MA·TE·RI·AL

ISSUE 1 | WINTER 2017

THE ART OF RESISTANCE

Wear-resistant metals and of-the-moment findings in materials research

MatSE

INTRODUCING MA·TE·RI·AL

BY THE UNIVERSITY OF ILLINOIS MATERIALS SCIENCE & ENGINEERING DEPARTMENT

TO KEEP IN TOUCH

We're thrilled to introduce to you: ma·te·ri·al – the new magazine from the Materials Science and Engineering Department at the University of Illinois at Urbana-Champaign. In this magazine, first and foremost, we want to keep in touch with you, our reader, our friends, our students, our alumni. Let's stay connected; we want to know what you're researching and interested in.

TO INSPIRE

We want to inspire you: to find new information you haven't seen before, to think of something in a new way, and to interact with you in a new way, through articles and stories from our department and beyond.

TO INTERACT

We want to hear your thoughts on this issue and what you'd like to see in the future; please send all inquiries to Marketing and Communications Coordinator Caitlin McCoy at csmccoy@illinois.edu. Also, find us on Facebook, Twitter, and Instagram!

THIS ISSUE

THE ART OF RESISTANCE

Wear-resistant materials, specifically metals, are a big deal. Wear can mean a number of different things: abrasion, corrosion, adhesion, erosion. But like with most things in life, we don't have to settle for less than ideal conditions. In this issue, you'll see research and engineering leading to the next generation of wear resistance.

RADIATION RESISTANT

WITH PROFESSORS PASCAL BELLON, ROBERT AVERBACK, SHEN DILLON, DALLAS TRINKLE

MatSE researchers are developing a new approach to the design of radiation resistant materials, based on concepts of nanostructuring and self-organization. While focus is on nuclear applications, the expectation is that the scientific advancements brought forth by this Cluster will have broad impact on materials needs for a number of other advanced energy technologies. The Cluster focuses on the fundamental processes controlling the formation of novel, self-organized, nanostructured materials, their long-term structural and dimensional stability, and the relationships between the nanoscale features and the macroscopic properties.

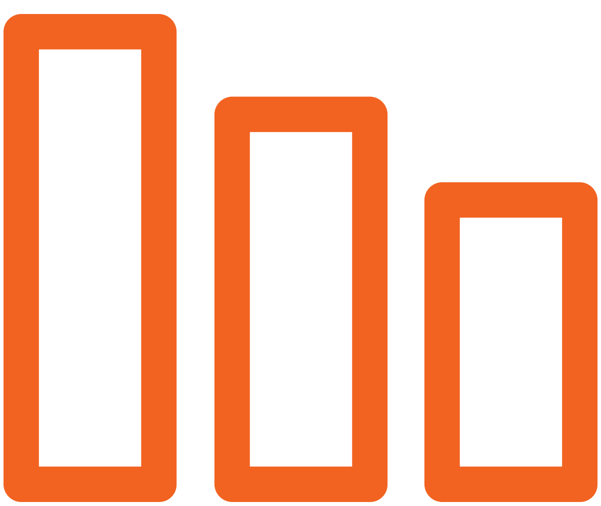
The research combines irradiation experiments, in situ and ex situ characterization of microstructure and properties, and atomistic simulations and continuum modeling.

The program builds on our past work on self organization in binary alloys, extending the approach to ternary and quaternary alloy systems that form stable compounds, in particular silicides, e.g., Cu-Si-X (X=W, Mo, Nb) systems. While these systems add complexity, they offer **new degrees of freedom**, which greatly expand our control of the stability and properties of these materials.

The research additionally explores the roles of sinks and defect fluxes on phase stability and self-organization, using samples fabricated with nanometer precision and characterized by advanced transmission electron microscopy and atom probe tomography techniques.
The Cluster also evaluates the properties of these new materials: their mechanical strength and their resistance to thermal and irradiation-induced creep.

NEW AND BETTER MATERIALS

"These materials for extreme irradiation environments are much more fundamental," Professor Pascal Bellon said. "As a scientist, I like new materials. But this can be disruptive to industry. Making changes, even small improvements to existing materials, may not be as dramatic, but it can make a huge impact in both safety and savings."



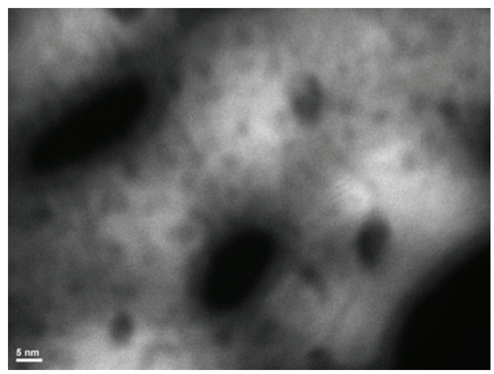


FIG. 1

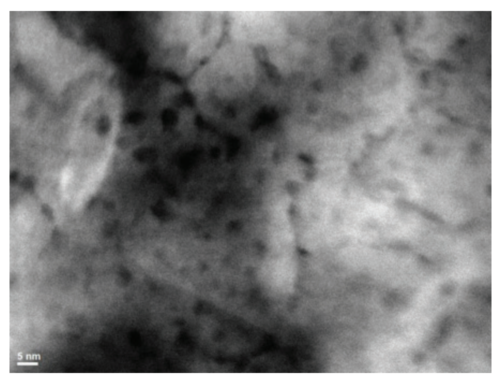


FIG. 2

Fig. 1. Z-contrast STEM images from plane view samples of Cu89Si7.5Mo3.5 irradiated at RT with 1.8 MeV Kr ions to a dose of 21016 ions/cm2 (left) and then annealed at 750 oC for 1 hour (right). The average size of the silicide precipitates (dark contrast) remains below 3 nm, despite the high temperature annealing.

NUCLEAR REACTORS: MATSE REACTIONS

Materials used in current nuclear reactors cannot meet key requirements of the advanced designs proposed for future reactors. In particular, their resistance to radiation damage is insufficient.

MatSE researchers, including Professor Pascal Bellon, are investigating approaches to increase materials radiation resistance, where small additions of carefully selected alloying elements are used to drastically slow down the kinetics of evolution of these materials.

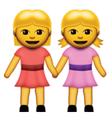
WHAT IS SELF-ORGANIZATION?

Self-organization is a spontaneous phenomenon in materials subjected to large strain plastic deformation processes. Self-organization often results in the stabilization of nanostructures, leading to local modifications of mechanical properties. Sliding wear is one of the deformation processes in which the layers of constituent phases tend to self-organize up to a certain depth below the sliding surface. The layers when formed from a low shear strength metal with appropriate microstructure could improve the overall tribological performance.

WHY DOES IT MATTER FOR MATERIAL WEAR-RESISTANCE?

In collaboration with BP-ICAM (International Centre for Advanced Materials), Professors Pascal Bellon and Robert Averback have been working on self-organized materials for wear applications. Plastic deformation by sliding processes such as wear generally lead to localized self-organization of microstructure. In immiscible (or not forming a homogeneous mixture when added together) alloy systems, the self-organization will be in the form of nano-layering of constituent elements, particularly near the surface. This phenomenon offers a possibility to explore these chemical layers of suitable metals as self-adaptive phases in applications demanding reduced wear rate and friction.

#twinning



MILLENIAL AND MATERIALS LINGO

Urban dictionary lets us know that #twinning is a popular take on the phrase "winning," referring to identical thoughts, behavior, or brilliance. But in materials science, it's way more fun.

All materials have stacking sequences in their crystal structures. FCC materials stack like ABCABC, while HCP materials stack like ABAB. However, materials do not always grow perfectly in order – sometimes, the crystal will become deformed, and the characteristic stacking sequence is reversed. This is called twinning, and the plane where the sequence changes is called the twinning plane.

LIKE A PAIR OF HANDS

The crystal on one side of the twin plane is a mirror reflection of the other, just like a pair of hands! For example, a twinned FCC structure might have a stacking pattern like ABCBA, rather than ABCABC. Now, twinning does not occur in HCP materials, because the stacking pattern for HCP can't be reversed; the opposite of ABAB is still ABAB.

MORE COMMON THAN YOU'D THINK

Although twinning sounds like it would not be very common, it's actually present in a lot of materials. Twinning is common in minerals because of phase transitions and subsequent stability during cooling, and the existence of twins is a large part of what gives minerals their characteristic iridescent texture, through the diffraction of light.

INTRODUCING: OUR STUDENT BLOG

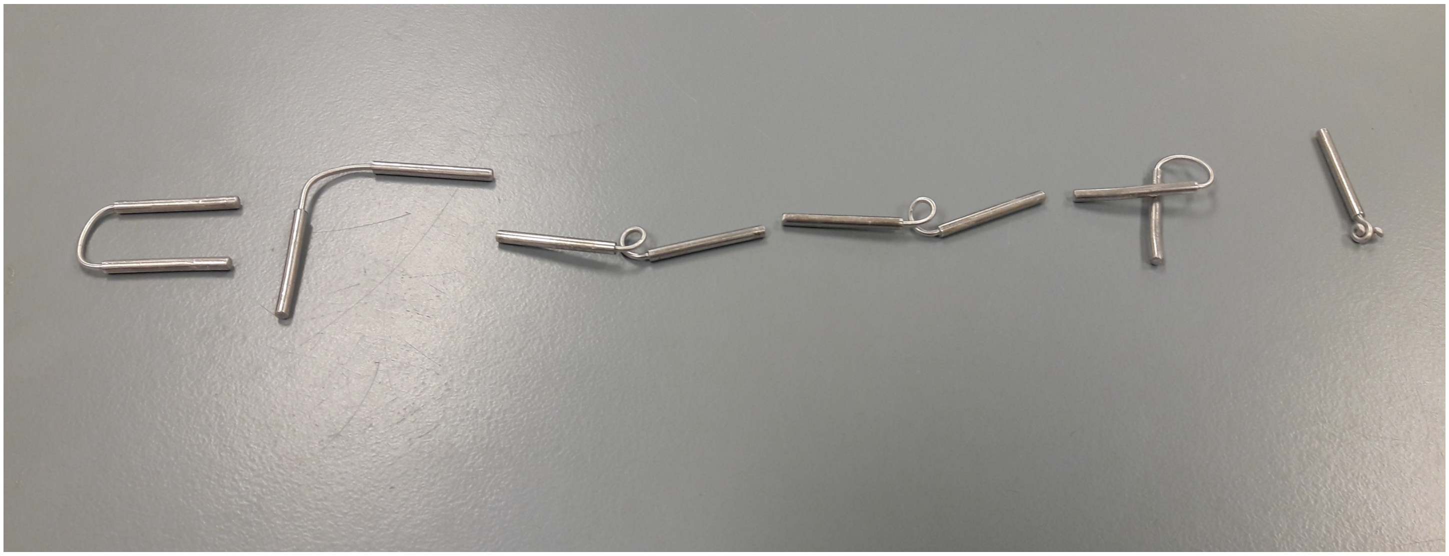
In September, MatSE launched its student blog to feature not only news that interests students, but news written by the students!

In the first blog post, MatSE senior Devon Goszkowicz (pictured, above) wrote about her 2017 summer internship with Sandia National Laboratories in Albuquerque, New Mexico as a Materials R&D intern.

In the post, she shared with classmates and prospective students what they may expect in the internship process: from getting the internship to finding housing during the summer and her biggest takeaways from the experience.

In her post, Devon shares: "For me, the best part of my internship was being able to apply the knowledge I had gained in my three years at university to work in two very different aspects of research and development. This internship allowed me to see how classroom material is represented physically, which was very useful for a visual learner like me. Additionally, as a female in engineering, I have become used to being one of very few women in many of my engineering classes. However, women and minorities were very well represented in my department, which was refreshing!"

Read more:
matse.illinois.edu/news/student-news



CREEP: FUNNY NAME, COOL THING

Creep. It calls to mind 1990s TLC songs, green Minecraft characters, and maybe even time spent in undergraduate labs. In materials science, it's the time-dependent and permanent deformation of materials under a constant stress.

Creep becomes a relevant mechanism when the temperature at which the material is used is above approximately 40 to 50% of its melting temperature.

Because materials aren't always used at room temperature, they can be used in extreme environments with elevated temperatures, like jet turbines, nuclear reactors, and even light bulbs.

Without considering creep, catastrophic failure can occur, causing casualties or losses of millions of dollars.

There are three main stages of creep.

In the first stage, the strain rate decreases as time increases, indicating a resistance to creep due to changes in the microstructure, as well as strain hardening.

The second stage of creep is when the creep rate is constant, due to the competition between strain hardening and recovery. Recovery is the process a material can undergo, allowing it to retain its ability to experience deformation. This stage of creep is most frequently studied because of its steady state and long duration relative to other states.

The third and final stage of creep occurs with a dramatic increase in the strain rate, which can be due to the reduction in cross-sectional area for tensile loads, as well as the creation of voids and other defects in the sample.

THE NEW MRSEC AT ILLINOIS

Have you heard? Innovative materials are the foundation of countless breakthrough technologies, and the Illinois Materials Research Science and Engineering Center (MRSEC) will develop them.

The new center is supported by a six-year, $15.6 million award from the National Science Foundation's Materials Research Science and Engineering Centers program. It is led by Professor Nadya Mason of Engineering at Illinois' Department of Physics and its Frederick Seitz Materials Research Laboratory.

You can learn more at: mrsec.illinois.edu

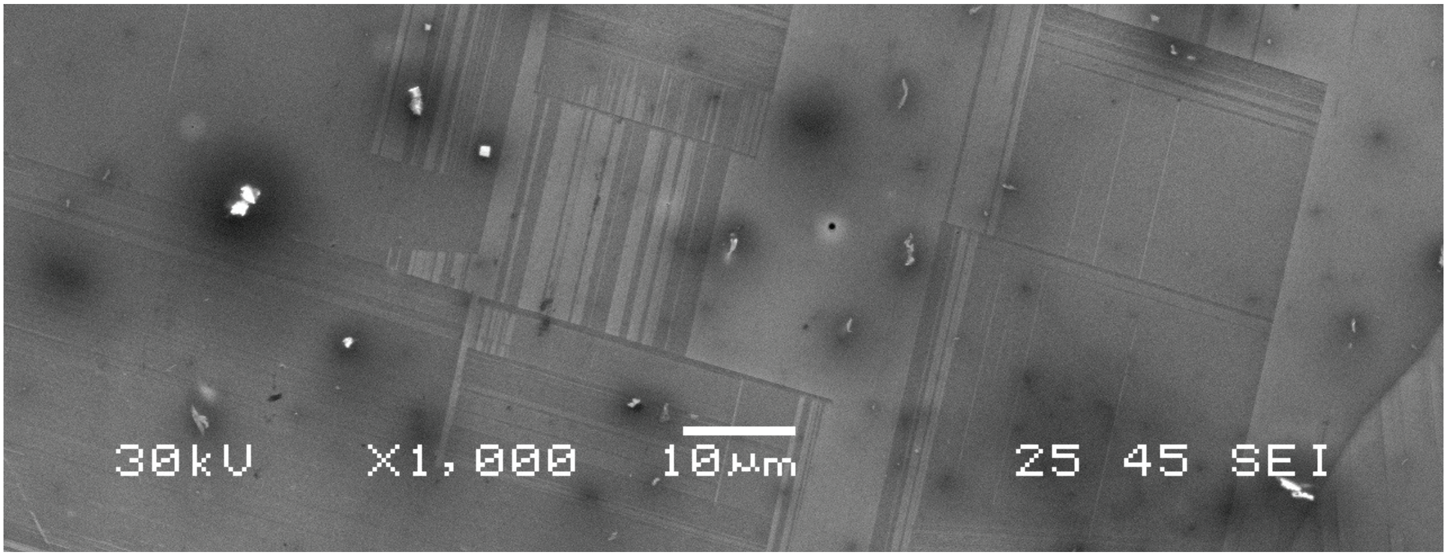
DISORDERED MATERIALS & METALLIC GLASSES

Many disordered materials deform plastically via strain softening. In these materials, plastic flow is localized to planar and narrow defects, called shear bands. The resistance to continuous flow of a shear band is what gives the material its mechanical stability and potentially its desired properties for engineering applications.

Due to the high spatiotemporal confinement and the disordered atomic structure, it has virtually been impossible to experimentally investigate and understand the microstructural origin of shear resistance and thus limits in stable plastic flow.

MatSE Professor Robert Maass, along with researchers from the Laboratory of Metal Physics and Technology in Zurich, Switzerland and the School of Materials Science and Engineering at UNSW in Sydney, Australia, reported on the temperature-dependent shear stability of eight different metallic glass alloys and showed that their shear resistance, characterized by the shear-barrier energy Es, is determined by the constituent-specific bond energy spectra of their typical topological atomic motifs.

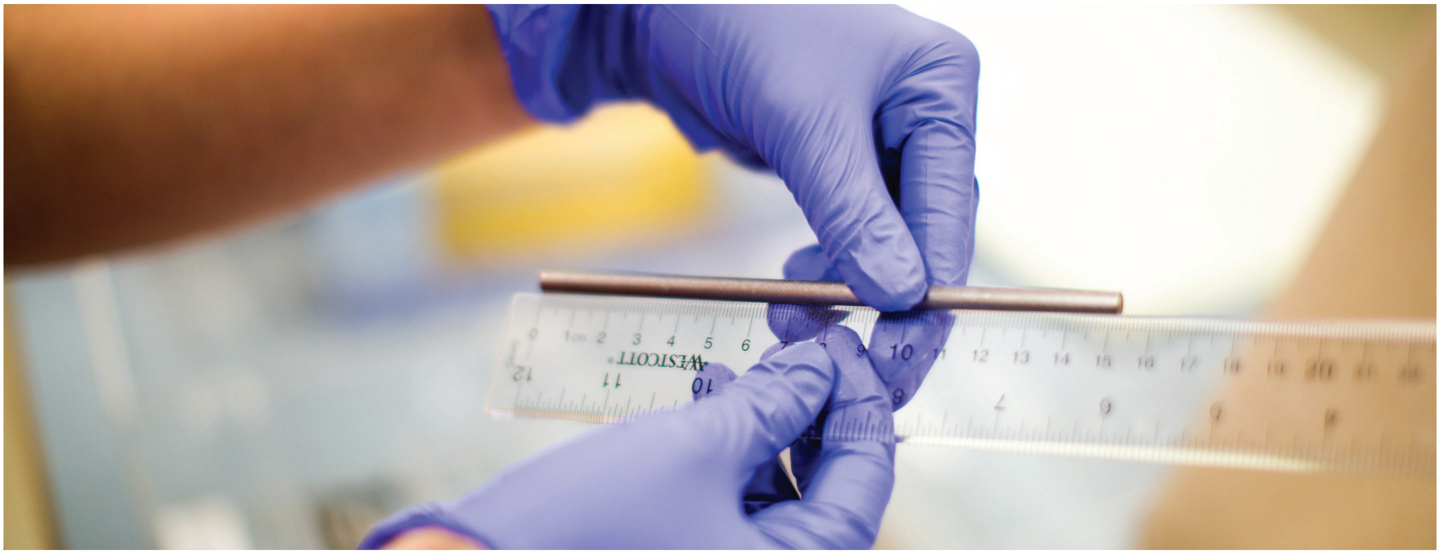
"Our model reveals a robust scaling across all alloys, giving unprecedented insights into the underlying atomistic origin of shear stability in metallic glasses," Maass said. "In addition to revealing a physical origin of the experimentally measured shear-barrier energy, our model identifies a tuning parameter for the making of ductile metallic glasses."



"The key here is that by looking at the atomic scale structure of the material we are able to predict what base elements are the most promising one for the development of a metallic glass that can deform in a stable way and not break."
– Professor Robert Maass

One general challenge in the field of disordered materials is the localization of strain upon the application of an external load.

Strain localization manifests itself as the development of thin planar shear regions in the disordered structure, called shear-bands 1, 2. This can be observed in crystalline metals, granular media, fluids, colloidal systems, as well as metallic glasses (MGs). All of these material classes exhibit different underlying mechanisms that lead to the development of shear bands.



V IS FOR VISCOSITY

Viscosity is a measure of the **resistance** of a liquid to flow. Liquids like acetone and water have a low viscosity, since there is little resistance for the molecules to overcome. Substances like molten glass and pitch, on the other hand, have very high viscosities and flow very sluggishly. Some liquids have viscosities that vary with shear rate – the classic example is cornstarch and water (oobleck), which acts more like a liquid when it’s strained slowly, and like a solid when you strain it quickly (which is why you can run across a pool of it).

JUNIOR LABS AT MATSE

Junior labs are the first chance students really get to get their "hands dirty" and explore beyond theory. The techniques, practices, data analysis, and communications skills students learn in their Junior Labs provide invaluable experience for graduate school, industry, or wherever life may take them.

In an effort to give students more insight into what they can expect in their Junior labs, we've updated the website with more in-depth information. Want to reminisce about MSE 307 and 308 or see what students are up to?

Visit: matse.illinois.edu/academics/undergraduate/curriculum/junior-labs

PINSHANE HUANG: PACKARD FELLOW

MatSE Professor Pinshane Huang is among 18 early career researchers across the nation to receive 2017 Packard Fellowships from the David and Lucile Packard Foundation.

“We are very pleased to have Pinshane recognized as one of the most innovative early career scientists in the nation,” said Professor David Cahill, MatSE Department Head. “Her work is advancing our understanding of materials at the atomic scale, and she is a great inspiration and asset to our department.”

The Packard Fellowship includes an unrestricted five-year $875,000 award to support research of the recipient's choosing. In its announcement, the Packard Foundation cited Huang’s research, which “develops techniques that use electron microscopes to characterize matter with single atom precision, with the ultimate goal of enabling an era in which materials can be designed and perfected at the level of individual atoms.”

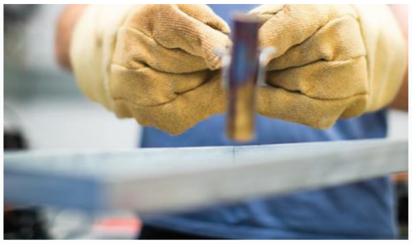
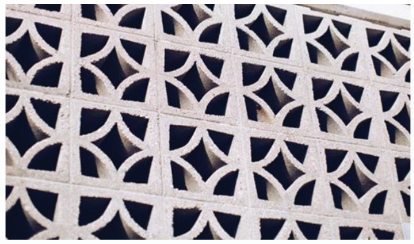
Huang’s group studies molecules and nanomaterials using electron microscopes to see each atom’s structure and behavior. Huang has pioneered methods to track each atom in a piece of glass as it bends and breaks, and to image defects in materials that are only a few atoms thick. The group’s research aims to produce next-generation nanomaterials for energy and catalysis – such as high-efficiency solar cells or batteries – and nanoelectronics such as flexible graphene-based devices.

“As a Packard Fellow, my goal is to dramatically expand the types of materials that we can understand at the atomic scale,” Huang said.

GET TO KNOW HUANG

Huang earned a doctorate in applied physics from Cornell University and completed a postdoctoral fellowship at Columbia University. In 2015, she joined the faculty at Illinois, where she also is affiliated with the Beckman Institute for Advanced Science and Technology and the Frederick Seitz Materials Research Laboratory. In addition to the Packard Fellowship, Huang has received a Young Investigator Award from the Air Force Office of Scientific Research, the 3M Non-Tenured Faculty Award and the Albert Crewe Award from the Microscopy Society of America.

"As a Packard Fellow, my goal is to dramatically expand the types of materials that we can understand at the atomic scale."
– Pinshane Huang


MATSE ALUMNI INSTAGRAM TAKEOVERS

Instagram is the social media platform to beat right now. Engagement with brands on Instagram is 10 times higher than Facebook, 54 times higher than Pinterest and 84 times higher than Twitter according to TrackMaven and SocialPilot.

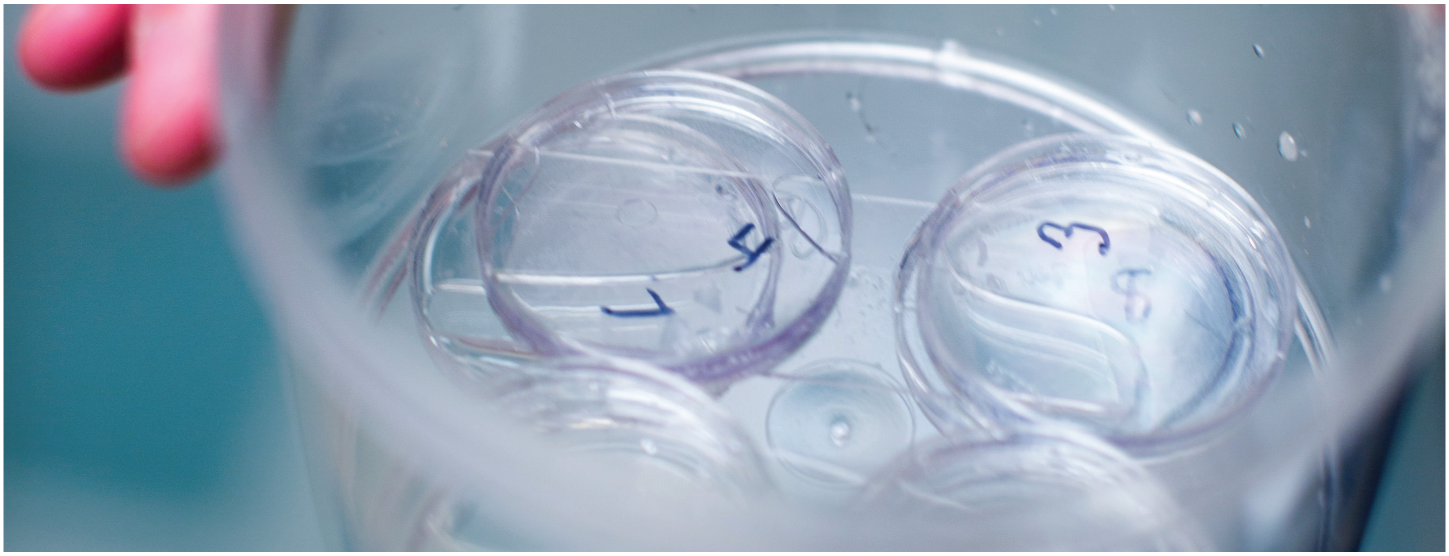
MatSE started an Instagram account spring semester 2017 to share photos of student events, faculty awards, and more. Alumni began volunteering to take over the account, one at a time, to engage students and answer their questions.

The MatSE Instagram account had an increase of 94 followers in the days surrounding the first Alumni takeover.

Instagram

Follow us

@IllinoisMatSE



BE A PART OF THE MA·TE·RI·AL COMMUNITY

Materials. They're matter from which a thing is or can be made. But our department is made up of more than just amazing materials; it's made up of a community of amazing people like you.

As we wrap this first issue of ma·te·ri·al, we want your input. Continuing advanced education of materials science and engineering takes a village; a village of committed, community-minded individuals.

Liked a story? Have an idea for something to see in the future? Want to participate in an Alumni Instagram takeover? Have an exciting student story to feature on the student blog? Reach out to us on social media or email our Marketing Department at: csmccoy@illinois.edu.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and support Illinois students, faculty, and research.
With you, we can make the world a better place.
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ENDING NOTE

"...IF WE CAN ACHIEVE THIS, THEN ONE DAY WHOLE ROOMS, BUILDINGS, PERHAPS EVEN BRIDGES MAY GENERATE THEIR OWN ENERGY, FUNNEL IT TO WHERE IT IS NEEDED, DETECT DAMAGE, AND SELF-HEAL. IF THIS SEEMS LIKE SCIENCE FICTION, BEAR IN MIND THAT IT IS ONLY WHAT LIVING MATERIALS DO ALREADY."

— *Mark Miodownik*

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MANIFESTO