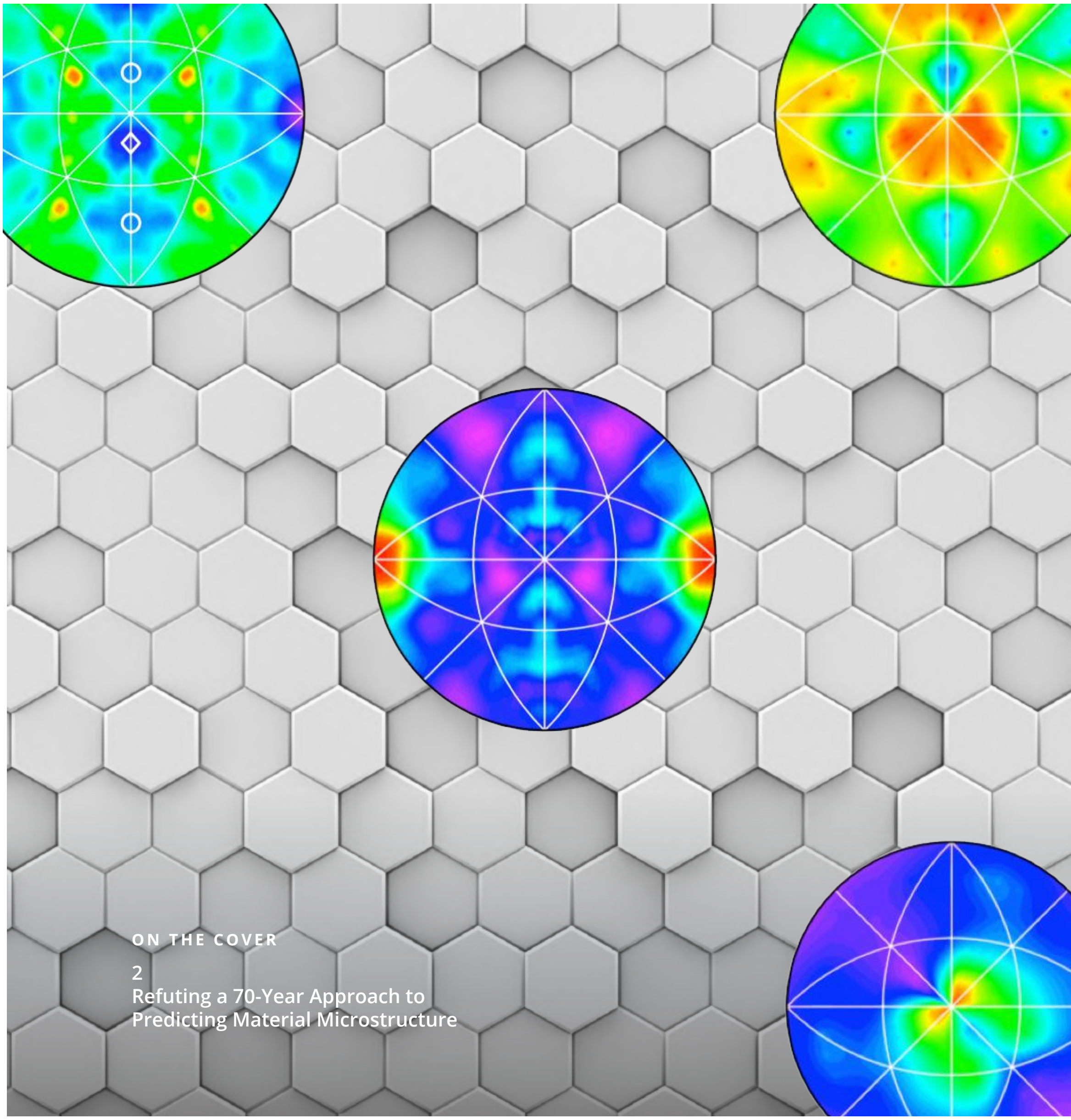
MSE

SPRING 2022



Carnegie Mellon University
Department of Materials Science
& Engineering

Welcome
Message from the Department Head

Dear Alumni, Students, Parents and Friends,

It has been an exciting and fruitful year since I began my role as Head of the Department of Materials Science and Engineering. I deeply appreciate the enthusiasm and commitment of our students, faculty and staff as we continue to learn and create, while maintaining the health and safety of our campus community.

I hope that this edition of our newsletter provides you a snapshot of some of the people and activities that make MSE at CMU such a special place. In these pages you will read about Professor McHenry's small but mighty motors that could revolutionize transportation. You will learn about the real-world materials challenges our undergraduate students have been working to solve in partnership with local companies. You'll also meet Dylan Lew, an MSE alumnus overseeing a Pittsburgh-based startup focused on repurposing food waste into something more useful.

While we say thank you to Professor Warren Garrison, who served the department for so many years, I'm excited to introduce our newest faculty member, Thomas O'Connor. Professor O'Connor joins us after a prestigious Harry S. Truman Fellowship at Sandia National Laboratory to pursue his research and educational vision for simulating the dynamics of polymer materials (plastics) from the molecular to processing scale.

I'm also extremely excited to share with you the recent launch of the MSE Student Impact Fund. This fund was established with a generous gift from Miles Miles Hinderliter (MSE BS '02), who serves on the Materials Science and Engineering Alumni Council, and will support the educational programmatic and physical infrastructure for our MSE undergraduate and graduate students. We believe strongly in a robust engineering education that provides our students with hands-on opportunities to learn, discover and create in comprehensive experimental and computational laboratories, while maturing the professional skills of our students. Thank you to all who have already supported this initiative.

Thank you for taking the time to read this version of our MSE newsletter. I hope you feel the same pride I do reading about the accomplishments of our students, faculty, staff and alumni. We thank you for your continued support of our department!

Sincerely,

Beth Dickey
Teddy & Wilton Hawkins
Distinguished Professor and
Department Head of Materials
Science & Engineering

ON THE COVER

2
Refuting a 70-Year Approach to Predicting Material Microstructure

PUBLISHER

Department of Materials Science and Engineering

EDITOR

Kaitlyn Landram, Manager of Communications

WRITERS

Madison Brewer, Jocelyn Duffy, Lynn Shea, Kaitlyn Landram

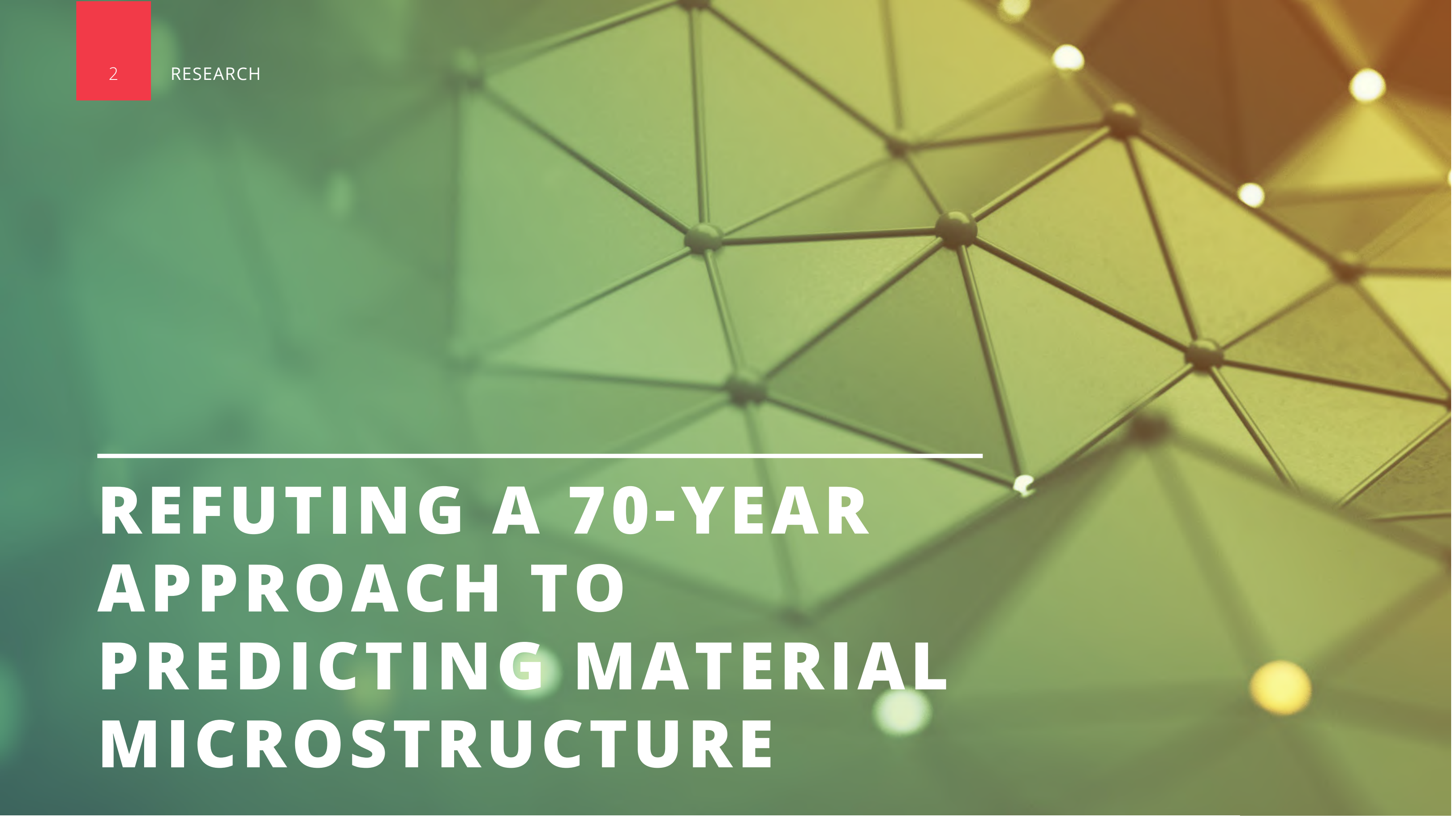
DESIGN

Debra Vieira, Senior Multimedia Designer, College of Engineering

MSE

Spring 2022

cmu.edu/engineering/materials/



REFUTING A 70-YEAR APPROACH TO PREDICTING MATERIAL MICROSTRUCTURE

A 70-year-old model used to predict the microstructure of materials doesn't work for today's materials, say Carnegie Mellon University researchers in Science. A microscopy technique developed by Carnegie Mellon and Argonne National Laboratory yields evidence that contradicts the conventional model and points the way towards the use of new types of characterizations to predict properties — and therefore the safety and long-term durability — of new materials.

If a metallurgist discovered an alloy that could drastically improve an aircraft's performance, it could take as long as twenty years before a passenger would be able to board a plane made of that alloy. With no way to predict how a material will change when it is subjected to the stressors of processing or everyday use, researchers use trial and error to establish a material's safety and durability. This lengthy process is a significant bottleneck to materials innovation.

Professors Gregory Rohrer and Robert Suter of Carnegie Mellon University's Department of Materials Science and Engineering and Department of Physics have uncovered new information that will help materials scientists to predict how the properties of materials change in response to stressors such as elevated temperatures. Using near-field high energy diffraction microscopy (HEDM), they found that the established model for predicting a material's microstructure and properties does not apply to polycrystalline materials and a new model is needed.

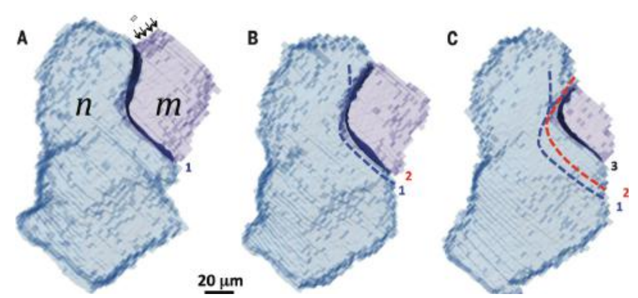
To the eye, most commonly used metals, alloys and ceramics used in industrial and consumer equipment and products appear to be uniformly solid. But at the microscopic level, they are polycrystalline, made up of aggregates of grains that have different size, shapes and crystal orientations. The grains are tied together by a network of grain boundaries that shift when exposed to stressors, changing the material's properties.

When they make a new material, scientists need to control its microstructure, which includes its grain boundaries. Materials scientists manipulate the density of grain boundaries in order to meet different needs. For example, the structure surrounding the passenger cabin in a car is made of an ultrahigh strength steel that contains more grain boundaries than the aesthetic body panels in the car's front-end crumple zone.

For the last 70 years, researchers have predicted materials' behavior using a theory that says that the speed at which grain boundaries move throughout a heated material is correlated to the boundary's shape. Rohrer and Suter have shown that this theory, formulated to describe the most ideal case, does not apply in real polycrystals.

Polycrystals are more complicated than the ideal cases studied in the past. Rohrer explained, "If one considers a single grain boundary in a crystal, it can move without interruption, like a car driving down an empty roadway. In polycrystals each grain boundary is connected to, on average, ten others, so it's like that car hit traffic — it can't move so freely anymore. Therefore, this model no longer holds." On top of that, Rohrer and Suter found that often polycrystal grain boundaries weren't even moving in the direction that the model would have predicted.

HEDM, a technique that was pioneered by Suter and colleagues using the Argonne National Laboratory's Advanced Photon Source (APS), was key to these discoveries. HEDM and its associated techniques allow researchers to non-destructively image thousands of crystals and measure their orientations within opaque metals and ceramics. The technique requires high energy X-rays available only at one of a few synchrotron sources around the world.



The dark blue shading represents a boundary separating two grains; as the boundary moves some elements that belong to grain m become part of grain n.

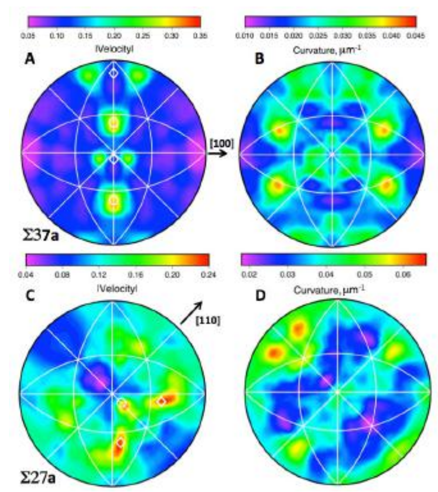
"It's like having 3D X-ray vision," said Suter. "Before, you couldn't look at a material's grains without cutting it apart. HEDM allows us to noninvasively view the grain orientations and boundaries as they evolve over time."

The development of HEDM began around 20 years ago and continues to this day. Suter's group worked with scientists at APS to develop procedures for the synchronized collection of thousands of images of X-ray diffraction patterns from a material sample as it undergoes precision rotation in an intense incident beam. High performance computer codes developed by Suter's research group convert the sets of images into three dimensional maps of the crystalline grains that make up the material microstructure.

Ten years ago, Suter's group (including Physics graduate students Chris Hefferan, Shiu-Fai Li, and Jon Lind) repeatedly measured a nickel sample after successive high temperature treatments resulting in the first observations of individual grain boundary motions. These motions failed to show the systematic behavior predicted by the 70-year-old theory. The point of view developed by the Carnegie Mellon researchers in the Science paper correlates grain boundary structure with systematic behaviors observed in the HEDM experimental data.

While the current analysis is based on a single material, nickel, X-ray diffraction microscopy is being used on many materials and Rohrer and Suter believe that many of those materials will demonstrate similar behavior to that seen in nickel. Similar applications to other material processing conditions also are being studied.

This research was funded by the National Science Foundation's Designing Materials to Revolutionize and Engineer the Future program (DMREF). The team's four-year grant was renewed for $1.8 million dollars effective October 1, 2021. Carnegie Mellon's Kaushik Dayal, Department of Civil and Environmental Engineering, Elizabeth Holm, Department of Materials Science and Engineering, and David Kinderlehrer, Department of Mathematical Sciences will also be involved in the next steps of research studying how and why polycrystals behave this way in different materials. Professors Carl Krill (University of Ulm, Germany) and Amanda Krause (University of Florida) are also part of the collaboration.



High energy diffraction microscopy images of grain boundary velocities and curvatures and computed mobilities. Velocities do not correlate with the other properties.

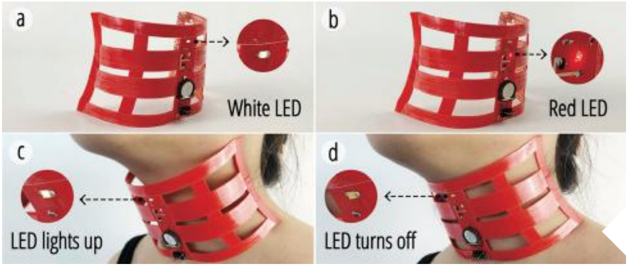
RESETTING THE STANDARD IN ORTHOPEDICS

Each year roughly 6 million Americans break a bone and head to their doctor for a plaster or fiberglass cast. After six long weeks of trying not to get the cast wet, and resisting the urge to itch the skin underneath, the patients return to their doctor to have the cast removed and tossed into the trash, unable to be used again. Mohammad Islam, Professor Materials Science and Engineering, Lining Yao, Assistant Professor, Human-Computer Interaction Institute, and Carmel Majidi, Professor Mechanical Engineering have created a new material system that could change this standard in orthopedics – ExoForm.

Exoform is a compact, customizable and semi-rigid wearable material with self-fusing edges for immediate, adjustable and repeatable use. It offers the unique ability to specifically conform to individual bodies without dependence on medical professionals. The idea for Exoform originated in the midst of the Covid-19 pandemic, as a facemask that could be 3D printed and self-molded to fit the wearer perfectly. Shortly after, the team realized the material's application could be more broadly utilized and the cast was created.

The Exoform cast distinguishes itself from the orthopedic materials currently available at local pharmacies i.e., finger splints and wristbands, in that it can successfully support a variety of complex body parts and adjust its stiffness throughout the healing process. It is also breathable and can be submerged in water, allowing for a more comfortable wearing experience.

Exoform begins as a flat structure and requires heat - between 70-80 degrees Celsius- to mold. To protect the wearer from burns, users must initially wrap 3 layers of gauze around their skin where they intend to wear the cast. The cast features a sensing and control system that can trigger a white LED light to indicate when the material is at a safe handling temperature. Once heated, the material takes a standardized shape around the body to initialize the rough fit. Users can then manually



Self-fusing edges enables Exoform to be reshaped and reworn

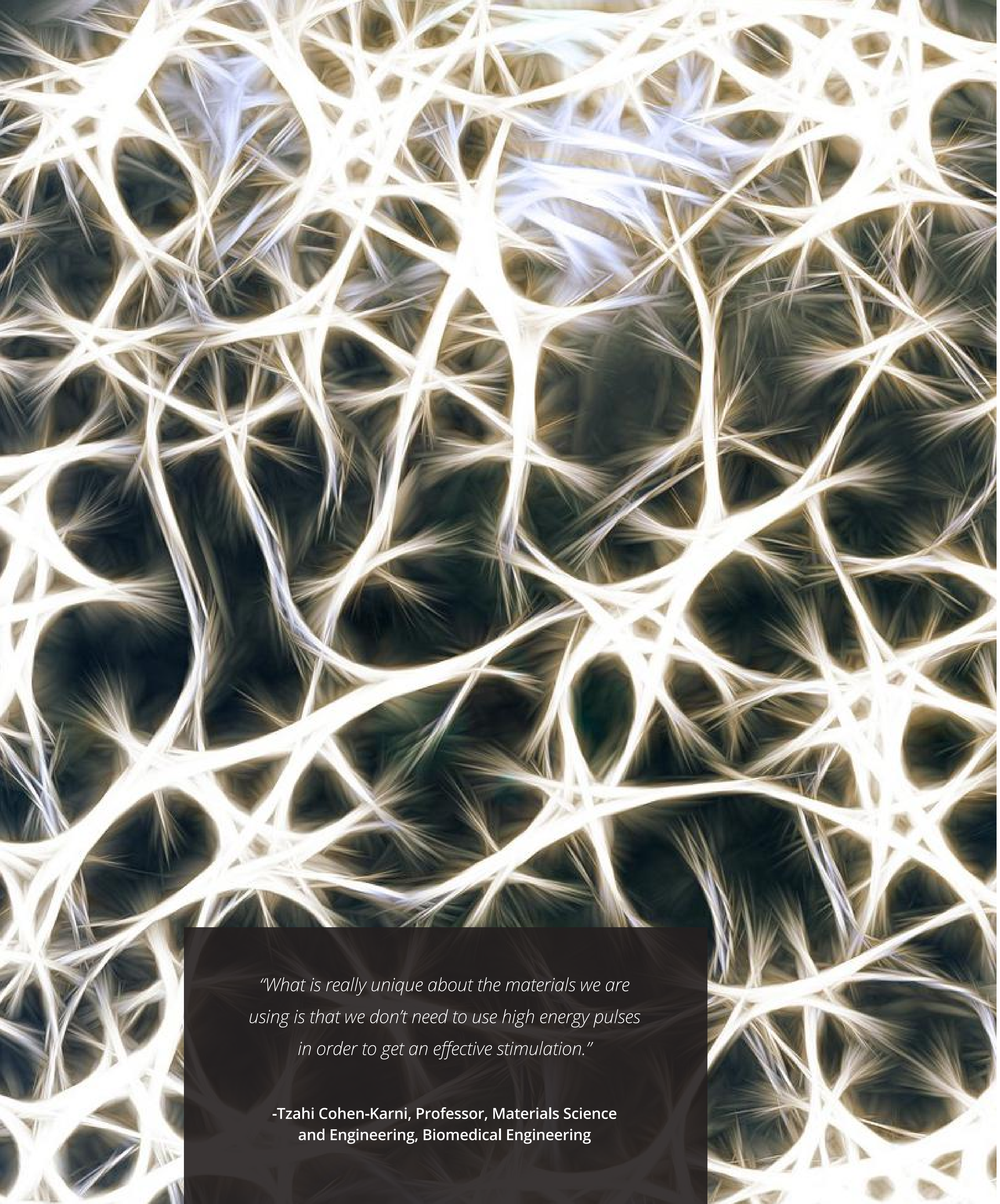
sculpt the material into their own perfect fit. The white LED light glows brightly and dims as the wearable is tightened.

Existing plaster and fiberglass casts remain stiff throughout the course of healing and limits the user's ability to move. This limitation delays the body's natural healing time. With Exoform, as the body begins to heal, the wearer can remove parts of the cast to loosens the material, allowing for increased mobility and ultimately a faster healing time. Once fully healed, the user can remove the cast on their own and begin to refuse the material.

With self-fusing edges, any pieces of the material removed during the molding and healing process can be added back on by pressing the edges together. This enables repeat usage. Within hours of the edges coming into contact, Exoform pieces self-fuse to the original flat form. This flat packing saves nearly 95% of the volume taken up by the assembled cast making it easy for storage in case one day a friend or family member needs a cast of their own. All in all, Exoform's level of accessibility means that future wearable devices can be tailored to fit users' needs without leaving anyone behind.

This research was published in Association for Computing Machinery Computer Human Interaction 2021 (ACM CHI).

Exoform, a customizable, semi-rigid material with self-fusing edges has the potential to eliminate many of the doctors visits that go along with broken bones, not to mention help them heal faster.



> *"What is really unique about the materials we are using is that we don't need to use high energy pulses in order to get an effective stimulation."*
>
> **-Tzahi Cohen-Karni, Professor, Materials Science and Engineering, Biomedical Engineering**

NEW MATERIAL AIDS IN NEURAL STIMULATION USING LIGHT

The ability to target and stimulate neurons brings a host of benefits including better understanding brain function and treating neurological diseases. Currently, state-of-the-art microelectrode arrays (MEAs) can stimulate neurons with high precision, but they lack cell-type specificity and require invasive implantation that can result in tissue damage – think stimulators used to help patients with tremors. Professor of Materials Science and Engineering, and Biomedical Engineering, Tzahi Cohen-Karni and his team have been exploring new materials to allow remote photostimulation, or the use of light to stimulate cells.

Cells can "talk" with one another by sending and receiving electrical signals. Inside a cell's membrane, a neuron in our brain for example, there are tiny pores called ion channels that let ions move in and out of the cell. Under normal conditions, the fluxes of ions across the membrane dictate whether a cell will send an electrical signal to its neighbors. In recent years, researchers have shown that it is possible to use pulses of light to alter the cell membrane's properties and elicit an electrical signal that can control cellular communication. Cohen-Karni's team aims to identify materials effective at controlling cell activities without causing distress. They recognized that multi-dimensional graphene (fuzzy graphene) posed as a great candidate for cellular stimulation but found that some materials were difficult to produce and couldn't absorb enough light to efficiently transfer light to heat.

In his current research published by the American Chemical Society, Cohen-Karni focused on transition metal carbides/nitrides (MXenes) flakes, a unique two-dimensional (2D) nanomaterial discovered by Dr. Yury Gogotsi's team at Drexel University. MXenes have been demonstrated to exhibit outstanding mechanical properties, high electrical conductivity, excellent electrochemical properties, and importantly are easy and inexpensive to produce.

Rather than study the material for its bulk properties, Cohen-Karni's team measured the photothermal properties of the material at a single flake level. The team dispersed flakes on the surface of dorsal root ganglion (DRG), cells in the peripheral nervous system, and illuminated them with short pulses of light. By studying the interface between cells and materials, it became clear that flakes would not be absorbed by the cells and Cohen-Karni could accurately measure the amount of light required to create cellular change.

"What is really unique about the materials that we are using in my lab is that we don't need to use high energy pulses in order to get an effective stimulation," Cohen-Karni explained. "By shining short pulses of light on the DRG-MXene interface, we found that the electrophysiology of the cell was successfully altered."

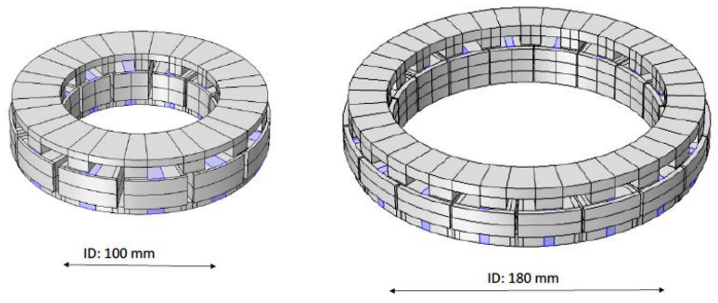
So what does this mean for the future of neurology? With an increased understanding of how to achieve neural stimulation and the ease of MXene production, researchers can more efficiently practice remote photostimulation. For example, researchers could embed MXenes into artificial tissue engineered in the form of a brain, and then use light to control the neural activity and further uncover the role of neurons in brain development. Eventually, this material could even be used as a non-invasive treatment for neural function disabilities, like tremors.

Other team members involved in the research included Materials Science and Engineering students Yingqaio Wang and Raghav Garg; Jane E. Hartung and Michael S. Gold from the University of Pittsburgh; Adam Goad and Dipna A. Patel from Drexel University; and Flavia Vitale from the University of Pennsylvania and the Center for Neurotrauma, Neurodegeneration, and Restoration.

POWERING SEA TO SPACE

Magnetic materials pose major limitations in power electronic applications at high frequencies, but MSE Professor Michael McHenry and alums Paul Ohodnicki (MSE MS ’06, Ph.D. ’08), Alex Leary (MSE MS ’12, Ph.D .’16) and Sam Kernion (MSE MS ’10, Ph.D. ’12) have made advancements on materials and their processing that can greatly increase motor and transformer efficiencies.

Power electronics, like motors, gain power through speed. The speed, however, requires the magnetic materials to switch at a higher frequency and this causes magnetic (eddy current) loss. Magnetic losses put off heat and that heat limits the motor’s overall performance. So, reducing magnetic loss is pivotal in paving the way for smaller motors with higher power.



Mockup of both 100 mm and 180 mm high power motors.

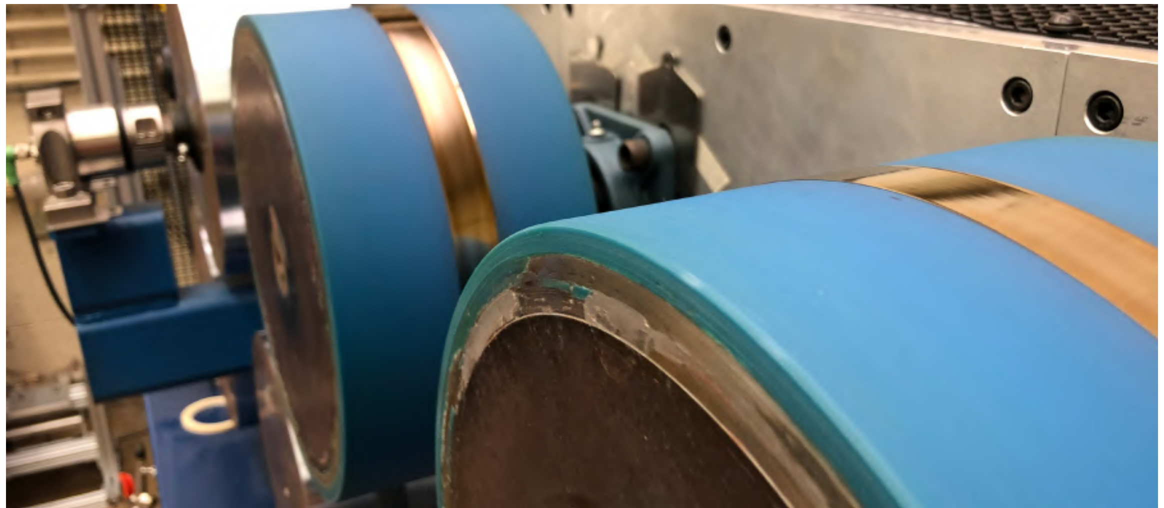
Extended off of McHenry’s award-winning research using cobalt-based metal amorphous nanocomposite (MANC) materials, McHenry’s team found that strain annealing soft magnetic amorphous ribbons under tension and then reannealing can lead to as much as a 50% magnetic loss reduction in their newly patented Iron-Nickel-based MANCs. This loss reduction allows higher power densities to be achieved in their alloys, putting them in line with the commercially available FINEMET alloy but with one key advantage - the team’s alloy is nonbrittle and therefore a more attractive material for high-speed motor applications.

Funded by the Department of Energy’s Advanced Manufacturing Office, McHenry’s team in collaboration with National Energy Technology Laboratory (NETL), NASA Glenn Research Center, and North Carolina State University has built a 2.5-kilowatt motor prototype combining rare-earth free permanent magnets with MANCs. The commercialization of this motor could decrease the size and weight of standard vacuum cleaners, lawnmowers, and other household appliances.

McHenry’s team is now looking to build higher power motors as they observed even greater magnetic loss reduction in larger radius magnetic cores – those relevant to motor vehicle technologies. With this application, McHenry’s alloys could one day be used in Naval submarines or NASA spaceships. With costs as high as $10,000/pound to put material into space, reducing the size of a motor while maintaining comparable power would have a drastic impact.

McHenry’s team will be able to process their alloys on a commercial scale at their Pittsburgh-based startup, CorePower Magnetics to bring their high-performance power electronic components to market.

Strain annealing is the process of heating soft magnetic amorphous metal ribbons under tension.



BUILDING FRIENDSHIPS AND FUTURE SUCCESS

Hanging with friends after a few hours of rock climbing.
Left to Right: Ryan Domalik, Jared Cohen, David Domalik, Gavin Christopher, Jodie Hung, Eliza Reedy.

On Friday nights, Jared Cohen gathers with fellow CMU students to celebrate Shabbat—the Jewish tradition of sharing a meal that commemorates the day God rested from creating the world.

In much the same way, the class of 2023 materials science and engineering and biomedical engineering major welcomes the rest, as well as the fellowship, after a week of rigorous coursework and lab duties.

"I don't want to be so overwhelmed with responsibility that I can't enjoy the entire college experience," said Cohen.

Although he had wanted to graduate early and move on quickly to graduate school, Cohen listened to his advisor Kurt Larsen, Assistant Dean for undergraduate studies, who advised him not to overdo it, especially when taking the challenging first-year engineering courses.

That new approach has served him well. Even though being more selective about the many exciting electives CMU offers can be difficult, Cohen is glad he has made time to pursue other opportunities. Last summer he interned with Lost Tribe E-Sports, and he has helped conduct biomedical research in the labs of Christopher Bettinger, Professor Materials Science and Engineering and Biomedical Engineering, and Charlie Ren, Assistant Professor of Biomedical Engineering.

"I learned to manipulate cells, design with CAD software, and operate 3D printers. The hands-on work helped me better understand the underlying biology," said Cohen. "Doing is what really pushes me."

For Cohen, there have been other benefits to balancing the many options he has. He serves as vice president and recruitment chair of the Alpha Epsilon Pi fraternity, is actively involved with the Hillel Jewish Students Association, and is co-president of the Materials Science and Engineering Undergraduate Student Advisory Committee.

"The leadership roles in these student organizations can be demanding, but I have made so many great friends. Serving these groups has taught me valuable skills that will contribute to my success."

STUDENT AWARDS

The Paxton Award for Best Doctoral Dissertation in Materials Science and Engineering
Yuanzhi Ma

Thesis Titled "*Formation and Evolution of Conductive Filament in TaOx Resistive Random-Access Memory*"
Advisor Marek Skowronski

The William W. Mullins Undergraduate Award
Nate Roblin

The Hubert I. Aaronson Undergraduate
Andrea Hwang

The James W. Kirkpatrick and Jean Kirkpatrick Keelan Scholarship
Avery Hause

The William T. Lankford Jr. Memorial Scholarship
Phillip Sin

ASM Golden Triangle Chapter Outstanding College Senior Award
Lindsey Helsel

MS Award for Research Excellence
Siyu Gao

MS Award for Academic Excellence
Zhening Yang

INDUSTRY PARTNERS: CAPSTONE PROJECTS

Allegheny Performance Plastics

Professor Michael Bockstaller - Ryne Detiz, Nick Amano, Cisakha Ho, Leon Lai

Polyamide-imide (PAI) is an amorphous thermoset material with exceptional chemical and mechanical stability with emerging applications, for example, as coating material in advanced energy or electronic systems. One challenge in the application of PAI-based materials is the formation of side products during material processing that render the structure and properties of materials inhomogeneous. In collaboration with Allegheny Performance Plastics, students are working to optimize the conditions for curing PAI. The objective is to develop a procedure to determine the kinetics of imidization reactions that control the formation of side products during processing of the material. The procedure involves the analysis of microstructure and properties of PAI and its correlation with environmental conditions (such as moisture content) and thermal history during processing of materials.

Boeing

Professor Tony Rollett - Yilun Wu, Ranjan Mahanth, Jalen Wilson, Sam Dumpala

Additive manufacturing can create residual stresses in materials. These changes in the material can cause its performance to falter. Thermal treatments are a common method to reduce residual stress, however the effectiveness of each type of thermal treatment is unknown. In partnership with Boeing, students are analyzing the characteristics of a low cost, low density aluminum alloy used for aerospace applications. By thermally exposing the material at varying times at elevated temperatures, students are seeking to establish a correlation to the amount of residual stress. Uncovering this can ensure that when materials, like the aluminum in a spaceship, are used they will operate to the highest quality.

Boston-area battery company

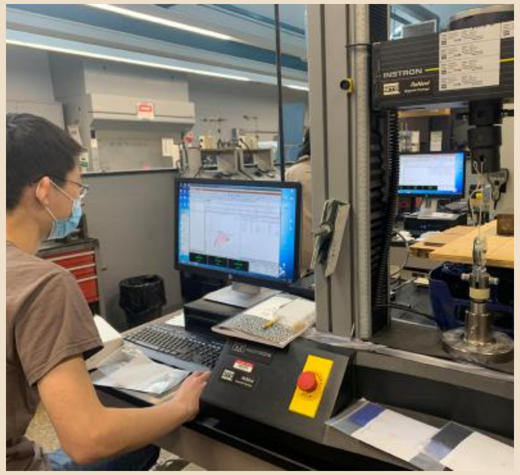
Professor Jay Whitacre - Emmara Barake, Eric Velge, Nathan Love

When batteries are charged too fast lithium ions pile up on the negative electrode. This lithium build up can cause the battery to explode via an internal short. When thinking about our cell phones and cars, this can pose a critical threat close to home. Historically, there has not been a good way to test at what point lithium begins plating a battery in use. In collaboration with an external partner, CMU students are working to improve the ultrasonic assessment of battery health and degree of lithium plating under different conditions. Students are taking a closer look at the batteries under Scanning Electron Microscopes, performing baseline testing studies, and uncovering how the acoustic signal changes with vs. without lithium plating.

Covestro

Professor Robert Heard-Maya Garg, Heeyum Choi Kim, Lucian Hodor, ChanYoung Park

Recycling is imperative to the environment, but it isn't always easy for materials to retain their properties after being broken down. In partnership with Covestro, students are analyzing the recyclability of glass and carbon fiber composites specifically for medical devices. Would it be possible to use recycled composites in lieu of more expensive polymers in medical device applications? Glass and carbon fibers could be used as a rigid replacement in applications where metal is currently used but first students are discovering how variables, such as fiber dimensions, dispersion and orientation are considered in the role of stress strain behaviors.



Integran Technologies Inc. - Professor Robert Heard - Doughlas Gearhart, Daniel Li, Sophie Paul

Covestro

Professor Mohammad Islam - Chantal Alano, Chloe Lenker, Xingyang Li, Kierstyn Cassidy

Thermoplastic polyurethane (TPU) is a polymer that is widely used as a material for the containment of liquids, like IV bags. The fabrication of these bags requires that the TPU be welded by a reliable radio frequency (RF) process. In partnership with Covestro, students are developing an experimental plan to investigate how TF welding impacts the TPU's mechanical properties and microstructure to ensure that the bags won't leak under stress.

INMETCO

Professor Robert Heard - Dilara Ozdoganiar, Tahlia Altgold, Vincent Dai

Inmetco is a metal recycling operation that uses Submerged Arc Furnace technology. Recycling metal depends on the ability to separate the reusable metals from waste and slag. The chemistry of the materials and the plant's operating conditions can impact the separation. Students are actively analyzing what factors are most likely to cause the metal slag separation issues that Inmetco is reporting. Understanding this will enable more metals to be reused and enable Inmetco to improve their product quality prediction process.

Integran Technologies Inc.

Professor Robert Heard - Doughlas Gearhart, Daniel Li, Sophie Paul

Integran Technologies Inc. has recently developed durable-hydrophobic, anti-adhesion epoxy coatings called Eco-Glide that are being considered for saltwater corrosion resistance applications on offshore oil rigs. These coatings are PTFE-free and low-VOC making them more ecofriendly than the current leading coating, Xylan. Students are actively analyzing the effectiveness of Eco-Glide against accelerated saltwater corrosion to determine if it is a viable, eco-friendly option that doesn't compromise on performance.

US STEEL RESEARCH

Professor Chris Pistorius-Cat Shi, Ben Xu, Nathyun Kim

Mold flux is a high-temperature lubricant, used during continuous casting of steel. In addition to lubrication, the mold flux also serves to moderate the rate of heat transfer between the solidifying steel and the copper model. Crystallization of the mold flux is known to correlate with a lower heat transfer rate, whether because of a direct effect of crystallization on heat transfer, or an effect on bubble formation during solidification. Crystallization may also decrease the flow of mold flux, to the detriment of lubrication. In partnership with US Steel Research, students are evaluating the crystallization tendencies by high-temperature confocal scanning laser microscopy and by analysis of slag rims from industrial casing

WHEMCO

Associate Professor Bryan Webler - Omry Alfi, Nick Acero-Blyshak, Nicholas David, Kelly Xiao

The rolls used to make flat-rolled steel products are made by centrifugal casting. During centrifugal steel casting, melt is poured inside a large spinning mold. As the melt cools, flux powder is added to create a protective glassy layer on the inside of the cast pipe. This flux addition process is often inconsistent and creates irregularities if it is delivered nonuniformly. As an essential step in steel processing, in collaboration with WHEMCO, students are analyzing this process and designing a system that improves the method of flux addition and ultimately product quality..

Covestro - Professor Mohammad Islam - Chantal Alano, Chloe Lenker, Xingyang Li, Kierstyn Cassidy

MODELING THE NEXT GENERATION OF MATERIALS

Thomas O'Connor likely spends more time thinking about molecules than most of us. The established researcher joined Carnegie Mellon University's Department of Materials Science and Engineering this fall as an assistant professor.

O'Connor, a theorist and physicist by education, specializes in simulating the dynamics of polymer materials (plastics) at both the industrial and molecular scale. Simulations allow him to tune physical properties in ways that cannot be done in a laboratory. This allows O'Connor to rapidly explore better ways to process materials. He has demonstrated everything from how polymer chains weave together during additive manufacturing to how best to pour ketchup out of a glass bottle.

"I like taking tools used in math and physics communities and asking how we could use them to break open new opportunities in materials engineering," O'Connor explained. He began working in polymer rheology—the study of how polymers flow and deform when impacted by a stress or force—and developed a reputation for applying new numerical methods to address long-standing problems.

"When I was a student, I learned about this new—and kind of complicated—mathematical method for modeling strong flows, and I realized that we could use it to solve some long-standing problems in polymer engineering," O'Connor recalled, and that is exactly what he's been doing. For the last three years, he's worked under the independent Harry S. Truman Fellowship at Sandia National Laboratories in Albuquerque, New Mexico, where he had the chance to develop his own research program. One of his largest projects was developing an open-source polymer modeling software called Reproducing Hydrodynamics and Elastic Objects, or RHEO for short. That research is now being brought to Carnegie Mellon.

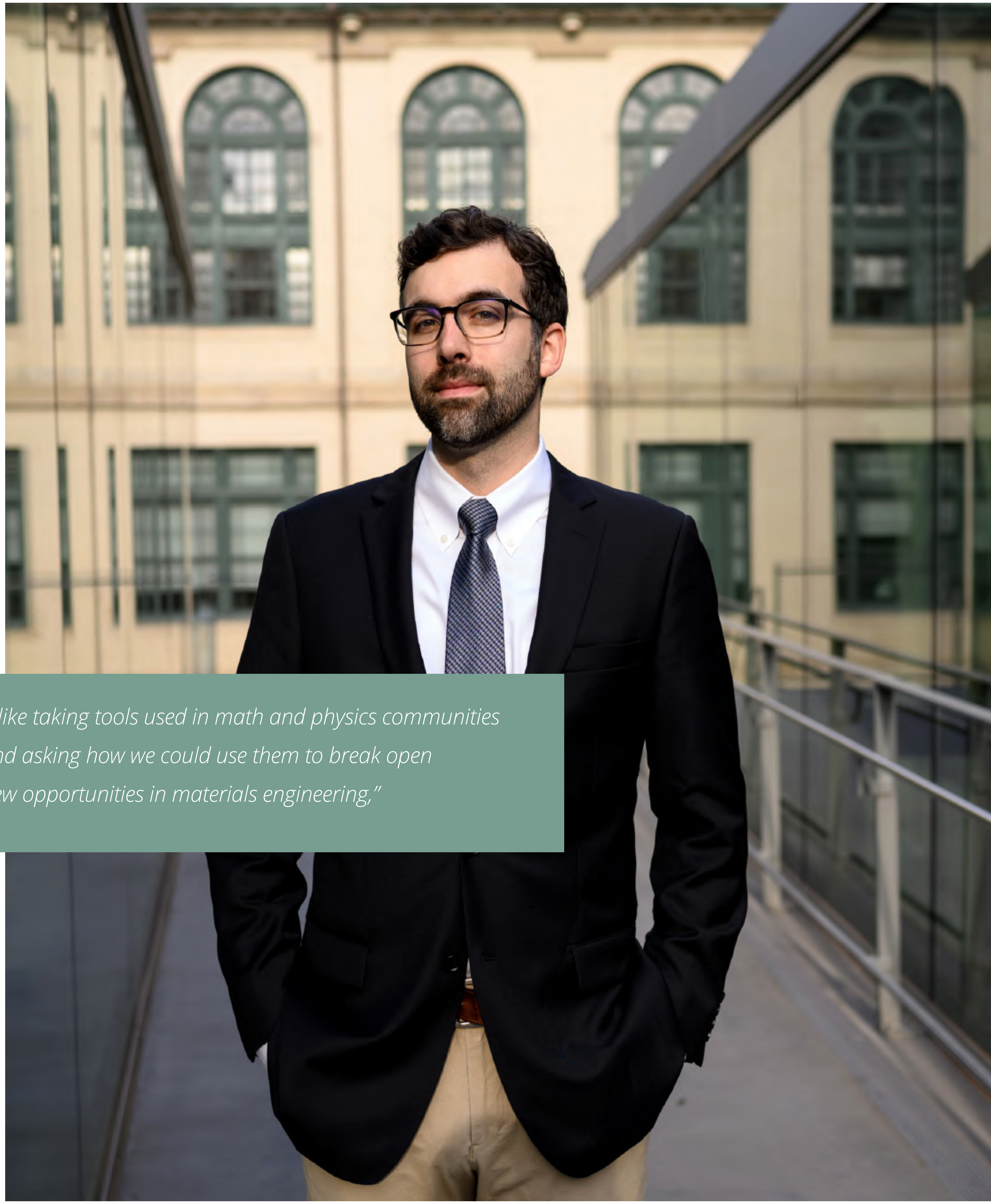
Today, O'Connor wants to focus on designing sustainable, soft materials using physical modeling and simulations. Recently, his simulations were used with the Department of Energy Office of Science to show that a special type of polymer liquid made up of polymer rings defies the rule of "strain hardening," the phenomena where a polymer liquid can be stretched gently so that it does not solidify. Stretching this special type of polymer liquid drives the polymer rings to tie together into long chains that act like massive molecules and ultimately increase the fluid's viscosity, or its ability to act like a solid. This discovery could be used to make recyclable plastics stronger.

Once the microscopic properties of a particular material, like polymer liquids, are understood, O'Connor can ask how they are best used in manufacturing. "The goal of the group is to not only understand how we can manipulate the properties at the molecular scale, but also how we can use these microscopic insights to improve how industries work with materials on the factory floor." For example, researchers can use the unique polymer liquid characteristic to help regulate polymer flow in industrial applications by designing intelligent fluids that can become highly viscous when elongated but flow easily under different conditions.

Last fall, O'Connor taught Methods of Computational Materials Science class alongside Materials Science and Engineering Professor Elizabeth Holm, who specializes in metallurgical material modeling. With O'Connor's focus in soft materials, he believes they make for a well-rounded introduction to the discipline.

O'Connor is incredibly excited to work with students in their environment. "Their energy, curiosity, and enthusiasm can be really encouraging, and really helpful. Research can be a long and tedious process, so it's great to spend time with folks with fresh perspectives who are interested and excited about it!"

O'Connor earned his bachelor's in physics from the Rensselaer Polytechnic Institute, and a master's in physics from Johns Hopkins University. He earned his Ph.D. in physics from Johns Hopkins University before moving on to the Sandia National Laboratory in 2018. He now comes to Carnegie Mellon as an assistant professor of materials science and engineering.



"I like taking tools used in math and physics communities and asking how we could use them to break open new opportunities in materials engineering,"

MEET MSE'S FIRST ASSOCIATE DEPARTMENT HEAD

In July 2021 the Department of Materials Science and Engineering named Professor Chris Pistorius as the Associate Department Head. He is the first to hold this position and works alongside Department Head Elizabeth Dickey.

Pistorius came to CMU in 2008 after 16 years at the University of Pretoria in South Africa. He joined the Center for Iron & Steelmaking Research, where he studies steel compositions and production. He is currently the Co-Director of the Center for Iron and Steelmaking Research (CISR).

"The huge advantage of CISR is that it's been running for a long time and has good links with various steel companies," Pistorius said. "When the position at CMU came up it seemed like an opportune time to jump across the Atlantic Ocean."

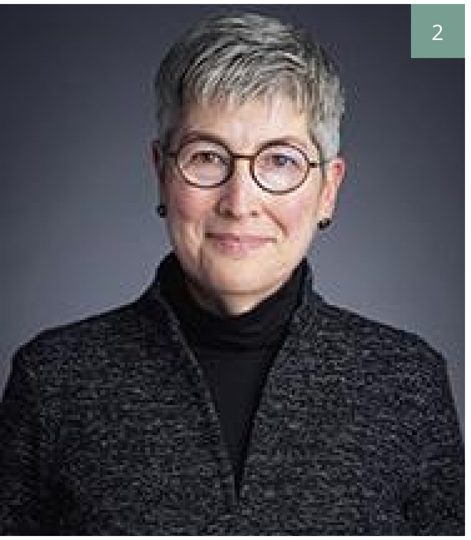
While at CMU, Pistorius has taught many classes, including thermodynamics and electives in metals production and processing. He also teaches a class on materials selection for civil engineering students.

Since becoming Associate Department Head, he has been working to improve the experience of graduate students. Pistorius and Dickey are implementing new programming that aims to help students adjust to graduate school.

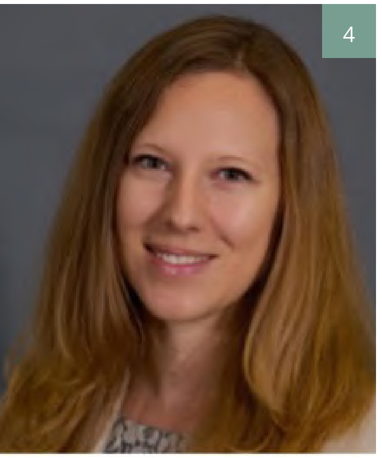
The department has made several "tweaks" to the incoming graduate student programming, according to Pistorius. They have introduced several first-year seminars that cover topics like publishing research and promoting diversity, equity, and inclusion. The goal, he said, is to make the transition as smooth as possible.

"This goes from how we recruit graduate students, how we orient them into our program when they arrive, and how we give them the best tools to succeed once they're here," Pistorius said. "For a typical graduate student, this is likely the most productive two or four years of their professional life. They choose to spend it with us, and that's quite a responsibility."


1


2


3


4


5


6

FACULTY AWARDS

President of The American Ceramic Society
Beth Dickey (1)

ASM Edward DeMille Campbell Memorial Lecturer for 2021, Structural Materials Division Distinguished Scientist/ Engineer Award
Elizath Holm (2)

Institute of Physics Early Career Lecturer
Thomas O'Connor (3)

Dean's early career award
Noa Marom (4)

AIST Brimacombe Memorial Lecture Award
Chris Pistorius (5)

The American Ceramic Society, fellow
Paul Salvador (6)

After 36 years of service to the Department of Materials Science and Engineering, Professor Warren M. Garrison retired in 2020. Past students, faculty and staff members joined Garrison and family over dinner in November to celebrate his achievements.

A beloved faculty member since 1984, Garrison taught many classes, but is especially known for teaching thermodynamics to generations of MSE students across multiple decades.

STAFF NEWS

Paige Houser, Senior Academic Advisor was awarded the 2021 Andy Award for Commitment to Excellence. The award honors staff members who take great pride in producing excellent work. They serve their customers with a steadfast commitment to quality performance. Nominees have an upbeat attitude and are consistently willing to invest considerable time and effort to overcome obstacles so that outstanding work might be delivered. Congratulations, Paige!

Kaitlyn Landram joined Carnegie Mellon University in the summer of 2021 as a communications manager. She works with the Department of Materials Science and Engineering to share research stories, coordinate social media and web development, build relationships with media, and circulate news internally. Welcome, Kaitlyn!

CLOSING THE FOOD LOOP

> *"We want to inform as many people as we can about the work we are doing to contribute to a sustainable world."*
>
> - Dylan Lew (MSE BS/MS '21), CEO, Ecotone Renewables

In the fall of 2017, Dylan Lew a freshman at Carnegie Mellon University joined a startup company that was shifting its focus from aquaponics to anaerobic digestion, a process where microorganisms break down biodegradable material in the absence of oxygen. The company, Ecotone Renewables, was looking for advice on the best way to store and utilize the biogas being emitted from their system. Lew was able to help. Fast-forward to today and Lew, a graduate from CMU's Materials Science and Engineering bachelor's and master's program, is proudly serving as the company's CEO, dedicated to building the tools necessary to empower communities to redevelop and grow through sustainable food practices

Globally, 30-40% of all food produced is wasted, but Ecotone Renewables is seeking to "close the food loop" by repurposing food waste in their exclusive system called the "Seahorse." Using rainwater, the system can "digest" food waste and turn it into renewable energy and nutrient-rich fertilizer.

The pilot system has been up and running for two years in Pittsburgh's East Liberty and Swissvale neighborhoods, processing ten tons of food waste each year. Most of the food they process comes from partnerships with 412 Food Rescue and the Greater Pittsburgh Community Food Bank who jointly provide 300 pounds of food waste each week. Another 85 pounds of waste comes from a community program, where neighbors are encouraged to drop off their filled compost bins. "It's nice to get the community involved because it gives us the chance to talk with local residents and really get them to understand and be involved in the process," shared Lew.

Fertilizer produced through the anaerobic digestion process is the company's main product. Last year, Ecotone Renewables donated 200 gallons of fertilizer to Sheridan Orchard, a Repair the World Location in East Liberty. Their donation helped the orchard harvest their largest crop yet, enabling 600 pounds of fresh produce to be donated back to the community.

The renewable energy produced onsite sets Ecotone Renewables apart from other food-waste management processes. Landfilling and food waste degradation around the world produces over eight percent of Greenhouse Gas emissions -that's twice the amount of pollution put out by the airline industry. In contrast, the Seahorse captures the emitted biogas and runs it through a retrofitted generator. The energy produced can then run the Seahorse, charge the team's phones, electric bikes, and even their vehicles. Soon, the team hopes to use the Seahorse's power to create a neighborhood energy hub with WiFi and charging stations open for the community.

Lew and the company's two other executives heavily rely on their team of twelve interns to keep the seahorse running. The intern team, including two current CMU students, Emma Barake and Alexandra Reyes, is on the ground feeding the system two to six times each week. On top of that, students conduct independent research projects. When their internship is complete the students are certified to operate anaerobic digestive systems for years to come. "The internship program has been working really well," said Lew. "Our students gain a lot of experience to really aide in their skill development."

Today, Ecotone Renewables is focused on building more Seahorse systems across the country and raising the funds to do so. Supermarkets and restaurants in Vermont, New York, Boston and Philadelphia have expressed interest in installing a system. Lew explained, "We want to inform as many people as we can about the work we are doing to contribute to a sustainable world."

MSE WOMEN NAMED PRESIDENT OF THREE PROFESSIONAL SOCIETIES

"If we're going to solve the really tough challenges facing the materials community there can't be parts of the profession that don't have a seat at the table."

- Ellen Cerreta, president of The Minerals, Metals & Materials Society

With less than 30% of researchers in science being female, it is no surprise that women in the field must overcome their own unique set of challenges. Elizabeth Dickey, MSE Department Head and alumnae Carolyn Duran (MSE BE '92) and Ellen Ceretta (MSE MS '97, Ph.D. '01) are breaking down barriers, increasing female representation in materials, and working to impact and encourage future generations through their executive roles in professional societies for scientists and engineers.

Carolyn Duran was introduced to materials science at Carnegie Mellon University the summer before her freshman year where her work with MSE Professor Alan Cramb would become so influential that she would stay within his research group for the next four years and later carry the passion for MSE and education into her career. Duran was named the 2022 President of the Materials Research Society (MRS) and has made it her goal to increase engagement between the society and industry.

"During my time at CMU, the graduate students took me under their wing in a very positive way," she remembered. "At the time I thought, 'Wow, I want to be just like them'. This field is relatively small and I've been able to stay connected with scientists from different parts of my life and continue to find sources of inspiration."

Over the last 20 years, Duran has served in various positions at Intel Corporation, and is currently transitioning back into a role focused on materials science in the Components Research organization, which focuses on semiconductor research to advance Moore's Law.

"When you have a vision of where you want to go, you have to come to the realization that your steps might not be straight and that's okay. You can keep your vision, and step sideways or backwards and still end up where you want to go," Duran advises.

Ellen Ceretta was named President of The Minerals, Metals, & Materials Society (TMS) in April 2021. She has been involved with TMS since early in her career where she met her post-doctoral mentor and was connected with the Los Alamos National Laboratory, where she still works today as a division leader. Ceretta's research focuses on the relationship between microstructure and dynamic material properties and provides innovative and agile materials science and technology solutions for national security missions.

"I could be the poster child for why joining a professional society is beneficial," Ceretta laughed. "Not only is it a great networking opportunity to find a job, but it's also a place where you can have a really honest look at your work and make sure that you're going in the right direction by leveraging all the know-how within the profession."

Ceretta is passionate about making TMS a society that promotes equity and inclusion. Throughout her career it has been helpful for her to see women at all levels of leadership succeed so that as she found her own path she could be guided by theirs.

"I feel strongly that we're going to be able to solve the really tough challenges that are in front of the materials community, but these are all-hands-on-deck problems. There can't be parts of the profession that don't feel like they have a seat at the table."

Elizabeth Dickey thanks her mentors, particularly her parents for enabling her to claim her seat at the engineering table.

"They always gave me the chance to fail," Dickey explained. "Failure is such an important part of learning and my parents never stopped encouraging me to try again. It made me feel capable to take chances in my career and has led me to where I am today."

Dickey is the 2021-2022 President of The American Ceramic Society and wants to focus her term on increasing membership and membership engagement. During her career she benefitted from a network of academic and industry partners, and she wants to continue to strengthen the connection of these two groups to play a role in mentoring students and young professionals.

"I'd encourage all students interested in engineering to consider Materials Science. Our work spans many industries and as new materials are developed; new jobs are created. We really make our own opportunities," said Dickey.

As more and more women, like Elizabeth Dickey, Carolyn Duran, and Ellen Ceretta become leaders in science and engineering, the representation dynamic will shift, and perhaps more people will think the same way as Duran's son:

"Many years ago, I remember saying to him, 'Maybe you'll become an engineer' and without hesitation he responded, 'But, girls do that.'"

Girls do, do that, and the world is advancing every day because of it.

MILES HINDERLITER
MSE BS ‘02

From engineering stealth fighters at Lockheed Martin to advising Executives at Barclays and now Campbell's Soup, Miles Hinderliter has found success in his career as he transitioned from engineering to finance.

“Finance is numbers oriented, but the thing that makes you stand out is interpreting those numbers – the same as in engineering. None of it means anything unless you can understand it and draw a conclusion.”

Miles believes that the education he received from the Materials Science and Engineering Department at CMU helped him to kickstart his career and to become the problem solver he is today.

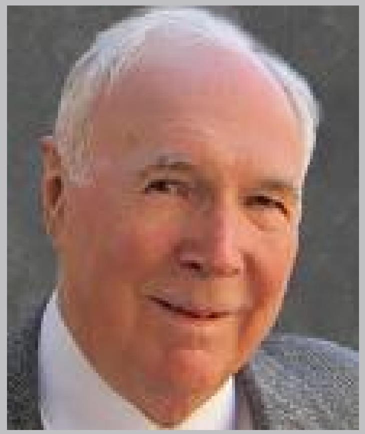
“I've had a lot of opportunities in the last 20 years, but nothing significantly changed my life the way my start at CMU did.”

He looks back at his time in MSE fondly, from the close-knit group of friends that he keeps today to the professors that went out of their way to support his research. It is for those reasons that Miles decided to give back to the Department.

Miles has given a gift to establish the MSE Student Impact Fund to support the student experience, including hands-on learning and research.

“My experience at CMU was as fun as it was challenging because of the opportunities I had, the friends I made, and the supportive professors that took something complicated and made it interesting. I'm grateful to be able to pay it forward now.”

IN MEMORIAM

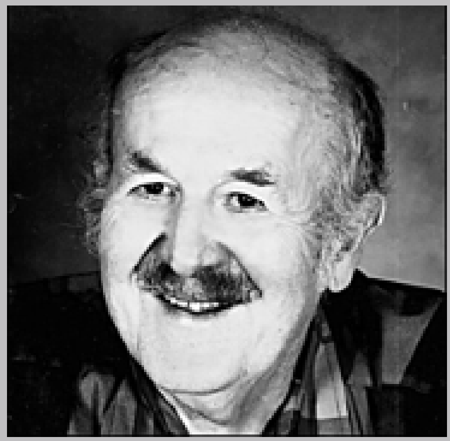


Harold W. Paxton, former head of the Department of Materials Science and Engineering, passed away on March 8, 2021 at age 94. Paxton, U.S. Steel University Professor Emeritus, had an incredible impact on MSE through his research, mentorship, and leadership. He was an important part of the Carnegie Mellon University community for almost 70 years. He started his career at Carnegie Institute of Technology in 1953 as assistant professor of Metallurgical Engineering. During his time at Carnegie Tech, now Carnegie Mellon, he served as head of MSE and director of the Metals Research Laboratory. After retiring from active teaching, Paxton worked as a consultant to government and industry. Some of his work was with United States Steel Corporation, where he served as vice president of research and eventually vice president of corporate research and technology assessment. Paxton was often recognized for his impressive contributions to the field of physical metallurgy. He was a Fellow of the American Association for the Advancement of Science, member of the National Academy of Engineering, and Fellow of the American Society for Metals and the Minerals, Metals & Materials Society of AIME (TMS). He was very active in professional societies, serving as president of TMS, chairman of the General Research Committee of the American Iron and Steel Institute, and president of American Institute of Mining, Metallurgical, and Petroleum Engineers during his career.

“Another important example of Harry Paxton's commitment to our department and to excellence is the Paxton Award. This recognizes the best doctoral thesis every year, has been made possible since 2005 by a gift from Ann and Harry Paxton, and serves as an annual reminder, at commencement, of the Paxton's.” said Chris Pistorius, Professor and Co-Director, Center for Iron and Steelmaking

“Harry Paxton is responsible for much of what MSE is today — he was a student, faculty member and head of the department. His philosophy about Materials Science and Engineering research and education is carried on in all our department activities. He will be remembered as an influential leader of the MSE Department and a globally recognized metallurgist who made significant contributions to the field,” said Greg Rohrer, W.W. Mullins Professor of Materials Science and Engineering and former head.

Beth Dickey, MSE Department Head, and Chris Pistorius, Associate Department Head, stand in front of a painting by Mrs. Ann Paxton, Harold's wife. The painting was commissioned by former MSE Department Head, Alan Cramb and it has remained in the MSE Department since 2001



Kenneth C. Russell (Ph.D. '64) passed away on March 25, 2020. He served as an esteemed faculty member at MIT for many years, beginning in 1964 as an assistant professor and was ultimately promoted to full professor in 1978. His research interests were in nucleation theory and radiation damage to materials. Kenneth was not just a graduate, but a beloved member and loyal supporter of CMU's Department of Materials Science and Engineering. He also faithfully attended the annual alumni “Saltminer's” dinner, and in 2012 he received the Alumni Achievement (Merit) award.

Carnegie Mellon University
Department of Materials Science & Engineering

Materials Science & Engineering Department
Carnegie Mellon University
5000 Forbes Avenue
Pittsburgh, PA 15213
www.cmu.edu/engineering/materials

Connect With Us!

Connect with us on social media

CMU_MSE

CMU_MSE

Department of Materials Science and Engineering at CMU & Look for our alumni group!