104108

"Wear Resistance of Cu/Ag Multilayers: A Microscopic Study." *ACS Appl. Mater. Interfaces.* doi.org/10.1021/





## ▲ Braun Group

The Braun team of engineers, chemists, and physicists is leading the discovery of new materials and structures for optics, rechargeable batteries, sensors, electrical machines, and coatings. Recent discoveries include new high-performance materials for rechargeable batteries, optical waveguides, and sensing toxic gasses. For example, a 3D structured silicon-based battery anode discovered by the Braun group stores three times more energy per unit volume than a conventional battery anode. As a central unifying theme, the Braun group uses advanced methods in polymer synthesis, self-assembly, and electrodeposition to form these materials.

**Publications**

"Modulating Noncovalent Cross-links with Molecular Switches." *J. Am. Chem. Soc.* doi.org/10.1021/jacs.8b12762

"Light-triggered thermal conductivity switching in azobenzene polymers." *PNAS.* doi.org/10.1073/pnas.1817082116

## ▼ Cahill Group

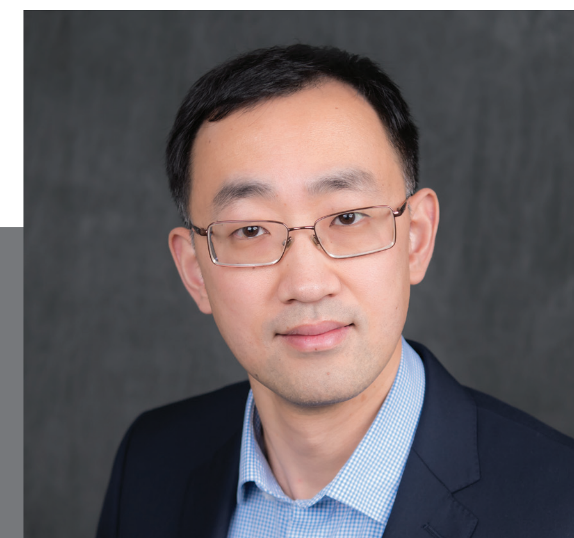
The Cahill group studies the basic science of heat, spin, charge and mass transport; and develops new materials for applications in thermal management, information technology, energy conversion, and separations. In materials, heat can be carried by lattice vibrations, electrons, and spin-waves. The lifetime of these excitations has a complex dependence the microstructure of materials; and at nanometer length scales and picosecond time scales, the coupling of heat between various excitations becomes a controlling factor. The Cahill group recently discovered pure currents of spin that are generated by a flux of heat passing through a ferromagnetic, the spin-dependent Seebeck effect.

**Publications**

"Thermal spin-transfer torque driven by the spin-dependent Seebeck effect in metallic spin-valves." *Nature Physics.* doi.org/10.1038/nphys3355

## ▼ Cao Group

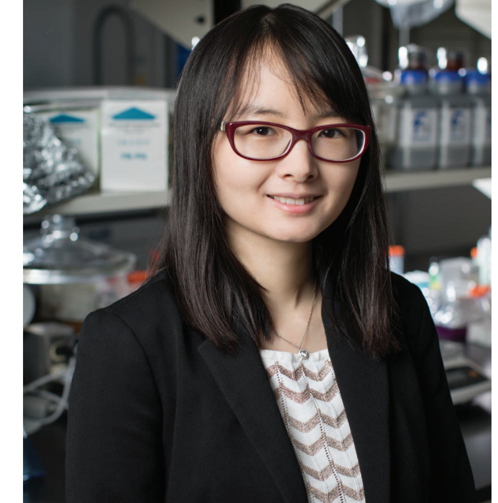
The Cao group focuses on exploiting new materials and processing techniques to realize electronic and optoelectronic devices and systems with unprecedented performance, power efficiency, and form factors. On one end, the group is pushing the limit of device scaling to answer the question about how small we can make transistors and memory cells. One the other end, we are expanding the boundary of electronics to meet the challenge of making them become more ubiquitous and more integrated with our daily life. The Cao lab recently demonstrated the smallest complete transistor with merely 40 nm footprint, and large-area flexible electronic circuits with nanosecond stage delays.



**Publications**

"Carbon nanotube transistors scaled to a 40-nanometer footprint." *Science.* doi.org/10.1126/science.aan2476

"Flexible CMOS integrated circuits based on carbon nanotubes with sub-10 ns stage delays." *Nature Electronics.* doi.org/10.1038/s41928-018-0038-8



## ▲ Chen Group

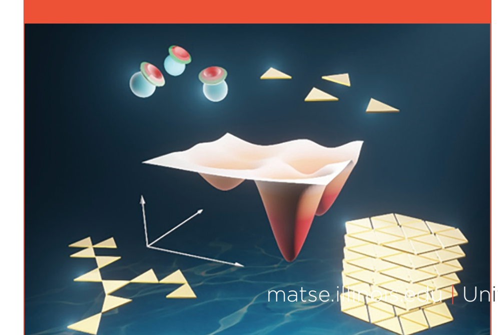
The Chen group members are "film-makers." They videotape how tiny machineries of materials and living cells move, interact, assemble, and transform in a liquid medium to perform their functions. Sometimes atomic resolutions are involved to track the paths of ions and atoms in charge conduction or chemical reactions. They also utilize deep learning-based analysis to extract the underlying physical rules encoding such dynamics. The systems are diverse, ranging from batteries, separation membranes, colloids to membrane proteins.

**Publications**

"Hierarchical self-assembly of 3D lattices from polydisperse anisometric colloids." *Nature Communications.* doi.org/10.1038/s41467-019-09787-6

"Imaging the polymerization of multivalent nanoparticles in solution." *Nature Communications.* doi.org/10.1038/s41467-017-00857-1

*Below: Reconfigurable nanoscale soft materials.*



## ▼ Cheng Group

The Cheng group focuses on developing advanced synthetic biomaterials and nanomaterials for disease treatment. We are specifically interested in rational design of biomaterials for cancer, antimicrobial and other biomedical applications. We demonstrated in vivo cell labeling via Click chemistry, a technology alternative to antibody-based targeting. We advanced the synthesis of protein-like polypeptides through open-air ring-opening polymerization. We also developed size-controlled polymeric nanomedicine for drug and gene delivery application. We train students at the interface of synthetic/polymer chemistry, biology, and materials science and engineering.

**Publications**

"Synthesis of polypeptides via bioinspired polymerization of in situ purified *N*-carbohydrates." *PNAS.* doi.org/10.1073/pnas.1901442116

"Selective in vivo metabolic cell-labeling-mediated cancer targeting." *Nat Chem Biol.* doi.org/10.1038/nchembio.2297

"Investigating the optimal size of anticancer nanomedicine" *PNAS.* doi.org/10.1073/pnas.1411499111

## Dillon Group

Dillon's group studies grain boundary, interface, and defect related structure-property relations, with an emphasis on developing novel in situ characterization methodologies to investigate such problems. Due to the complexity of interfaces their thermodynamics and kinetics remain poorly understood, particularly in complex and service environments. In the past few years, the group developed and demonstrated the first in situ TEM characterization of Li-ion batteries in commercial electrolyte, and the first in situ XPS and in situ AES characterization of surface reactions in Li-ion batteries, which provided new insights into the mechanisms for Li-ion battery degradation. Recently, we have been investigating the role of nanostructuring in affecting irradiation induced creep and interfacial mechanic using in situ TEM based methods. We have also developed novel ultrahigh temperature in situ microscale testing methods to measure, for the first time, grain boundary diffusion mediating point defect formation enthalpies, migration enthalpies, and activation volumes.

**Publications**

"High temperature irradiation induced creep in Ag nanopillars measured via in situ transmission electron microscopy." *ScienceDirect.* doi.org/10.1016/jscriptamat.2018.01.007

"The influence of dopants and complexion transitions on grain boundary fracture in alumina." *ScienceDirect.* doi.org/10.1016/j.actamat.2017.09.002

"$LiMn_2O_4$ Surface Chemistry Evolution during Cycling Revealed by *in Situ* Auger Electron Spectroscopy and X-ray Photoelectron Spectroscopy." *ACS Appl Mater Interfaces.* doi.org/10.1021/acsami.7b10442

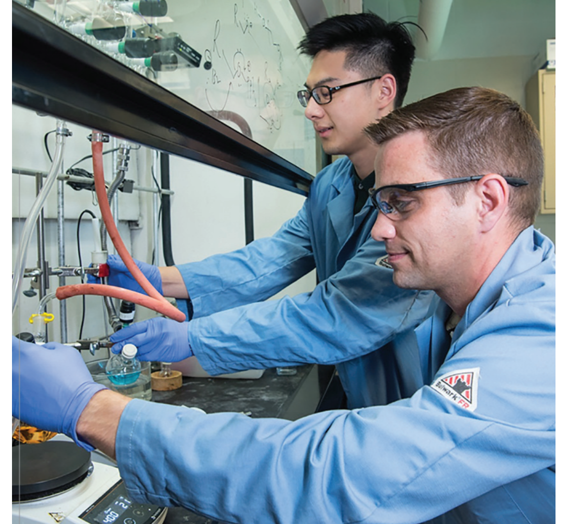
"Insights into Solid-Electrolyte Interphase Induced Li-Ion Degradation from in Situ Auger Electron Spectroscopy." *J. Phys. Chem. Lett.* doi.org/10.1021/acs.jpclett.7b02847

## Hoffmann Group

The Hoffmann research group works at the intersection between materials science, condensed matter physics, and electrical engineering to create, explore, and derive new insights and functionalities in magnetic materials. We synthesize thin film heterostructures and more complex lithographically patterned device concepts with the goal to understand and control their physical, chemical and metallurgical properties. A special focus is on novel phenomena related to spin transport and spin dynamics, where we recently demonstrated spin current generation in antiferromagnets, and electrically driven topological spin textures (magnetic skyrmions).

**Publications**

"Opportunities at the Frontiers of Spintronics." *Phys. Rev. Applied.* doi.org/10.1103/PhysRevApplied.4.047001



## Evans Group

The Evans group develops new materials for energy storage, membrane separations, and recyclable plastics. Most of our projects focus on understanding the properties of charged polymers and how they are impacted by the presence of a charged interface (electrode). To study the interfacial physics of ionic polymers, we combine materials synthesis with advanced spectroscopic methods to probe materials with nanoscale resolution. We then use this fundamental insight to understand how to design materials at the molecular scale which can improve their performance.

**Publications**

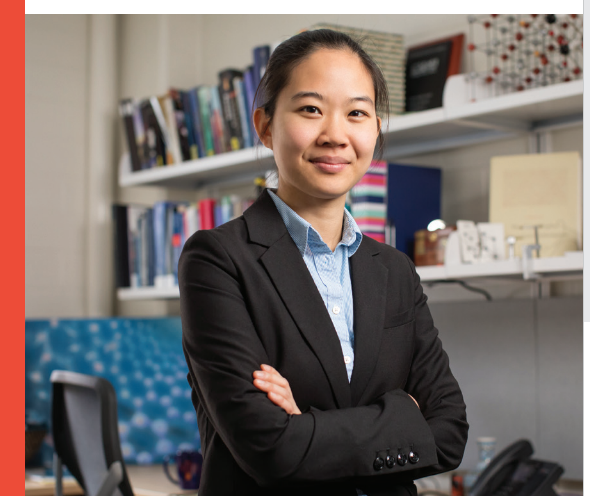
"Effect of Network Architecture and Linker Polarity on Ion Aggregation and Conductivity in Precise Polymerized Ionic Liquids." *ACS Macro Lett.* doi.org/10.1021/acsmacrolett.9b00293

"Precise Network Polymerized Ionic Liquids for Low-Voltage, Dopant-Free Soft Actuators." *Advanced Materials Technologies.* doi.org/10.1002/admt.201800535

"Molecular Design of Precise Network Polymerized Ionic Liquid Membranes for Toluene/Heptane Separations." *Ind. Eng. Chem. Res.* doi.org/10.1021/acs.iecr.9b03059

## Huang Lab

The Huang lab is a nanoscience and electron microscopy group that seeks to understand the structure and properties of materials, one atom at a time, and use this knowledge to aid in the design of new nanomaterials and devices. To do so, the Huang group develops new techniques using the latest generation of aberration-corrected scanning transmission microscopes to study systems such as 2D materials, nanoparticles, and molecular crystals. Her group recently showed that stacks of graphene can be made incredibly soft, for applications such as flexible, high-quality electronics.



**Publications**

"A Review on mechanics and mechanical properties of 2D materials- Graphene and Beyond." *Extreme Mechanics Letters.* doi.org/10.1016/j.eml.2017.01.008

"Quantitative Imaging of Organic Ligand Density on Anisotropic Inorganic Nanocrystals." *Nano Lett.* doi.org/10.1021/acs.nanolett.9b02434

"Engineering the Structural and Electronic Phases of $MoTe_2$ through W Substitution." *Nano Letters.* doi.org/10.1021/acs.nanolett.6b04814

## Kriven Group

The Kriven research group has three main directions in the basic science and engineering of ceramics:

**(i)** Low energy synthesis of soft agglomerates of nano powders of oxides, carbides, nitrides

**(ii)** In situ, in air, synchrotron powder diffraction to 3,200°C of ceramics (oxides, carbides, nitrides) to determine phase diagrams, thermal expansions, phase transformations, solid state chemical reactions

**(iii)** Synthesis, microstructure characterization and mechanical property evaluation of geopolymers and geopolymer composites, (as well as alkali activated materials) are ceramics made from liquids under ambient conditions. 4D printing of geopolymer composites which are capable of 1200°C and have good freeze-thaw resistance.

**Publications**

"Synthesis of $NaTi_2(PO_4)_3$ by the Organic Entrapment Method and its Thermal Expansion Behavior." *J. Am. Ceram. Soc.* doi.org/10.1111/jace.14420

"In situ Determination of the $HfO_2$-$Ta_2O_5$ Temperature Phase Space up to 3000°C." *Journal of the American Ceramic Society.* doi.org/10.1111/jace.16271

"Geopolymer-Based Composites." *Ceramic and Carbon Martix Composites.* doi.org/10.1016/B978-0-12-803581-8.10068-2

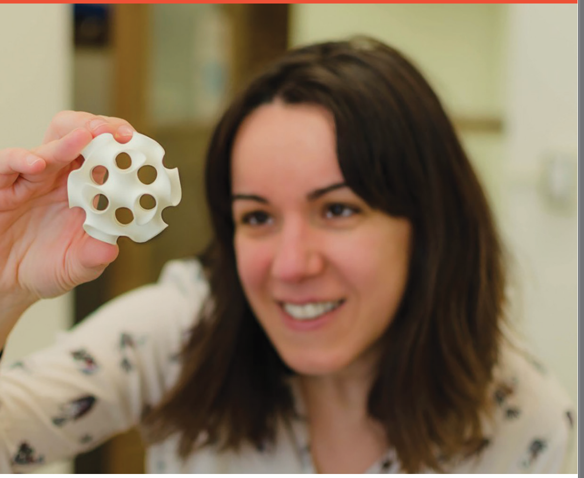
## Krogstad Group

The Krogstad research group is interested in how materials subject to extreme environments evolve—examples include metal alloys found in the heat exchangers of oil refineries, ceramics subject to radiation damage, thermal protection systems for space vehicles, and electroceramics or shape memory alloys found in high performance actuators and sensors. Usually such combinations of high temperatures, stresses and aggressive chemical environments lead to adverse changes in the structure and the properties of functional and structural materials, but these are also common parameters used to process materials and establish desirable properties! With this perspective we aim to leverage extreme environments to affect positive materials evolution in service.

**Publications**

"Effect of surface chemistry and roughness on the high temperature deposition of a model asphaltene." *ACS Energy & Fuels.* doi.org/10.1021/acs.energyfuels.9b00386

"Influence of a nanotwinned, nanocrystalline microstructure on aging of a Ni-25Mo-8Cr superalloy." *Acta Mater.* doi.org/10.1016/j.actamat.2018.07.007



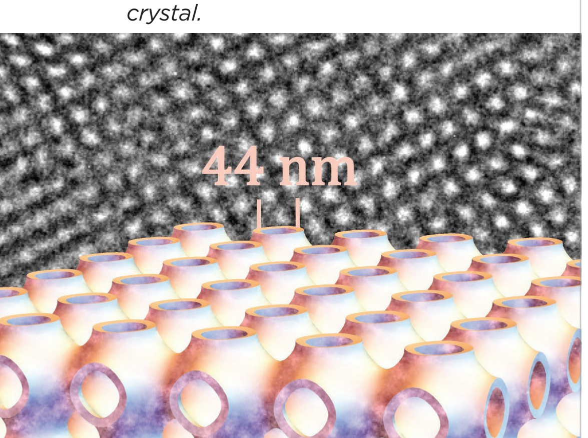
## ▲ Leal Group

The Leal team of materials scientists, physicists, and chemists is advancing the understanding of biomolecular matter organization and generating new materials for therapy and technology. One example is the study of lipid membranes that, in nature, can evolve from two-dimensional sheets into tubular, multilayered, and porous aggregates. What is the origin and function of such complexity? Can we artificially synthesize analogous materials? The Leal lab recently demonstrated that nanoparticles having membranes folded into grid-like nanostructures host nucleic acids and therapeutically deliver genes to cells with unprecedented efficiency.

**Publications**

"Cuboplexes: Topologically Active siRNA Delivery." *ACS Nano.* doi.org/10.1021/acsnano.5b03902

*Below: Cryo-EM image of lipid membranes forming a regular lipid-water-lipid-water pattern in a large crystal.*




## ▶ Perry Group

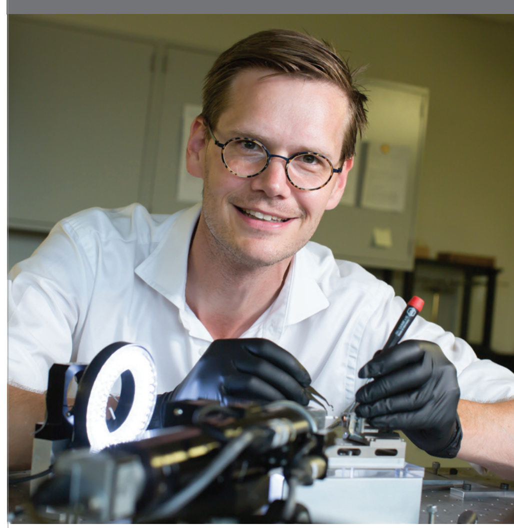
The Perry group investigates functional oxide materials that enable energy conversion/storage, sensing, actuation, and electronics, and are often used in extreme environments. We seek to understand and control point defect concentrations and kinetics in the oxides in order to tailor their electro-chemo-mechanical behavior, including ionic conductivity, surface catalytic activity, and chemical expansion. To achieve this goal, we develop synthetic approaches for complex oxide thin films and ceramics and in situ characterization methods to identify structure-property relationships over a wide temperature and gas atmosphere range.

**Publications**

"Emergence of Rapid Oxygen Surface Exchange Kinetics during in Situ Crystallization of Mixed Conducting Thin Film Oxides." *ACS Appl. Mater. Interfaces.* doi.org/10.1021/acsami.8b21285

"In situ optical absorption studies of point defect kinetics and thermodynamics in oxide thin films." *Advanced Materials Interfaces.* doi.org/10.1002/admi.201900496

"Modifying grain boundary ionic/electronic transport in nano-Sr and Mf- Doped La $GaO_{3-\delta}$ by sintering variations." *Jour. Electrochem Soc.* doi.org/10.1149/2.0151910jes

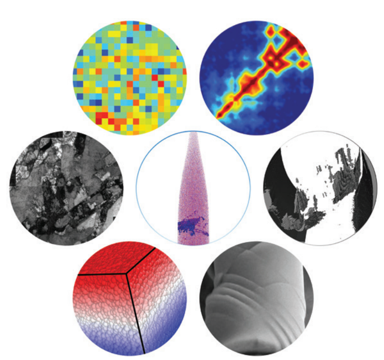


## ◀ Maass Group

We do the metals! The Maass research group in interested in structure-property-processing relationships of metallic materials. We advance the knowledge of fundamental structural processes in both crystalline and amorphous metals, identify new mechanisms, and use out-of-equilibrium processing to generate novel microstructures. Our current focus areas include collective defect dynamics in crystals, aging and rejuvenation of metallic glasses, and sub-millisecond thermal processing. We enjoy working closely together with theory and materials simulation to gain a deeper understanding of our experimental results.

**Publications**

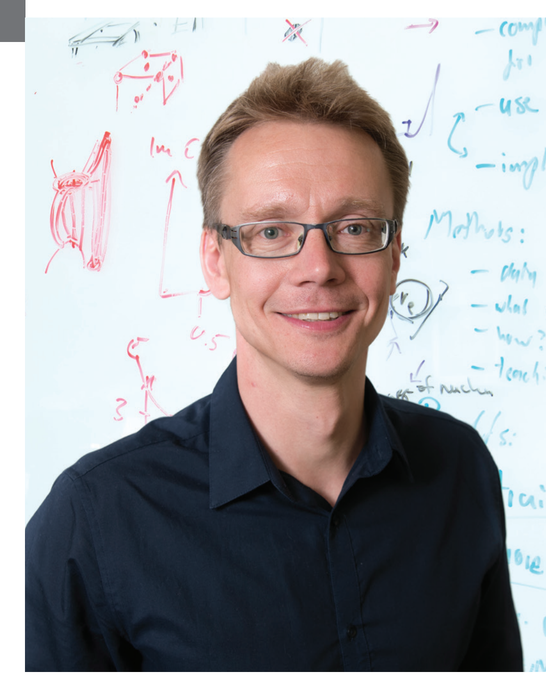
"Nontrivial scaling exponents of dislocation avalanches in microplasticity." *Phys. Rev. Materials* doi.org/10.1103/PhysRevMaterials.2.120601



*Above: Structure-property relationships from the bulk to the nano-scale. Credit: Amlan Das.*

## ▼ Schleife Group

Materials are real-world realizations of quantum mechanics; novel states emerge from coupling of charge, spin, and lattice degrees of freedom, and external excitations. The Schleife group (http://schleife.matse.illinois.edu) uses advanced computation to predict this interplay for materials in electronic/energy applications and under extreme conditions. We study electronic excitations, triggered by interaction with radiation, and subsequent femto-second relaxation processes. Modern first-principles simulations are of high fundamental interest and important for materials characterization, e.g. for electronic, optical, and photonic applications as well as nanomaterials. Amongst our most recent successes is the investigation of hot-electron mediated ion diffusion in materials.



**Publications**

"Hot-Electron-Mediated Ion Diffusion in Semiconductors for Ion-Beam Nanostructuring." *Nano Lett.* doi.org/10.1021/acs.nanolett.9b01214

"Pushing the frontiers of modeling excited electronic states and dynamics to accelerate materials engineering and design." *Comput. Mater. Sci.* doi.org/10.1016/j.commatsci.2019.01.004

## ▲ Schweizer Group

The Schweizer group performs theoretical research at the interface of materials science, soft condensed matter physics and physical chemistry. We develop, and apply to experiment, new predictive microscopic equilibrium and nonequilibrium statistical mechanical theories of the structure, thermodynamics, phase behavior, dynamics and rheology of soft materials in the liquid, suspension, liquid crystalline, nanocomposite, thin film, rubber network, and amorphous solid states. Present emphasis is on the nonlinear rheology of entangled synthetic and biological polymer liquids, activated dynamics and viscoelasticity of glass and gel forming bulk and confined colloidal, polymeric and molecular systems, and transport of penetrants, nanoparticles and ions in soft materials.

**Publications**

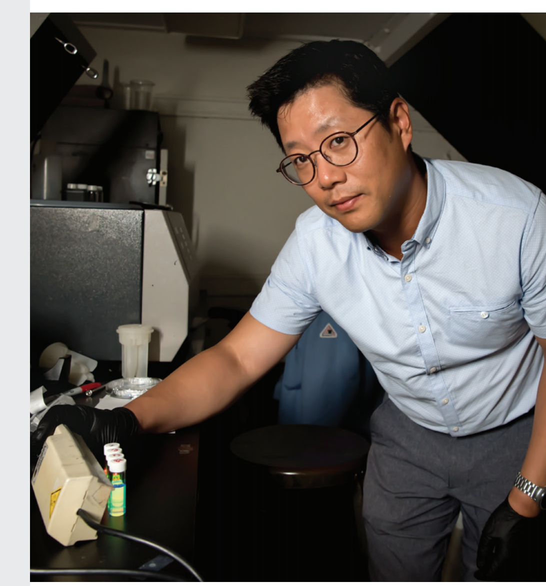
"Elastically cooperative activated barrier hopping theory of relaxation in viscous fluids. II. Thermal liquids." *J. Chem. Phys.* doi.org/10.1063/1.4874843

"Consequences of Delayed Chain Retraction on the Rheology and Stretch Dynamics of Entangled Polymer Liquids under Continuous Nonlinear Shear Deformation." *Macromolecules.* doi.org/10.1021/acs.macromol.8b00671

"Dynamic Gradients, Mobile Layers, Tg Shifts, Role of Vitrification Criterion, and Inhomogeneous Decoupling in Free-Standing Polymer Films." *Macromolecules.* doi.org/10.1021/acs.macromol.8b01094

## ▼ Shim Group

The ability to efficiently separate, combine, and direct charge carriers is central to all of electronics, photovoltaics, and optoelectronics. Interfacing different semiconductor materials with atomic precision is an obvious route to achieving such capabilities. To do so through widely-accessible and cost-effective means is not. The Shim Research Group is developing novel semiconductor materials with nanoscale precision through solution chemistry for next-generation photovoltaic, display, and lighting technologies. For example, solution-processable semiconductor nanorods recently developed in the Shim lab are enabling large-area, patternable LED arrays to both emit and harvest light without additional components, thus facilitating use of clean, renewable energy sources and reducing energy consumption.



**Publications**

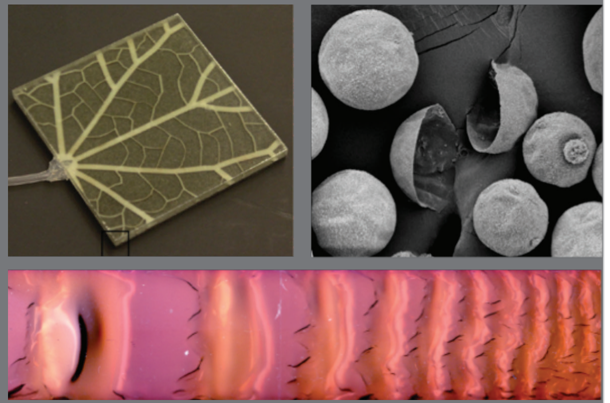
"Double-heterojunction nanorod light-responsive LEDs for display applications." *Science.* doi.org/10.1126/science.aal2038

## Statt Group

As a new faculty member, I hope to build a diverse team of materials scientists, physicists, and chemists in the next years to advance the development of new functional polymeric materials for applications in transportation, energy, and health. For example, for self-healing and sensing polymers, it is important to investigate how exactly are macroscopic forces transmitted to the microscopic scale in heterogeneous materials. We will use computational and theoretical tools to gain a fundamental understanding of those microscopic properties and processes. This knowledge will help in designing new and improved polymeric materials.

## Sottos Group

Inspired by autonomous function in biological systems, the Sottos group develops polymers and composites capable of self-healing and regeneration, self-reporting, and self-protection. A key aim of her collaborative research program with the Autonomous Materials Systems group at the Beckman Institute is to exploit processing methods used in nature such as morphogenic patterning to achieve unprecedented material architectures and mechanical responses in these complex materials. Sottos is co-founder of Autonomous Materials Inc. (AMI), holds 21 U.S. Patents and has authored over 230 journal papers.



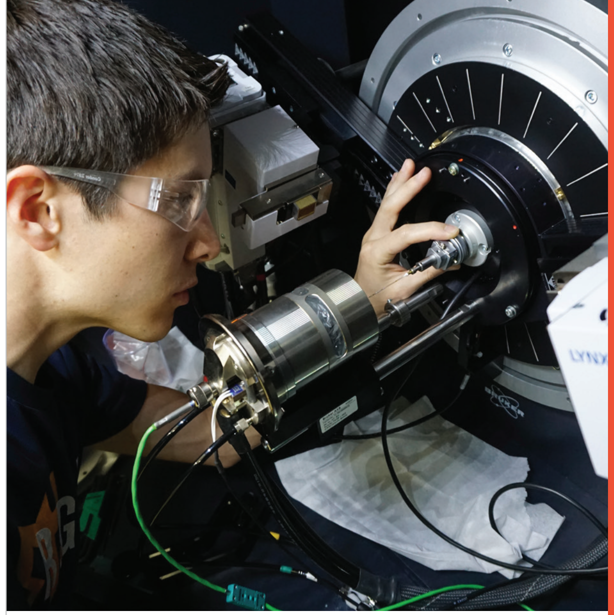
**Publications**

"Polymers with autonomous life-cycle control." *PubMed.* doi.org/10.1038/nature21002

"Restoration of Large Damage Volumes in Polymers." *Science.* doi.org/10.1126/science.1251135

"Autonomic healing of polymer composites." *Nature.* doi.org/10.1038/35057232

*Above: Examples of autonomous materials systems: (top left) A bio-inspired vascular network enables self-cooling of a structural composite, (top right) microcapsules containing a damage indicating payload for coatings, (bottom) morphogenic pattern formation in a thermosetting polymer.*

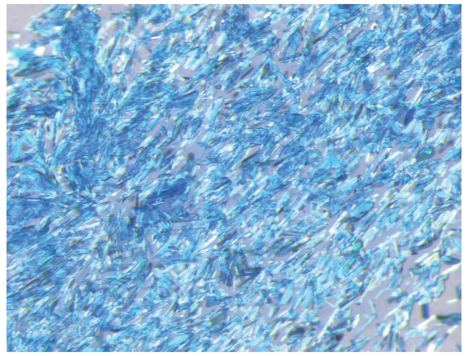


## Shoemaker Group

The Shoemaker group uses chemistry—"How can I get atoms to arrange this way in a crystal?"—to create new functions for physicists and engineers—"How can I use that crystal to make a magnetic device?" We utilize the entire periodic table to make unexplored materials that are poised on the edges of stability, so that a subtle stimulus (light, magnetism, or electrical current) creates a large response. One of our favorite tricks is to discover new materials by crystallizing them in an X-ray beam at temperatures up to 1000°C.

**Publications**

"Uncovering anisotropic magnetic phases via fast dimensionality analysis." *Phys. Rev. Materials.* doi.org/10.1103/PhysRevMaterials.2.094403



*Above: True-color optical microscopy of single crystals of the new copper coodination compound discovered by undergraduate Jai Sharma and graduate student Zhelong Jiang in the Shoemaker group.*

## Zhang Group

The Zhang Group works at the interface between solids and liquids. We study both the fundamental atomic structure of the solvation layers at liquid-solid interfaces, and the related applications in energy conversion technology. We recently developed an atomic force microscopy (AFM) technique that can image the three-dimensional electric double layer structure at liquid electrolyte – solid electrode interfaces. We achieved atomic resolution images in liquid and in operando conditions with electric voltage applied to the electrodes. This state-of-the-art technique will offer unprecedented insights into the atomic scale mechanism of electrocatalysis, molecular charging, and surface redox reactions, critical for fuel cells, supercapacitors, and batteries.

**Publications**

"3D Mapping of the Structural Transitions in Wrinkled 2D Membranes: Implications for Reconfigurable Electronics, Memristors, and Bio-Electronic Interfaces." *ACS Appl. Nano Mater.* doi.org/10.1021/acsanm.9b01232

"Nanoimaging of Organic Charge Retention Effects: Implications for Nonvolatile Memory, Neuromorphic Computing, and High Dielectric Breakdown Devices." *ACS Appl. Nano Mater.* doi.org/10.1021/acsanm.9b01182

## Trinkle Group

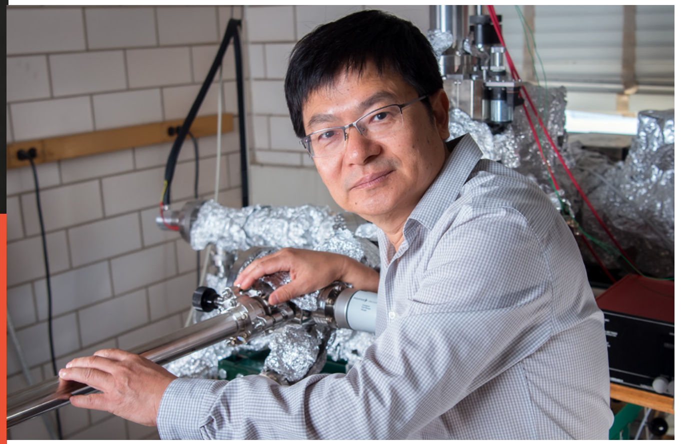
Dallas R. Trinkle's research group focuses on computational methods for studying defects in materials at the atomic-scale using density-functional theory, and novel techniques to understand problems in mechanical behavior and transport. This has led to *ab initio* predictions of solid-solution softening in molybdenum, solute strengthening and softening in magnesium alloys, pipe diffusion of hydrogen in palladium, diffusion of oxygen in titanium and solutes in magnesium, among others. Most recently, he developed a different approach for modeling diffusion that unifies disparate methods, and enables entirely new computational methods.

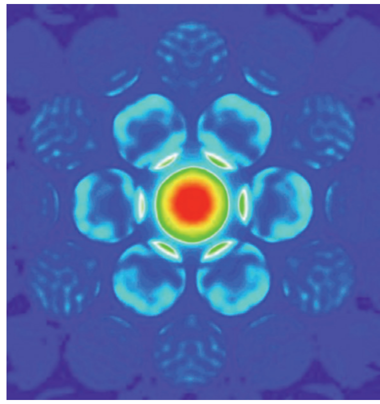
**Publications**

"Variational Principle for Mass Transport." *Phys. Rev. Lett.* doi.org/10.1103/PhysRevLett.121.235901

## Zuo Group

The research in Prof. Zuo's group at University of Illinois, Urbana-Champaign involves the study of structure-property relationships at high spatial and time resolution, and the development of electron diffraction and imaging for novel materials characterization. Currently, the group is studying new materials of high entropy alloys, Li and Mg batteries and transistor devices. On the Mg battery research, the group is collaborating with researchers at University of Illinois and Shell Company to develop new cathode materials based on fundamental understanding of chemical transformation caused by Mg insertion. On high entropy alloys, the group is examining the strengthening mechanism by systematically examining the nanoscale strain and stress relationship in these materials.





**Publications**

"Dislocation avalanche mechanism in slowly compressed high entropy alloy nanopillars." *Communications Physics.* doi.org/10.1038/s42005-018-0062-z

"Effects of Particle Size on $Mg^{2+}$ Ion Intercalation into λ-$MnO_2$ Cathode Materials." *Nano Lett.* doi.org/10.1021/acs.nanolett.9b01780

*Above: Tetragonal symmetry of Barium Titanate as recorded by convergent beam electron diffraction (CBED) along the pseudo-cubic [111] zone axis.*

“MY TRAINING AT MATSE LAID DOWN A VERY SOLID FOUNDATION FOR MY CAREER IN SEMICONDUCTOR INDUSTRY. I ESPECIALLY APPRECIATED THE UNIQUE INTERDISCIPLINARY COLLABORATIVE RESEARCH ENVIRONMENT WITHIN CSL AND MRL.”

# Zhiyong Ma

## 2019 DISTINGUISHED ALUMNI AWARD

Zhiyong Ma received his PhD from Materials Science and Engineering in 1994, conducting his research as a member of Professor Les Allen's group. Prior to coming to Illinois, Dr. Ma received his bachelor's degree from Shanghai University in 1984 and masters in Materials Science and Engineering from Purdue in 1990.

“Working for a very driven assistant professor can be a plus. I was Professor Allen's first PhD student. Both he and I had very clear motivations. I wanted to be out on time while he needed a tenure. I was lucky enough to get all the attentions from Les. We worked together on the experimental designs and we discussed and revised papers together. We saw each other seven days a week,” said Ma. “Les is results driven, a bit impatient, and very adept at quickly translating something conceptual to simple apparatus. His group developed some of the unique research capabilities for studying nanoscale materials. We all benefitted greatly from his very demanding training. One thing worth to be brought up is that Les gave me the free rein to define my thesis project and allowed me to pursue other research interest and collaboration. This not only helped develop my research style but also expanded my research scope and adaptability.”

Currently, Ma is with Intel as Vice President of their Technology and Manufacturing Group and Director of their Technology and Manufacturing Labs. Ma is responsible for all aspects of labs operation in support of silicon and assembly technology development and manufacturing, product fault diagnostics, and silicon and platform benchmarking.

“My training at MatSE laid down a very solid foundation for my career in semiconductor industry. I especially appreciated the unique interdisciplinary collaborative research environment within CSL (coordinated science laboratory) and MRL (materials research laboratory). It promoted very productive collaborations and led to numerous scientific breakthroughs. I still use some of methodology I learned then to my organization whenever I can.”

Additionally, Ma is engaged with universities around the Pacific Northwest, helping sponsor research, hosting technical workshops, and helping students and faculty grow. Ma is an active member and currently co-chair of the AVS topical conference on Frontier for Characterization and Metrology for Nanoelectronics with NIST and IMEC.

For current students, Ma has this advice: “Follow your passion, be curious. Getting a degree is less important than developing all the necessary skills to become a competent, adaptable researcher or technologist for tomorrow's challenges. Machine learning, artificial intelligence, and autonomous driving rely heavily on continued advancement of computing power. The future of nanoelectronics is all about materials innovations. You are definitely in the right field and have a very bright future.”

# Hunter McDaniel

## 2019 YOUNG ALUMNI AWARD

Hunter McDaniel received his PhD from Materials Science and Engineering in 2011. As a graduate student in Moonsub Shim's research group, Hunter was first introduced to the material that would eventually inspire his entrepreneurial spirit—semi-conductor nanocrystals. Prior to coming to Illinois, Hunter received his bachelor's degree at the University of California-Santa Barbara in 2006, double majoring in Electrical Engineering and Physics.

After Hunter left Illinois, he joined Los Alamos National Laboratory as a post-doc from 2011-2014. Upon completing his post-doc, Dr. McDaniel founded UbiQD, Inc. and is currently the CEO.

UbiQD manufactures nanomaterials called quantum dots (QDs) and polymer composites at its facility in New Mexico. QDs are known for their near-perfect ability to convert one color of light into another. UbiQD developed a safe, low-cost, and reliable nanotechnology, and is currently applying it in greenhouses to red-shift the sun's spectrum for improved crop yield.

This platform technology has many applications beyond spectrum-optimized greenhouses, and Hunter's vision is to become the leader of the growing multi-billion-dollar QD industry.

“The big market for quantum dots is in displays. There are about $2.5 million or so TVs being sold with quantum dots in them and maybe $10 billion worth of products on the market with quantum dots. Nanotechnology is here, and it's real.”

Hunter says that about 4-5 years ago, quantum dots were an “interesting academic thing,” but they weren't in any products yet. Their first use was in lightbulbs and Christmas lights, and now almost every major TV manufacturer has a product using quantum dots.

UbiQD, Inc. figured out a way to make quantum dots, cheaper, more stable, and less toxic than the nascent stage dots. The chosen market for their specific material is agriculture. “It is a simple product we could manufacture roll to roll at scale, and the market is very accessible and growing,” says Hunter. “We love agriculture and dealing with farmers, and greenhouses are just so cool.”

Hunter says that the road to a successful business is not an easy one. Building the right team of experts, gaining creditability, and attracting financing requires persistence and the willingness to try and fail.

His advice to aspiring entrepreneurs? “Kiss a lot of frogs and throw a lot of darts. There's a lot of rejection. If you are stubborn or thick skinned, and you can keep pushing, you can get there.”


“KISS A LOT OF FROGS AND THROW A LOT OF DARTS. THERE'S A LOT OF REJECTION. IF YOU ARE STUBBORN OR THICK SKINNED, AND YOU CAN KEEP PUSHING, YOU CAN GET THERE.”

# Alumni updates

Meena Banasiak has been appointed to Board of Directors for Loaves and Fishes Community Services. Loaves & Fishes is an anti-poverty, hunger relief agency serving food and leadership services to the Naperville and DuPage areas. **2006 BS MatSE**

Paul Clem has been promoted to Distinguished Member of the Technical Staff, Sandia National Laboratories Dept. 1353. Electrical Sciences & Experiments, Dept 1353, encompasses experimental capabilities including traditional and advanced-concepts in electromagnetics, survivability related to electromagnetic pulse (EMP) and System-Generated EMP (SGEMP) environments, high-voltage sciences, high heat flux science, and advanced power systems. **1996 PHD MatSE/Ceramic Science**

Kimberly Fields now leads ATI's Flat Rolled Products Group. Ms. Fields will be responsible for all aspects of the group's business strategy, sales and operations, and functional and business line leaders, to drive growth, earnings and cash flow. ATI's leadership position as a producer of stainless-steel sheet, specialty plate, and specialty coil is backed by one of the world's most powerful mills. **1992 BS MatSE**

Leiming Li has been profiled in World Oil's "Innovative Thinkers." Li serves as R&D advisor chemist at Multi-Chem, Halliburton's specialty chemicals business. He says he is currently working on R&D projects related to novel oilfield chemicals for oil and gas well treatments. **2002 PHD MatSE**

Donna Senft has recently become Chief Scientist of the Air Force Global Strike Command at Barksdale AFB, LA. The Chief Scientist position is a Senior Level Executive position advising the Global Strike Commander and staff on critical new technologies and innovation. **1995 PHD MatSE**

Kyle Wilcoxen was promoted to Consultant, Director at Information Resources, Inc. He will continue to leverage IRI's data cloud, visualization, applications and private cloud solutions to uncover the latest consumer and shopper insights across the US and global markets. **2006 BS MatSE**

## Engineering Visionary Scholarship

**Laion Neves**, a recent graduate from the Department of Materials Science and Engineering, had dreamed of attending Illinois Engineering for a long time. Laion said, "For years I've held Illinois Engineering as one of the highest regarded programs in my mind. Attending a world class university with innovative courses has always been a dream of mine."

Laion was part of the Material Science and Engineering honors society, Keramos. One event which they host weekly called "Play with Clay," was one of Laion's absolute favorite activities. Laion has the heart of an entertainer and engaged that side of him with his work for LabEscape. LabEscape is a playground full of educational fun in the form of an escape room littered with challenges. Families and groups must work together and engage with physics-based puzzles to solve various scenarios. Laion has worked on the creation of new puzzles and in running a community science outreach program through LabEsape. Laion loved his work and his classes, specifically the lab courses. Laion says that his eight-week lab course on ceramic processing, "was by far one of my favorite classes I've ever taken." In his free time, Laion likes to play board games with his wife when they both have the time.

Laion is thankful for his scholarship support and is honored to be a recipient of the Engineering Visionary Scholarship. Laion says, "After I graduate, I plan on contributing to scholarships as I know first-hand how valuable a role they play in a student's life."

### Double your impact!

**The Engineering Visionary Scholarship (EVS) Initiative** is preparing students for a bright future by making a world-class engineering education more accessible.

Scholarship support helps The Grainger College of Engineering recruit and retain the best students, has resulted in a more diverse student body, and prepares the next generation of science and engineering leaders.

Double your impact before The Grainger Matching Challenge expires! $5 million in matching funds remain. **All qualifying gifts and commitments made to the EVS Initiative will be matched, now through December 31, 2019.**

Gifts to the EVS Initiative have an immediate impact and will support future generations of engineering students. To learn more, visit evs.grainger.illinois.edu or contact Kendra Wolf at kjwolf@illinois.edu or 217-300-7297.



# The 2019 Racheff-Intel Award Winners

## FOR OUTSTANDING GRADUATE RESEARCH IN MATERIALS SCIENCE AND ENGINEERING

Left to right: Cheng-Wei Lee, Gregory Sparks, Jaba Mitra, Aram Yoon

In memory of Ivan Racheff, a distinguished alumnus of the University of Illinois, the award is given for excellent graduate research in any sub-field to students currently enrolled in the Graduate Program of the Department of Materials Science and Engineering at the University of Illinois.

Cheng-Wei Lee (Schleife, advisor) was recognized with the Racheff-Intel Award for his work on "Hot-Electron-Mediated Ion Diffusion in Semiconductors for Ion-Beam Nanostructuring." Cheng-Wei developed a first-principles framework to bridge time scales from femto-second electron dynamics to ion diffusion. He then quantitatively studied excited-electron distributions and the emerging ion dynamics in magnesium oxide upon proton irradiation. His results point towards novel means for diffusion enhancement in semiconductors.

Gregory Sparks (Maass, advisor) was recognized with the Racheff-Intel Award for his work on "Nontrivial scaling exponents of dislocation avalanches in microplasticity." Gregory developed a novel experimental method to trace dislocation avalanches in microplasticity. He uses his data to test emerging statistical models for avalanches near the depinning transition and to search for non-trivial scaling laws that can help the development of novel statistical model in crystal plasticity.

Jaba Mitra (Cheng & Ha, advisors) was recognized with the Racheff-Intel Award for her work on "Micromanipulation of Nucleic Acids and Peptides at the Single-Molecule Level by Integrated Force-Fluorescence Spectroscopy." Jaba uses single molecule fluorescence microscopy to measure and understand the conformation and folding of DNA during transcription and replication.

Aram Yoon (Zuo, advisor) was recognized with the Racheff-Intel Award for her work on "Environmental Switching of Crystallographic Shear Plane Defects in Rutile Nanocrystals." Aram uses environmental transmission electron microscopy to study the atomic-scale structure and dynamics at the surfaces of nanocatalysts. Her work aims to understand the fundamental processes that govern the performance of catalysts used for harvesting solar energy and producing clean fuels.



Group photo on page 22: Former students of James Economy; Group photo on page 23: Family of James Economy

# Professor James Economy

## AND FAMILY ESTABLISH NAMED PROFESSORSHIP

*The James Economy Professorship will support MatSE in the recruitment of established researchers dedicated to the development of new materials for societal purposes. The Professorship was announced at a $90^{th}$ birthday celebration held in March 2019 and attended by colleagues of the past and present, former students, and family.*

### A LIFETIME OF ACHIEVEMENTS

Professor James Economy has, for nearly 60 years, been a recognized leader in the field of materials science and engineering with respect to developing new materials in key technological areas, in shaping materials education, and in developing future generations of young entrepreneurial scientists and engineers.

Dr. Economy obtained his B.S. Degree in Chemistry from Wayne State University in 1950. He received his Chemistry Ph.D. at the University of Maryland in 1954. From 1954 to 1956, Dr. Economy was a postdoctoral researcher in the Chemistry Department at the University of Illinois, Urbana-Champaign. In 1956, he joined Allied Chemical in Tonawanda, New York, and headed up a research group on the newly emerging field of polyolefins. When Allied Chemical moved to New Jersey in 1960, Economy transferred to the Carborundum Company as manager of the Chemistry Department.

During his tenure at the Carborundum Company from 1960-75, his research was selected 14 times for the IR-100 Award recognizing outstanding technical development in American industry. From 1965 to 1972, his group developed more than 20 new materials with commercial potential and brought a number of them to the marketplace (at least four of these are still available today). From 1975-89, Dr. Economy was manager of the Polymer Science and Technology Department in the Research Division of IBM, where his group achieved worldwide prominence for scientific and technological achievements. When Carborundum began to sharply reduce its research funding, Economy moved to IBM to serve as director of polymer research at the San Jose Research Laboratory.

Economy's research at IBM was gaining the notice of faculty and administrators from the University of Illinois. In 1988, the University of Illinois offered him the position of Head of the newly formed MatSE Department (a merger of the Department of Ceramic Engineering and the Department of Metallurgical and Mining Engineering), and he accepted.

"One of the first things I had to do as Department Head was to get a curriculum put together that would integrate the four areas of concentration—metals, ceramics, polymers, electronic materials," Economy said. Over the next few years, he hired around 10 faculty members, bringing a new breadth of expertise to the department. The new MatSE curriculum started in the 1991-92 academic year. In the new curriculum, MatSE students could specialize in a given material while learning about the broad spectrum of materials. Economy developed and taught two courses at the University of Illinois: an undergraduate materials synthesis course and a graduate course on polymer synthesis. The department began offering scholarships to incoming freshmen and actively recruiting top students, which resulted in an increase in the quality and number of undergraduates enrolled in MatSE. The Kiln House was renovated into state-of-the-art undergraduate laboratories. A new alumni group was established, and the MatSE Alumni Association was formed. During Economy's tenure as Head, the materials program at Illinois became one of the top three programs in the nation.

After serving as head for 11 years, Economy decided it was time to step down. Almost immediately he took the initiative to organize a successful submission for an NSF Science and Technology Center on Advanced Materials for Water Purification. He subsequently headed the program for the first two years during its formative period. "The goal of the center," Economy said, "was to develop revolutionary materials and systems for safely and economically purifying water." The award was worth $4 million per year for 10 years.

To the outside observer, Economy's research group definitely has an entrepreneurial bent. All of his students have been involved in some way with starting up business activities. Economy is a strong proponent of the Illinois Launch program at the University. "Our graduates have a unique potential, as opposed to any other students in the College of Engineering, to pursue start-ups because of the critical role of new materials development in start-up companies," he said. Economy discovered a thermosetting polyester which seems to solve a host of problems. He also continues research into advanced materials for water and air purification. These research activities have led to several new companies established jointly by Economy and his students.

Professor Economy has published over 250 research papers and 47 book chapters, and he holds over 100 U.S. patents. He was elected a member of the National Academy of Engineering in 1987, and he became a Fellow of Polymer Materials Science and Engineering and the American Academy of Arts and Sciences in 2003. His awards from the American Chemical Society include the Schoelkopf Medal in 1972, Phillips Medal in 1985, and H.F. Mark Award in 1998. He also received the Southern Research Burn Institute Award in 1976, American Institute of Chemist: Chemical Pioneer Award in 1987, P. J. Flory Award in 2001, and Fiber Society Founders' Award in 2005. He has held many offices in technical societies, including chairman of the Polymer Division in 1985, and president of the Macromolecular Division of the International Union of Pure and Applied Chemistry from 1994-98.

He has been a member of the National Academy of Engineering and a fellow of Polymer Materials Science and Engineering and the American Academy of Arts and Sciences. In 2007 he was named a Founder Professor in the College of Engineering at the University of Illinois. He has 100 U.S. patents with many foreign equivalents, and his list of publications numbers close to 250. Professor James Economy has made countless and immeasurable contributions to the Materials Science community, both internationally and here at Illinois. His leadership and knowledge have changed how we study materials and teach our students. His drive and passion helped make the Materials Science and Engineering department at the University of Illinois one of the best in the world.

# GLAM Campers Explore Materials

## WHAT STUDYING MATERIALS ENGINEERING IS LIKE

Eighteen female high school students from Illinois, and even a couple from the east coast (New Jersey and Connecticut) were on campus the week of July 7–13 to participate in the 2019 edition of Girls Learn About Materials (GLAM). In addition to learning about a variety of different materials, teams of students completed design projects targeting specific materials, during which they learned more about their material and even designed a prototype using it. They also honed their presentation skills by creating and presenting a poster at the end-of-the-week poster session. The ultimate goal of GLAM is to foster enthusiasm for STEM and MatSE among aspiring female engineers and scientists.

*Above: Jessica Krogstad, faculty coordinator for GLAM, and campers work together to assemble a photovoltaic cell using berry juice.*

*Below: During a lab on biomaterials, campers patiently look on as their pulverizer and calf skin samples freeze in liquid nitrogen.*



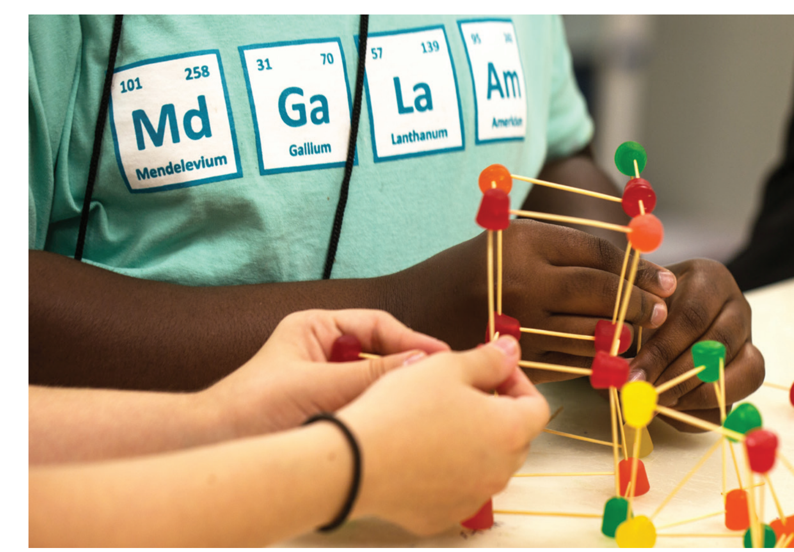

# Middle School Girls Learn About Materials

## WHILE DOING COOL HANDS-ON ACTIVITIES TO "MAKE STUFF BETTER"

Twenty-two middle schoolers showed up on campus from July 15–19 for Mid-GLAM, a summer day camp designed to pique middle school girls' interest in materials engineering. In its third year, the camp, led by Materials Science and Engineering (MatSE) Assistant Professors Cecelia Leal and Robert Maass, introduced girls to materials via fun, hands-on activities.

Camp activities encouraged the girls to consider how to "make stuff better." So the various hands-on activities were related to "Making Stuff Colorful," "Making Stuff Change Color," "Making Stuff Prettier," and "Making Stuff Smarter (safer, stronger, cleaner, recyclable, and faster). For example, during one activity, campers made some quite pretty ooey, gooey, oobleck and slime that contained glitter and changed color based on temperature.

In another activity about making stuff stronger, girls used toothpicks and gumdrops to make structures, which they then tested by piling on academic journals (in some cases, a great number of them!). In another activity, groups of girls predicted then tested the strength of various materials (newspaper, plastic wrap, aluminum foil, copier paper, wax paper, and freezer paper) by dropping a spoon from increasingly greater heights. Participants also made batteries and tested their effectiveness.




*Top: Cecilia Leal, founder of Mid-GLAM with Robert Maass (not pictured) testing gumdrop/toothpick structures with middle school teams.*

*Story and photos: Elizabeth Innes, I-STEM*

**Pascal Bellon**
Donald W. Hamer Professor, 2016
Stanley H. Pierce Faculty Award, 2009

**Paul Braun**
Fellow, Materials Research Society, 2018
Friedrich Wilhelm Bessel Research Award of the Alexander von Humboldt Foundation, 2013
AIME Robert Lansing Hardy Award, TMS, 2002

**David Cahill**
Innovation in Materials Characterization Award, Materials Research Society, 2018
Yeram S. Touloukian Award, American Society of Mechanical Engineers, 2015

**Qing Cao**
35 Innovators under 35 (TR35), by MIT Technology Review, 2016
Forbes 30 under 30 Science, 2016

**Qian Chen**
Alfred P. Sloan Research Fellow in Chemistry, 2018
Air Force's Young Investigator Research (YIP) Program Award, 2017
Forbes 30 under 30 Science, 2016

**Jianjung Cheng**
Fellow, American Association for the Advancement of Science, 2016
Fellow, American Institute for Medical and Biological Engineering, 2015
NIH Director's New Innovator Award, 2010

**Shen Dillon**
American Ceramic Society's Coble Award, 2015
NSF CAREER Award, 2013
DOE Early Career Award, 2011

**Chris Evans**
NSF CAREER, 2017
ACS Petroleum Research Fund Doctoral New Investigator, 2017

**Axel Hoffmann**
University of Chicago, Distinguished Performance Award, 2017
Fellow, American Vacuum Society, 2017
President's International Fellowship, Chinese Academy of Sciences, 2016
Fellow, IEEE, 2014
Fellow, American Physical Society, 2011

**Pinshane Huang**
Presidential Early Career Award in Science & Engineering (PECASE), 2019
Sloan Fellowship in Physics, 2018
Packard Fellowship, 2017

**Jessica Krogstad**
Robert L. Coble Award for Young Scholars, American Ceramic Society's, 2019
NSF CAREER Award, 2017
DOE Early Career Award, 2016

**Waltraud Kriven**
James I. Mueller Award for Outstanding Research in Advanced Ceramics, Engineering Division of the American Ceramic Society, 2017
Fellow of the Australian Ceramic Society, 2009
Academician of the World Academy of Ceramics, 2004
Fellow of the American Ceramic Society, 1995

**Cecilia Leal**
Racheff Faculty Scholar Award, 2019
UIUC Campus Distinguished Promotion Award, 2019
Illinois Grainger College of Engineering Dean's Award for Excellence in Research, 2018
NIH New Innovator Award, 2016
NSF CAREER Award, 2016

**Robert Maass**
TMS Emerging Leaders Alliance Award, 2019
German Materials Society Masing Memorial Medal, 2019
NSF Career Award, 2017
Emmy Noether Award by the German Research Foundation, 2014

**Nicola Perry**
J. Bruce Wagner, Jr. Award, Electrochemical Society, 2019
DOE Early Career Award, 2018
Edward C. Henry Award, American Ceramic Society, 2009

**Andre Schleife**
ONR YIP Award, 2018
ACS Petroleum Research Fund Doctoral New Investigator, 2017
NSF Career Award, 2016

**Ken Schweizer**
Joel Henry Hildebrand Award in the Theoretical and Experimental Chemistry of Liquids, American Chemical Society, 2016
Polymer Physics Prize, American Physical Society, 2008
John H. Dillon Medal, American Physical Society, 1991

**Moonsub Shim**
Dean's Award for Faculty Research, University of Illinois, 2014
Willet Faculty Scholar, 2010-2014
Xerox Award for Faculty Research, University of Illinois, 2007
NSF Career Award, 2004

**Daniel Shoemaker**
DOE Early Career Award, 2015
23rd Louis Rosen Thesis Prize, Los Alamos Neutron Science Center, 2011

**Nancy Sottos**
Swanlund Endowed Chair, 2019
Engineering Science Medal, Society of Engineering Science, 2018
Lazan Award, Society for Experimental Mechanics, 2011

**Dallas Trinkle**
TMS Brimacombe Medal, 2019
AIME Robert Lansing Hardy Award, 2014

**Yingjie Zhang**
Graduate Student Award, Materials Research Society, 2015
Dorothy M. and Earl S. Hoffman Scholarship, American Vacuum Society, 2014

**Jian-Min Zuo**
Outstanding Overseas Young Scientist Collaboration Award, China National Science Foundation, 2007
CAREER Award, Division of Materials Research, National Science Foundation, 2005
Burton Award, Microscopy Society of America, 2001

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