Center for Materials Processing

2021 Annual Report

ENGINEERING

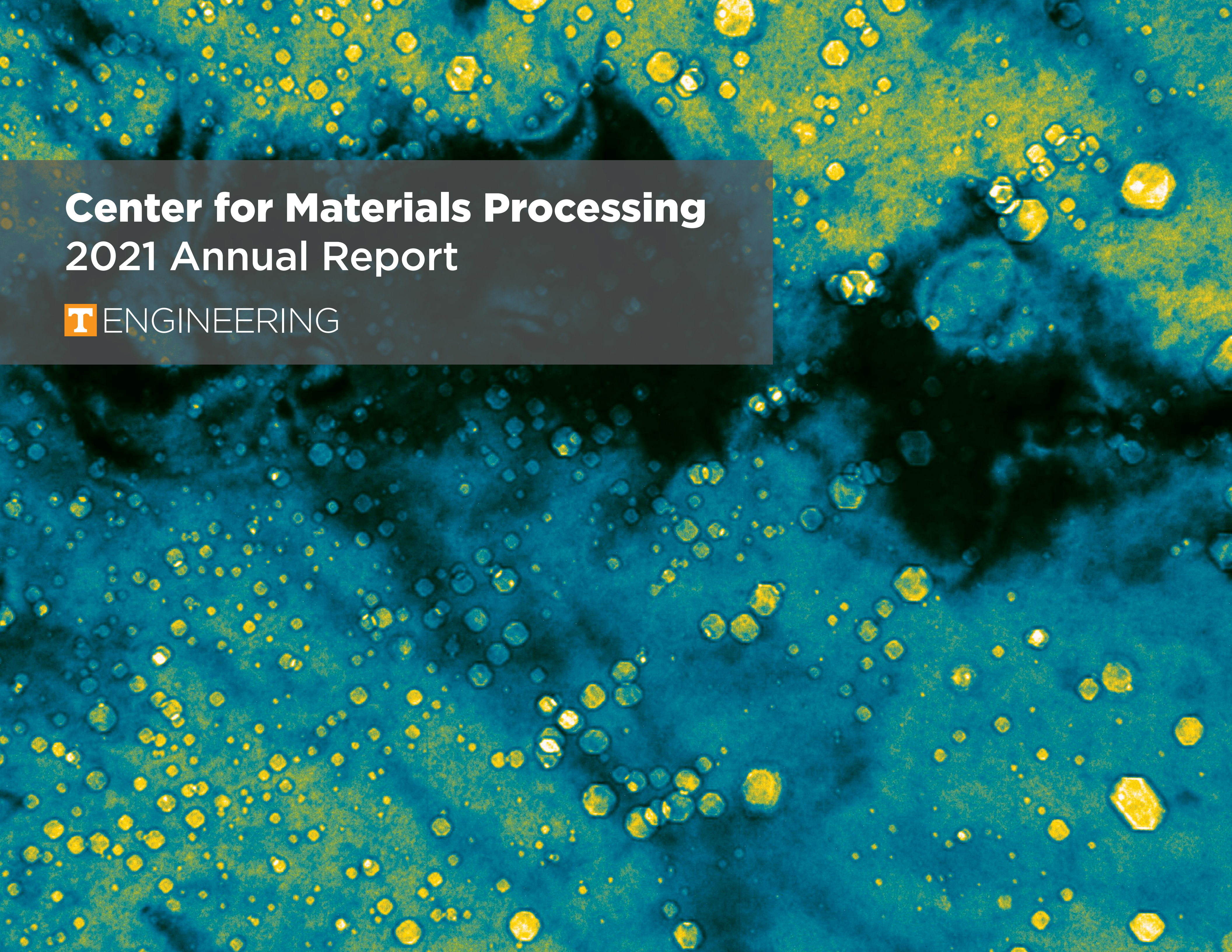
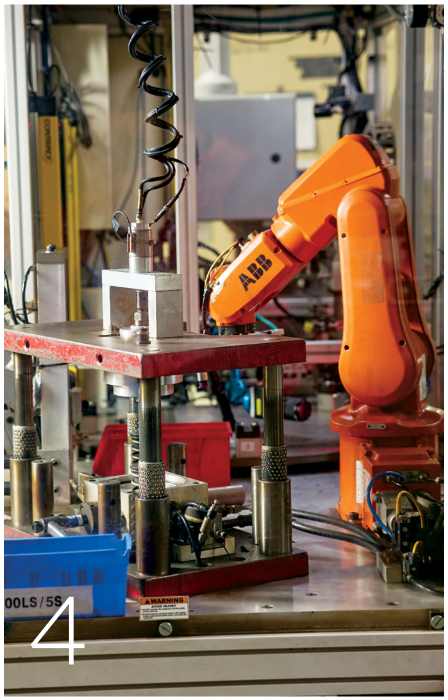
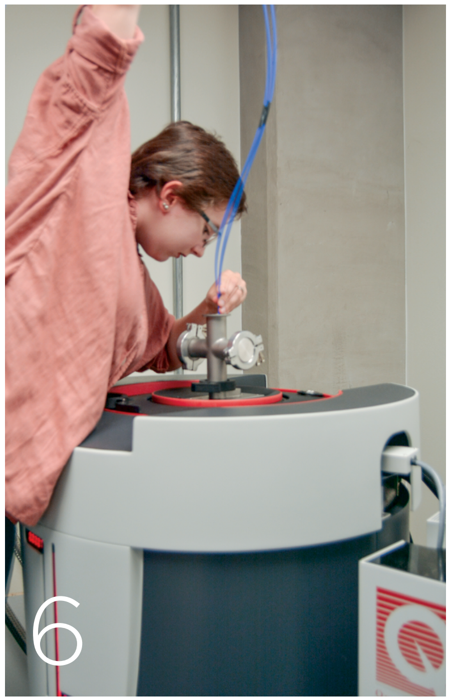
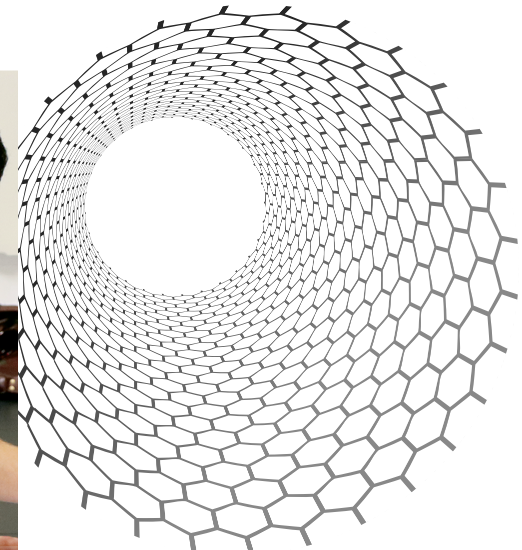
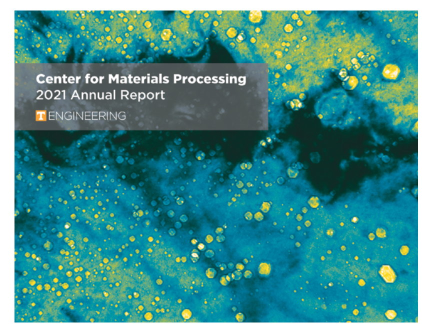


Table of Contents









On the Cover: Colorized TEM image of irradiation-induced cavities in Fe-10Cr model alloy.
Photo Credit: Yan-Ru Lin

Project Manager: Melissa Callahan
Designer: Jill Knight

Advisory Committee

Established in early 2014, the CMP Advisory Committee works with the CMP Director (Rawn) and Associate Director for Industrial Partnerships and Undergraduate Research (Duty) regarding various areas of research that the CMP can advocate for and invest in for the future. The CMP leadership and the Advisory Committee are working together with the goal of bringing positive recognition to the CMP, the Tickle College of Engineering, and the University of Tennessee in areas related to materials processing. In past meetings the CMP Advisory Committee included discussions focusing on how the CMP can help provide a link between local industry and the University of Tennessee.

- **Sudarsanam Suresh Babu**, PhD
UT/ORNL Governor's Chair of Advanced Manufacturing
Professor – Mechanical, Aerospace, and Biomedical Engineering
Tickle College of Engineering
University of Tennessee, Knoxville

- **William Dunne**, PhD
Associate Dean – Research and Technology
Tickle College of Engineering
University of Tennessee, Knoxville

- **Neal Evans**, PhD
Local Industrial Consultant

- **Veerle Keppens**, PhD
Professor and Head, Materials Science and Engineering
Tickle College of Engineering
University of Tennessee, Knoxville

- **Beth Snipes**
Senior Materials Engineer
Technology for Energy Corporation (TEC)

- **Danny Norman**
Center for Industrial Services
University of Tennessee

- **William Peter**, PhD
Director, Manufacturing Demonstration Facility
Oak Ridge National Laboratory

- **Trevor Toll**
Research Engineering
Analysis and Measurement Services (AMS) Corporation

Mission Statement

The Center for Materials Processing supports teaching and conducting basic and applied research emphasizing relationships between processing, structure on various scales, and properties of all classes of materials. This support improves existing processing and synthesis techniques, develops new materials and technologies, transfers improvements to the applied sector, and equips students to thrive in the broad field of materials science and engineering. The Center fosters interdisciplinary activities and establishes partnerships with industries and other institutions as appropriate.

Executive Summary

As the pandemic with its extraordinary circumstances added levels of complexity to both work and everyday life, the Center for Materials Processing (CMP) embraced the message from Chancellor Donde Plowman to be creative, compassionate, and flexible. In doing so, the CMP increased the number of both facility level and full memberships, graduate and undergraduate students supported, and more than doubled the publications from the previous year. Eleven graduate students that have been affiliated with the CMP graduated and are continuing their careers in research, including positions in the private sector and as post-docs at national laboratories. Several of the undergraduate students partially supported by the CMP to conduct undergraduate research under the supervision of faculty members have achieved high profile awards, including Fulbright Scholarships, an NSF Graduate Research Fellowship, and top honors from the Office of Undergraduate Research at the annual Exhibition of Undergraduate Research and Creative Achievement (EURēCA) event.

CMP Staff

Claudia Rawn

Director

Claudia Rawn has been director of the Center for Materials Processing (CMP) since July 1, 2012. She is as an associate professor in the Department of Materials Science and Engineering at the University of Tennessee and has taught Introduction to Materials Science and Engineering, X-ray Diffraction and Structural Characterization of Materials, Principles of Ceramics, and is one of the original faculty associated with the Materials Processing course that was first introduced to MSE in 2005. Rawn has served as the chair of the Undergraduate Affairs Committee in the department, the Materials Advantage faculty advisor, and is on the University of Tennessee's Undergraduate Research Advisory Committee. Her research interests include investigations of crystal structures, phase transitions, and thermophysical properties of a variety of materials using in-situ X-ray and neutron scattering methods. Rawn is the PI and site director of the UT site of the Manufacturing and Materials Joining Innovation Center (Ma^{2}JIC), funded by the National Science Foundation (NSF) Division of Industrial Innovations and Partnerships (IIP) and individual industrial memberships. She received her bachelor's in materials engineering from Virginia Tech, her master's in chemistry from George Mason University, and her doctorate in materials science and engineering from the University of Arizona.

Chad Duty

Associate Director for Industrial Relations (April 2021–)

Chad Duty began in the role of Associate Director for Industrial Relations with the CMP on April 1, 2021. Duty joined the University of Tennessee in August 2015, is an Associate Professor in the Department of Mechanical, Aerospace, & Biomedical Engineering at the University of Tennessee, and maintains a Joint Faculty appointment with Oak Ridge National Laboratory's (ORNL) Manufacturing Demonstration Facility (MDF). Prior to joining UT, he was a Senior Research Scientist and Group Leader of the Deposition Science & Technology Group at ORNL. Duty's research focuses on advanced materials and process developments for additive manufacturing, or 3D printing. This work led to the commercialization of a large-scale 3D printer for polymer composites called BAAM (for Big Area Additive Manufacturing) and the manufacturing of the world's first 3D printed car (the Strati). Duty received his bachelor's in mechanical engineering from Virginia Tech in 1997 and his doctorate in mechanical engineering from Georgia Tech in 2001. After spending a few years with Lockheed Martin on the redesign of the C-5 Galaxy, he joined ORNL as a Wigner Fellow in 2004.

Chris Wetteland

Associate Director for Industrial Relations and Undergraduate Research (2017-2020)

Chris Wetteland was the Associate Director for Industrial Relations and Undergraduate Research from 2017-2020. In December 2020, Wetteland left the University of Tennessee to return to Los Alamos National Laboratory. During his time in the Department of Materials Science and Engineering, Wetteland served in several different capacities including an Associate Professor of Practice, where he taught the laboratory coursework and senior design. Wetteland had a special bond with the students and worked tirelessly to help them develop not only their laboratory skills but also their critical thinking skills and their ability to express themselves both through oral presentations and writing. His research interests include radiation damage in nuclear materials, ceramic processing, solar energy, ion beam analysis, advanced manufacturing, early solar system processes, and STEM outreach. Wetteland received his bachelor's degree in Geology from Northeastern Illinois University, a master's in Ceramics and Materials Engineering from Rutgers, and a PhD in Earth and Planetary Sciences from UT. Wetteland previously worked at Los Alamos National Laboratory as a staff member from 1997-2006, where his primary research was in ion beam analysis and radiation damage in materials. From 2010-2013 he was a research fellow at the University of Wisconsin-Madison, where he investigated accelerated aging of nuclear materials using particle accelerators.

CMP Staff

Amber White

Administrative Specialist

Amber White has served as the administrative specialist for the CMP and the RMC since November 2016. Before joining the university, she spent five years in social work, specializing in low-income senior housing and fair housing regulation.

Karen Boyce

Financial Specialist

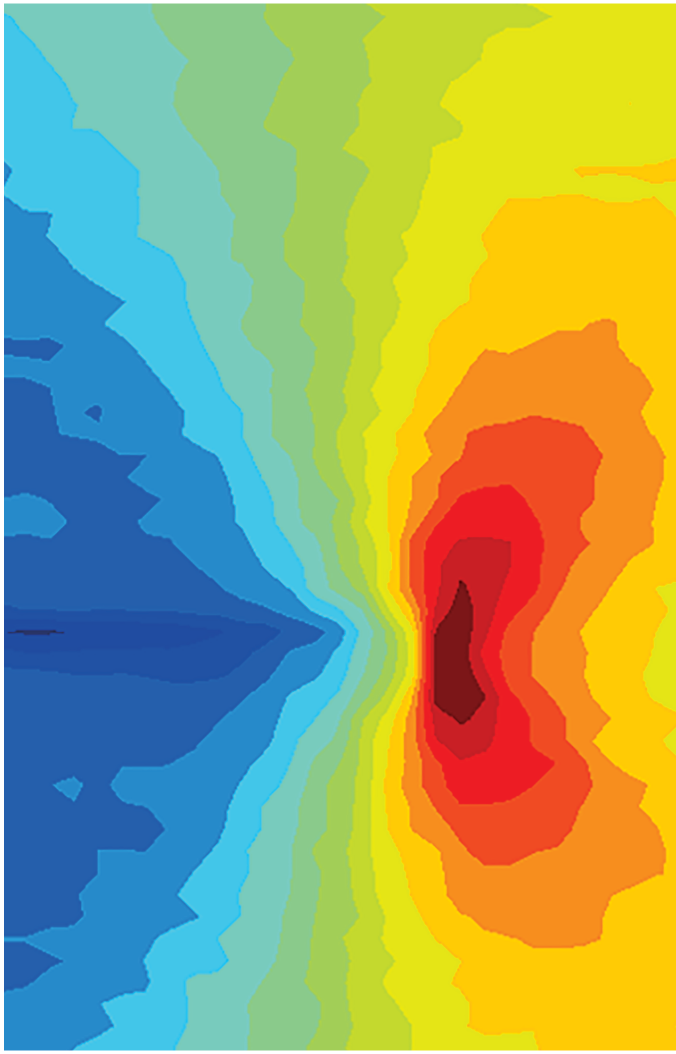
Karen Boyce is the financial specialist for the CMP, the Scintillation Materials Research Center (SMRC), the Reliability and Maintainability Center (RMC), and the Manufacturing and Materials Joining Innovation Center (Ma²JIC) University of Tennessee, Knoxville, site. She has been working within various university systems since 1995 and joined UT in June 2011. Boyce was awarded the 2021 Tickle College of Engineering Pass the Torch Award recognizing a staff member that had demonstrated all-around achievement and exceptional service to the college.

Gerald Egeland

Student Supervisor

Gerald Egeland is the Center for Materials Processing student supervisor and works with the undergraduate students on CMP Industrial Membership sponsored research. He has a joint appointment with the Department of Materials Science and Engineering serving as the undergraduate laboratory manager and the departmental safety officer. Egeland graduated with his bachelor's in Materials Science and Engineering in 1997, a master's in 2000, and a doctorate in Materials Science in 2005 from New Mexico Institute of Mining and Technology. His graduate work focused on biomimetic materials, carbon nanotubes, nuclear-fuel and radiation damage characterization and was performed at Los Alamos National Laboratory. After obtaining his doctoral degree, he was a Postdoctoral Research Associate at the Paul Scherrer Institute in Switzerland before transferring to Idaho National Lab and eventually the University of Nevada, Las Vegas. His personal research has included working on radiation damage of alloys, ceramic powder processing for advanced fuel, and fuel-cladding interactions. Over the years in his various capacities, Egeland has supervised students and technicians and began teaching while at UNLV, producing and teaching a graduate SEM course. He also taught chemistry part-time at both Nevada State College and the College of Southern Nevada.

Photo Credit: Di Xie
Strain mapping around a crack tip to characterize a ZK60 Mg alloy during a fatigue crack growth.



Academics and Industry Enjoy Mutual Benefits in CMP Partnership with Fulton Bellows

Writing by Randall Brown. Photography by Shawn Poynter.

A long tradition of Volunteer involvement comes full circle for Knoxville manufacturer Fulton Bellows through an ongoing membership with the Center for Materials Processing (CMP). The company was founded in 1902 by UT meteorologist Weston Fulton and now engages with the CMP by placing UT materials science and engineering (MSE) students at the cutting edge of developing better materials.

Fulton shares an industry-wide challenge to develop new products in areas of aerospace, automotive, and oil and gas. These are rarely designed with old technologies, so the CMP student program helps Fulton connect with the latest materials, processes, characterization instrumentation, and modeling and databases.

Cole Franz, a five-year BS/MS student in MSE, has been the primary student working with Fulton since 2020. His first order of business when he is on-site is to listen and gather information from the people who make the facility work.

"At every level of Fulton's operation, the people, the machinery, and the processes come together essentially as puzzle pieces," said Franz. "Together, with the scientific knowledge that my mentors have taught and graciously provided to me, I utilize this information to help solve problems."

"Cole has performed above and beyond any expectations that Fulton could have imagined," said Kelly Ferguson, manufacturing engineer manager at Fulton. "He has been very instrumental in helping us identify issues and then developing solutions to overcome."

In return, Franz is able to apply these lessons when he is back in the classroom.

"Due to the nature of the analyses, my understanding and use of equipment that is vital to the materials scientist has improved," he said.

“I believe that the MSE department as a whole can greatly benefit from an improved understanding of industrial needs, better preparing our students for their careers.”
—Assistant Professor Eric Lass

“On multiple occasions, Cole has also prepared and presented findings to a high-level customer of Fulton,” added Ferguson. “We could not have asked for more.”

The processes at Fulton Bellows transform metals—often exotic metals—from sheet or coil into thin-wall tubes, which are then formed into bellows for assembly applications.

“Often times, our processes will push the material to the extreme limits of its performance,” said Ferguson. “Cole has been working with us to identify adjustments to our process to avoid these boundaries so that we can keep material properties more uniform and predictable. Our business is all about consistency—if we have a consistent process, we can adjust accordingly to overcome issues that arise. Through the partnership with the CMP, we are able to normalize our processes and provide a more consistent product.”

Assistant Professor Eric Lass, the faculty point-person for students and Fulton, feels that the relationship has given him an industrial perspective of day-to-day issues related to engineering and increased knowledge of the expectations for entry-level engineering graduates.

“I believe that the MSE department as a whole can greatly benefit from an improved understanding of industrial needs, better preparing our students for their careers,” said Lass. “We are also planning to have a capstone, senior design project sponsored by Fulton this upcoming academic year, which will provide our seniors first-hand experience into real-world industry-related problems.”

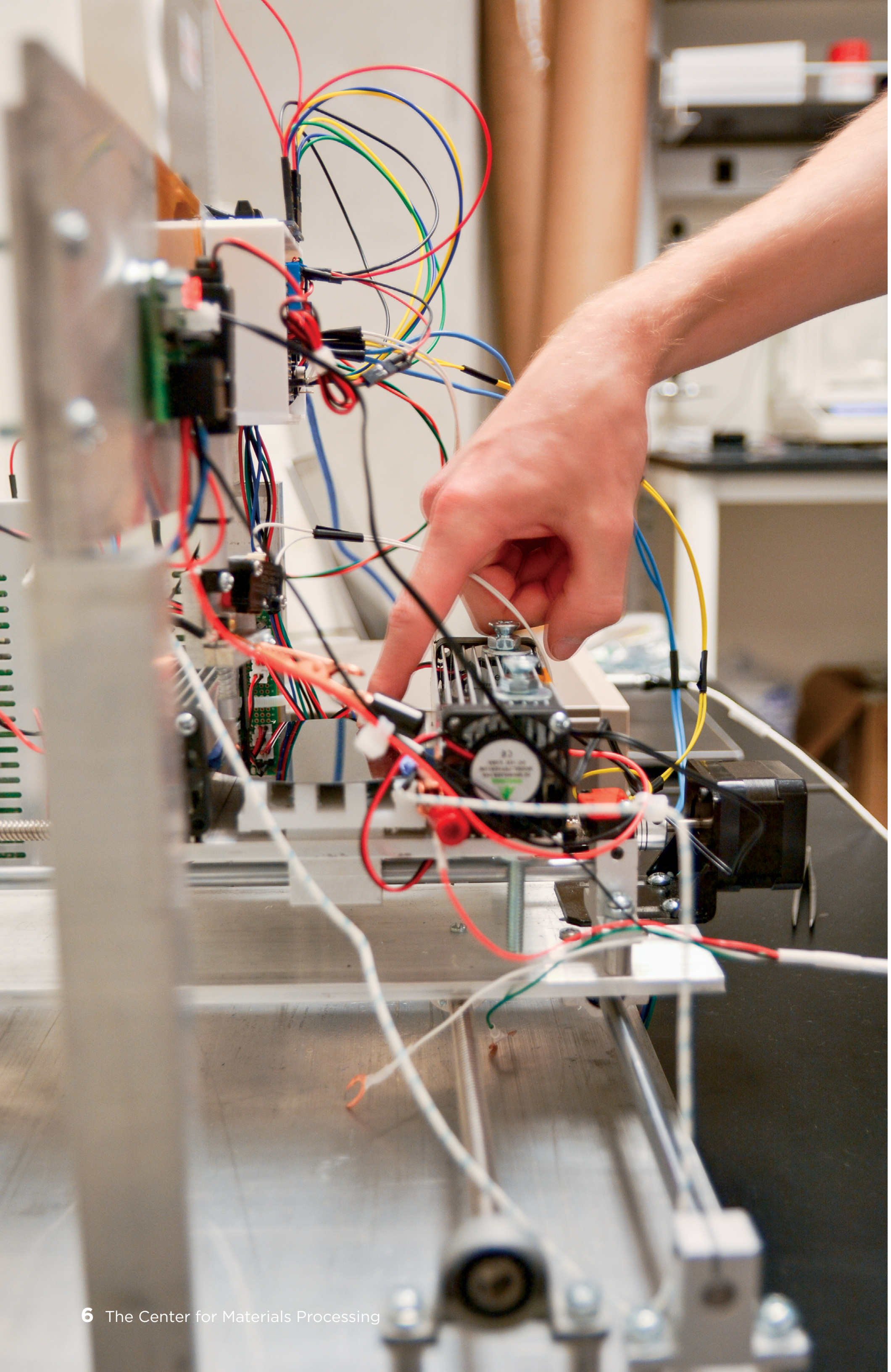
For Franz, the exercises in technical communication revitalized his interest in how engineering problems are solved.

“No matter anyone’s role or responsibility, everyone has critical information and unique perspectives to contribute to the optimal solution,” he said. “I’ve realized that no one person can be responsible for or can solve complex problems. It requires a team.”

A new CMP student, rising junior Jack Frederick, joined the program for summer 2021. He will participate in a deep dive of multiple materials projects for product lines as Fulton addresses a spike in demand with the return of certain markets after 2020’s downturn.

“These students are already getting prepared to be ready for identifying opportunities to im-

prove our processes which will ultimately result in reduced scrap costs and improved yield,” said Ferguson. “This will allow Fulton Bellows to be more competitive in a very demanding market, with the goal being improved quality, increased market share, and sustainability for our business.”



Exploring the Boundaries

Writing by Meghan McDonald. Photography by Yvette Gooden.

Neither Lizabeth Quigley nor Noah Hobson majored in Materials Science and Engineering (MSE). Quigley graduated last May from the Mechanical, Aerospace and Biomedical Engineering Department, while Hobson majored in Computer Science. Both of these recent graduates, however, learned the ropes of research in Dustin Gilbert's Advanced Materials and Manufacturing lab.

"Our research group is incredibly multidisciplinary," said Gilbert, an MSE assistant professor. The group is focused on nanomaterials and regularly collaborates with researchers in food sciences, ecology, and other disciplines. "It's so beneficial because we're all experts in our respective domains, but a lot of the most interesting science out there lives at the boundaries, where no one has all the experience to accurately investigate."

Gilbert recruited Quigley in 2019 for an undergraduate research role funded in part by the Center for Materials Processing. "He was doing things I'd never heard about," said Quigley. "Learning new things is so exciting to me, and each project I've done in his lab focuses on something a little different."

"Nanomaterials are still an unknown field in many ways," Gilbert said. "For undergrads who are learning so much foundational knowledge in class, nanomaterials are an opportunity to walk into something you can't look up in a book. It's a powerful experience."

In the lab, Quigley ran simulations, prepared samples, analyzed data, and forged relationships with graduate research assistants. Her experience prepared her to participate in the National Institute of Standards and Technology (NIST) summer fellowship and to take a leading role in her group senior design project here at the University of Tennessee. She noted that her professor and teammates trusted her ability to run a significant part of that project.

Gilbert initially hired Hobson to create a website for his lab; Hobson soon found his long-term niche within the group. "I listened for people talking about processes that took too long on the computer," he said. "I learned how data files were used so I would know what would help in the workflow."

Gilbert saw the potential. "Noah knows programming and hardware backward and forward. I had an idea for a machine at that time, but our lab didn't have the right skillset. He was a match. Starting then, I would say to him, here's what I want, can you figure out how to get there."

Hobson took on larger projects over time and learned how to run projects from start to finish. Over the past summer, he participated in the 2021 NIST summer fellowship. Now, he's a first-semester Ph.D. student in Computer Science at Purdue University. His long-term goal is to work at a national lab.

"My current field of study is basically how we use English to communicate with computers," Hobson said. "The field is changing all the time. The exciting part to me is doing something nobody's done before."

Quigley also started as a Ph.D. student at Purdue this fall. "I didn't consider grad school before starting at the lab. I discovered a love for research, and I wanted to do more."

Gilbert is proud of both researchers for pursuing grad school. Gilbert pointed out that Quigley entered the Material Sciences program at Purdue. "I once asked her why she was in MABE," he said. "She told me it gave her the most diverse experience to satisfy her curiosity. Now, she's switched over!"

"I think Liz and Noah both have a thirst to understand the unknown," Gilbert said. "Now they've learned they have the tools and talents to find answers to their questions. The world's a giant Indiana Jones adventure, and they can explore what they want." •

Top: Lizabeth Quigley, Bottom: Noah Hobson.

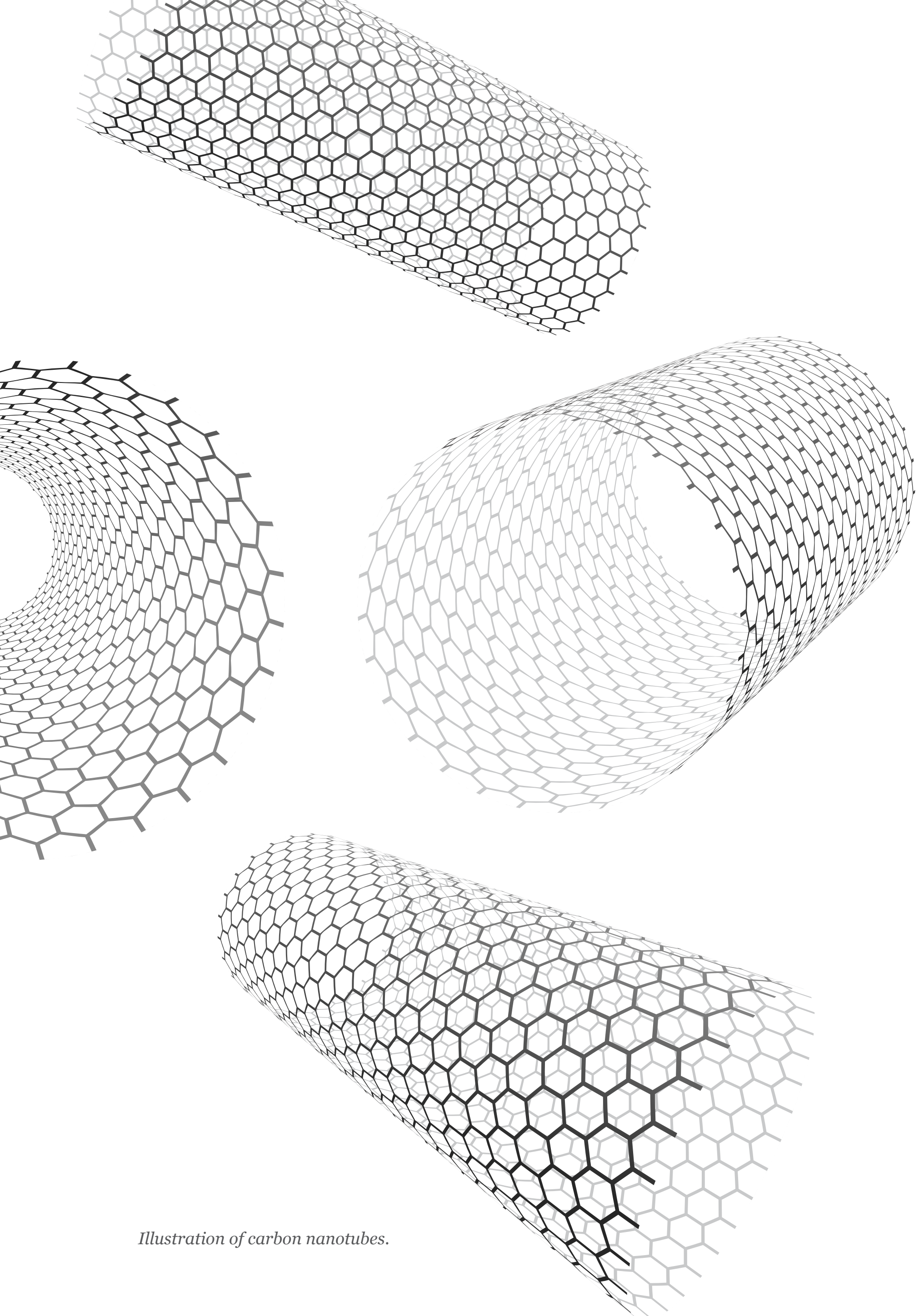


Illustration of carbon nanotubes.

On the Fast Track to Growth

Writing by Meghan McDonald. Photography by Randall Brown.

American Nanotechnologies, Inc. (ANI) is quickly approaching a tipping point for tech startups: earning revenue for the first time. "Our partnership with the Center for Materials Processing is, well, at the center of that," said William Fitzhugh, the startup's founder. "We've gotten the most from our partnership thanks to Jacob Clark, our undergraduate research assistant."

ANI specializes in a new, cost-efficient process to purify carbon nanotubes for use in semiconductors. Carbon nanotubes offer game-changing possibilities for flexible electronics and 5G telecommunications. To date, however, producing a pound of this material could cost $300,000,000. For obvious reasons, carbon nanotubes have not gone commercial. Fitzhugh aims to change that.

In 2019, Fitzhugh earned a two-year fellowship with Innovation Crossroads, the entrepreneurial research and development program at Oak Ridge National Laboratory. That program brought him to East Tennessee and introduced him to University of Tennessee researchers and facilities.

"The Center for Materials Processing was perfectly positioned to help us. We didn't have funds to hire, but they gave us access to a high-caliber engineering student by funding a research position," Fitzhugh said. "Originally, we desperately needed elbow grease, but our partnership has gone above and beyond that. Jacob Clark is a third arm for me. He's helped with things that will ultimately get us to market faster."

Clark, a senior in the UT Materials Science and Engineering Department, has worked with ANI for the past year. He was intrigued when CMP faculty first told him about the research. "'Carbon nanotubes' is a buzzword for me—it's cool, exploratory science," he said.

Clark's responsibilities include running spectroscopy purity analyses on ANI's carbon nanotubes. "Will is a great mentor. He's taught me a lot about nanotubes that I wouldn't have gotten until a 400-level course," Clark said. "In a classroom setting now, I think I'm on the fast track to seeing the end goal of the theoretical knowledge—because I've already been in the lab, which is the application."

Clark has been investigating grad school and research careers. "My experience in the lab has definitely given me insights into what's coming next. It's knowledge of how a lab actually runs, plus Will has told me insights about getting into a grad school program and what it's like to do research there."

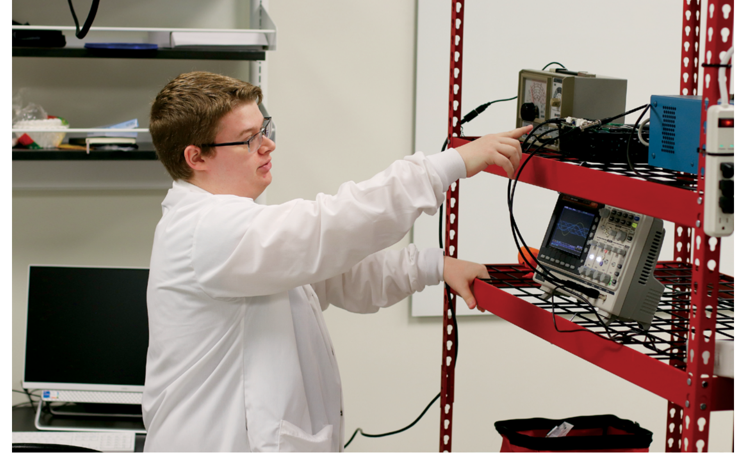
Over the summer, Clark added another valuable skill to his resume: programming the control system for ANI's nanotube separation process. "Coding is the most frustrating but satisfying thing ever," Clark said. "I quickly learned that it makes a lot of things easier if I can understand code and the inner workings of equipment on the software level." It could also give Clark a competitive edge in his academic and professional career.

Clark's programming work is key to making ANI's process modular. The modular design, in turn, will play an important role in helping ANI expand its output and bring down the cost of processing the nanotubes.

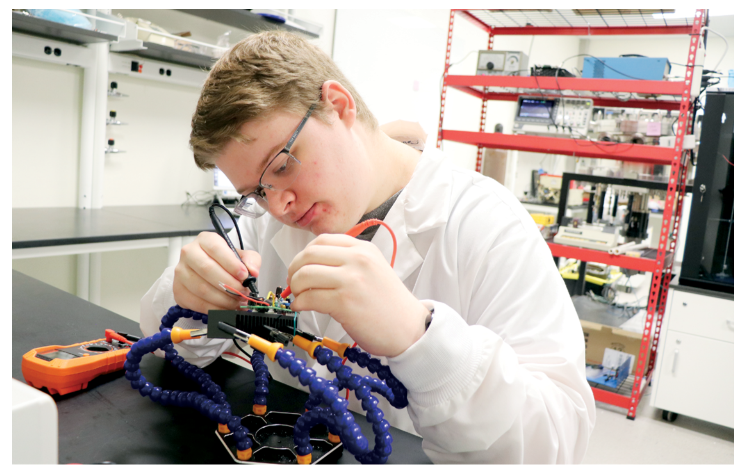
"Each module we add to our system will provide more power and create a bigger electric field to filter particles," Fitzhugh said. "Once we reach a couple hundred watts, we'll be able to sell into the research market—our starting point."

"I quickly learned that it makes a lot of things easier if I can understand code and the inner workings of equipment on the software level."
—Undergraduate Research Assistant Jacob Clark

"By doing this in an economical way," he said, "we can build a supply chain people have wanted to commercialize for decades. We have the potential to breathe fresh air into electronic devices developed over the last 15 years that could be transformative. And we can take the first pass at new devices, like sensors to detect explosives or even viruses. No incumbent materials can do that." •

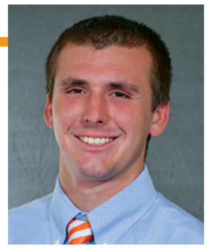


Left: Jacob Clark, Right: William Fitzhugh



CMP Supported and Associated Graduate Students

James Brackett



What is your thesis topic?
In-situ Multiple Material Processing in Large Scale Material Extrusion Additive Manufacturing

How is materials processing involved in your research?
My research utilizes advances in instrumentation to improve the multiple material (MM) processing capabilities in large-scale material extrusion additive manufacturing (AM). A g-code enabled dual-hopper attachment allows for on-the-fly material switching during printing, which enables complex site-specific properties. By studying the processing conditions and blending behavior during material switching, my research will provide the information necessary to tweak processing conditions and control material placement within the printed structures. This improved processing capability allows AM to fulfill requirements for advanced applications using MM that single-material structures struggle with.

Provide an example of where the material, process, or properties you are studying might find an application.
Multi-material additive manufacturing (MMAM) provides the capability to deliberately place a given material anywhere within a geometrically complex structure. Specifically with the dual-hopper on the BAAM (big area additive manufacturing), the improvements in control over the deposition process provided by my research will allow for distinct regions of different capabilities. For instance, a simple core-shell structure is achievable with this improvement by selecting a flexible, impact-resistance material for the outer shell and a strong and stiff material for the inner structure to provide adequate resistance against deformation. Without characterization of the processing capabilities of the dual-hopper, a finely tuned core-shell structure would not be possible.

Xuesong Fan

What is your thesis topic?
My thesis work focuses on the mechanical properties of high-entropy alloys (HEAs), including improving the ductility of body-centered-cubic (BCC) HEAs and enhancing the strengths of face-centered-cubic (FCC) HEAs. The first part involves utilizing the concept of phase-transformation-induced plasticity (TRIP) to improve the tensile ductility in a TiZrHfNb refractory HEA system with BCC structures. The second part of my thesis work is to design and develop new FCC-structured HEAs that are enhanced by introducing nano-precipitates.

How is materials processing involved in your research?
To design and develop new HEAs, the first and foremost thing is the synthesis of metallic samples. Fabricating methods (e.g., arc-melting, drop-casting, and suction-casting) are usually used to combine four or more pure elements to form a single solid-solution phase. Moreover, thermomechanical processing (e.g., rolling, homogenization, annealing, and aging) is generally performed to further improve their mechanical properties. By combining different processing methods, our aim is to develop advanced structural materials and understand the relationship among processing-structure-properties.

Provide an example of where the material, process, or properties you are studying might find an application.
Similar to commercial Ni-based superalloys, HEAs with FCC structures are considered as promising alternatives for high-temperature applications due to their lower cost and better mechanical performance in a wide temperature range. By introducing ordered precipitates as the strengthening phase, the strength of the FCC-based HEAs can be potentially improved due to the dislocation-precipitates interactions, which hinder dislocation movement.

Kate Higgins

What is your thesis topic?
Utilization of automated synthesis and machine learning for the exploration of hybrid organic-inorganic perovskite combinatorial libraries.

How is materials processing involved in your research?
To create combinatorial libraries of various hybrid organic-inorganic perovskite systems, I utilize a pipetting robot, commonly used in the biological field, to make microcrystals. This requires taking into consideration certain aspects, such as solvents, antisolvents, and fabrication methods.

In the last year, CMP has supported eleven graduate students, the majority of whom received funding through its competitive application process. These students, along with students supported by industrial memberships and contracts affiliated with CMP, are featured here.

Provide an example of where the material, process, or properties you are studying might find an application.

Hybrid organic-inorganic perovskites have emerged as a promising candidate for solar cell applications. However, the stability of these materials under illumination and in ambient conditions remains elusive. In this project, I am first determining the optimal compositions for this application based on their optoelectronic properties. Further, I am developing a method to measure the change in these optoelectronic properties over time in ambient conditions. From this, I will be able to determine which hybrid organic-inorganic perovskites have the best intrinsic stability.

Yan-Ru Lin

What is your thesis topic?

My thesis topic is on the fundamental understanding of microstructural evolution of irradiation-induced defects in high purity Fe and Fe-Cr alloys. The main material characterization technique for the irradiated samples utilizes state-of-the-art transmission electron microscopy.

How is materials processing involved in your research?

The expected impacts related to materials processing include providing comprehensive information on the microstructural phase stability of Fe-Cr alloys, ideal Cr content for advanced ferritic/martensitic steel design, and dependence of He on phase boundary temperature. In addition, the fundamental understanding obtained from the selected model alloys can be applied to other more complex ferritic/martensitic steels with novel material processing techniques that are in the beginning stages of exploration by other researchers (e.g., nanostructured steels produced by additive manufacturing).

Provide an example of where the material, process, or properties you are studying might find an application.

Ferritic/martensitic steels are promising structural material candidates for fusion and advanced fission reactors due to their desirable mechanical properties and significant resistance to degradation from neutron irradiation. One of the most attractive properties for nuclear applications is its superior resistance to void swelling. The addition of nano-dispersoids in ferritic/martensitic steels can further enhance the high-temperature creep strength. This improvement enables these nanostructured steals to become candidates for cladding tubes in next generation sodium-cooled fast reactors and other potential applications.

Hannah Maeser

What is your thesis topic?

Fiber alignment and mesostructure play a key role in tailoring the anisotropic properties of carbon fiber reinforced polymer composites (CFRC) for use in automotive applications. My dissertation topic focus is to develop novel non-invasive methods for characterizing the effect of composite manufacturing processes on micro/meso structure and relation of the resulting structure to mechanical properties.

How is materials processing involved in your research?

Discontinuous CFRCs are susceptible to fiber misalignment during high-throughput molding and manufacturing methods such as compression molding using sheet molding compounds. How the partially cured material is placed into the mold or the length of the molding time can affect how the fibers flow and orient around the part geometry. I am developing a novel non-destructive evaluation (NDE) method called thermal digital image correlation (TDIC) to determine the preferred fiber orientation that results in the part during manufacturing. I seek to develop a set of guidelines, confirming against TDIC, on how to process the uncured composite material during molding to reduce or control fiber misalignment. I am also exploring the use of thermography for identifying defects such as pores or resin rich regions.

Provide an example of where the material, process, or properties you are studying might find an application.

A good example of where my research might find an application in the field is in quality control of composite automotive parts. Discontinuous composites offer a low-cost composite solution for light-weighting for fuel efficiency, corrosion resistance, and energy absorption through crushing. However, due to the material's susceptibility to misalignment during molding to complex shapes, a rapid quality control method is needed to evaluate parts in development and during full-line manufacturing. Refining the TDIC method and using it to develop guidelines for processing discontinuous composites during molding will allow for the expanded use of discontinuous CFRCs for complex molded structural components of automobiles and infrastructure.

CMP Supported and Associated Graduate Students

Grace Pakeltis

What is your thesis topic?
I am studying the plasmonic and phononic phenomena in 2d and 3d nanostructures through high resolution electron energy loss spectroscopy.

How is materials processing involved in your research?
At the center of my research is a dedication to the advancement of materials processing through micro and nanofabrication techniques. The investigation of fundamental plasmonic phenomena is advanced by improvements in micro- and nano- 3d manufacturing. I utilize a hybrid fabrication approach combining focused electron beam induced deposition, atomic layer deposition, and sputtering to create a direct write method for 3D plasmonic structures. The development of this material's processing technique creates a path towards robust geometric studies to elucidate plasmonic property trends.

Provide an example of where the material, process, or properties you are studying might find an application.
The field of plasmonics exploits the unique property of metallic nanostructures to manipulate light at the nanometer scale. The efficiency in which plasmonic nanostructures couple light into intense optical nearfields has a variety of applications across multiple fields (e.g., sensing, imaging, photovoltaics, and photocatalysis.)

"Grace has been a pleasure to advise. She is amazing in the lab and has pioneered some interesting 3D plasmonic architectures. She is also an expert user on an advanced scanning transmission electron microscope doing low-loss electron energy loss spectroscopy of her plasmonic structures. Her research has predominantly been performed at ORNL's CNMS and she works great with the staff and our theory collaborators at the University of Washington."

— Philip Rack, Professor, Leonard G. Penland Chair & Associate Department Head

Hyojin Park

What is your thesis topic?
My thesis topic is to establish the weldability, characterization of macro/micro-structure, and mechanical performance of lap-jointed Ti-6Al-4V alloy.

How is materials processing involved in your research?
The process involved in my research is frictional stir spot welding (FSSW). This welding process is a novel solid-state joining technique where the metal interfaces are bonded without melting despite significant frictional heating. Additionally, this process results in unique microstructural evolution, leading to the change of mechanical properties. Specifically, titanium and its alloys show a variety of microstructure depending on the thermal processing history. For my study, key objectives are to provide fundamental understanding of the microstructural development/joining mechanism and to establish the relationship among the processing, microstructure, and mechanical performance of the weldments.

Provide an example of where the material, process, or properties you are studying might find an application.
Friction stir spot welding has been applied in many fields, such as aerospace and automotive, in which structural parts are made of aluminum and steel alloy systems. Recently, usage of Ti-alloys is increasing in transportation industries to improve energy efficiency and safety. However, the application of FSSW on Ti-6Al-4V posed several challenges due to the refractory nature of Ti-Alloys. My research on the development of the pinless FSSW of Ti-6Al-4V alloy and the basic understanding of its process couple open it to a variety of new industry applications.

Brandon Shaver

What is your thesis topic?
My dissertation is focused on evaluating the electrical properties of uranium dioxide as a candidate material for solid-state direct-conversion neutron detectors. Dopant materials have been studied in

ion-implanted single crystal samples that have been subjected to neutron irradiation. Cerium dioxide has also been used as a non-radioactive surrogate to safely study material processing methods of improving electrical properties.

How is materials processing involved in your research?
Uranium dioxide does not inherently meet the electrical properties necessary to effectively function as a semiconducting material in a solid-state neutron detector. Materials processing methods to incorporate dopant materials are critical to this research. Carefully selected dopant materials can directly impact the microstructure and electrical properties.

Provide an example of where the material, process, or properties you are studying might find an application.
While there are several challenges beyond optimizing the electrical properties of uranium dioxide that must also be addressed, a solid-state neutron detector based on this material could offer the potential for the development of devices with incredibly high detection efficiencies.

Di Xie

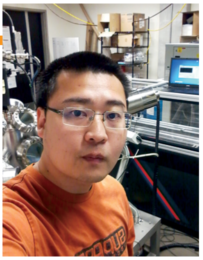
What is your thesis topic?
My thesis title is “In-situ Diffraction Studies of the Fatigue Behavior in Magnesium Alloys,” and my efforts are focused on investigating the roles of the surrounding plasticity and fracture-process zone in fatigue experiments of magnesium (Mg) alloys through combining fatigue crack growth studies with in-situ, nondestructive measurements and micromechanical modeling studies. My research is aimed at allowing us to bridge the gap between microscopic failure processes and macroscopic fatigue crack growth properties.

How is materials processing involved in your research?
Processing and applications of magnesium alloys are mostly focused on the improvement of their mechanical properties through heat treatment or alloy design. However, there is a huge knowledge gap between this emphasis on property enhancements and the feasibility and integrity of processing and applying Mg alloys. The fundamental understanding of the failure mechanism is essential for preventing the occurrence of the failure in processing Mg alloys. We seek to establish the relationship between macroscopic properties and microstructural failure mechanisms through a synergistic study of experiments using in situ diffraction techniques and micromechanical modeling of the fatigue behavior of advanced Mg alloys.

Provide an example of where the material, process, or properties you are studying might find an application.
Mg alloys are low-density alloys of interest to the automotive and aerospace industries due to the ever-increasing demand for weight reduction and, consequently, fuel savings. The limited knowledge of materials failure mechanisms, however, places the ultimate restrictions on the technological viability of Mg alloys. Our theoretical/experimental synergistic efforts will help achieve a fundamental mechanistic understanding of relevant materials failure issues, enabling us to address some key technical hurdles and improve the practical application of lightweight alloys.

“Di has demonstrated an amazingly quick and deep grasp of mechanics modeling on material deformation and failure mechanisms. Discussing with her is always inspiring and eye-opening, not even mentioning numerous times when she corrects my ignorance from her real hands-on knowledge.”
— Yanfei Gao, Professor

Junyi Yang



What is your thesis topic?
My dissertation title is “Many body physics in pseudospin- ½ iridate.” Theoretical attempts to solve any many body problem are often limited by the computational capability; thus, experimental study of representative materials becomes necessary. In systems like iridate, which combines electron correlation and spin orbit coupling, there is a rare S–½ square lattice system for studying many body physics described by Hubbard Hamiltonian. This study will provide us a better understanding of the fundamental science; additionally, it could open new possibilities for realization of exotic phenomenon like high temperature superconductivity.

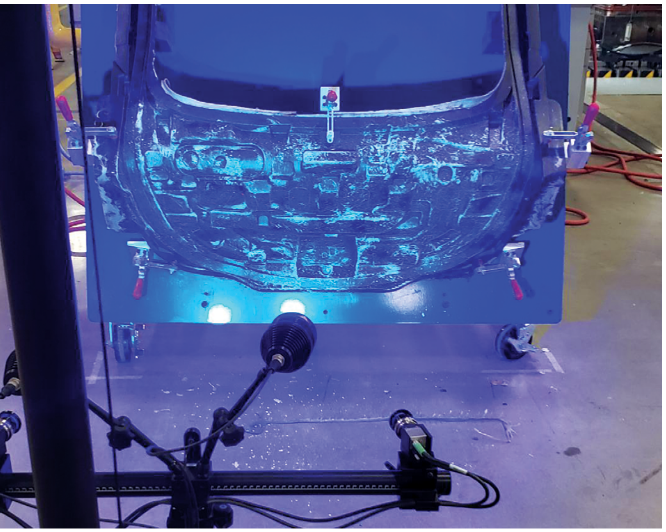


Photo Credit: Hannah Maeser
Analyzing a carbon fiber sheet molding compound automotive part with thermal digital image correlation (TDIC) after compression molding.

How is materials processing involved in your research?
The realization of pseudospin–½ iridate systems requires state-of-the-art synthesis methods, and advanced characterization techniques are necessary to understand its properties. The key concept in the 5d transition metal oxides is the strong interplay between charge, spin, and structural degrees of freedom. While bulk single crystal iridate is often too robust, the iridate heterostructures achieved by an atomic level layer-by-layer growth technique provide a much higher tunability. The structural degree of freedom by applying epitaxial strain on the iridate heterostructure, achieved by synthesizing iridate on various substrates with different lattice mismatch, can be used to tune the strength of the electron correlation. Through characterization experiments like X-ray diffraction, the structural distortion and deformation induced by epitaxial strain can be accurately determined. Combined with the measurements of electronic and magnetic properties, we are able to understand the electron interaction under different correlation limit.

Provide an example of where the material, process, or properties you are studying might find an application.
The development of semiconductors has become more and more difficult to keep up with Moore's law, and the focus has moved to alternative electronic devices like spintronics. The iridate superlattices can also be made into antiferromagnetic spintronics. Through an atomically controlled layer by-layer growth technique, we are able to make an iridate superlattice that approaches quasi-2D limit. By applying an external magnetic field on the iridate superlattice, the strength of magnetization and ordering temperature can be controlled. This can be used as a switch where the on and off of magnetic ordering is controlled by an external magnetic field.

Yajie Zhao

What is your thesis topic?
My thesis project focuses on the stability of Cr-enriched alpha prime (α') precipitates in high purity FeCr alloys under heavy ion irradiation conditions.

How is materials processing involved in your research?
Ion irradiation is an important and complicated material processing method, which could both destroy the nanoscale precipitates by forming damage cascades and enhance the precipitate formation by accelerating the diffusion process. We performed ion irradiations on high purity FeCr alloys at different temperatures and ion fluxes. Using focused ion beam (FIB) for sample preparation and atom probe tomography (APT) as the main characterization method, the evolution of α' precipitation as a function of irradiation conditions is studied.

Provide an example of where the material, process, or properties you are studying might find an application.
Ferritic-martensitic (FM) steels with high Cr concentration are promising structural materials for Generation IV fission and fusion reactors mainly due to their superior void swelling resistance compared to conventional austenitic steels. However, high-Cr FM steels are known to undergo pronounced hardening and embrittlement due to the formation of dislocation loops and Cr-rich α' precipitates. My study will help to understand the kinetics of α' precipitation and thus provide knowledge about how to mitigate this mechanical degradation problem.

Thesis/Dissertation Titles

Walker Boldman, PhD
"Exploration of Thin Films for Neuromorphic, Electrofluidic, and Magneto-Plasmonic Applications"

ADVISOR: Philip Rack, MSE
CURRENT EMPLOYER: Development at CNS Y-12 (Oak Ridge, Tennessee)

Bernadette Cladek, PhD
"Local Structure and Dynamic Studies of Mixed CH4-CO2 Gas Hydrates via Computational Simulation and Neutron Scattering"

ADVISOR: Claudia Rawn, MSE
CURRENT EMPLOYER: Oak Ridge National Laboratory, Neutron Scattering Directorate

Nadim Hmeidat, PhD
"Process-Structure-Property Relationships in 3D-Printed Epoxy Composites Produced via Material Extrusion Additive Manufacturing"

ADVISOR: Brett Compton, MABE
CURRENT EMPLOYER: University of Tennessee, Knoxville, Department of Chemistry, Joint Institute for Advanced Materials (JIAM)

Yongtau Liu, PhD
"Chemico-physical interactions in metal halide perovskites"

ADVISOR: Bin Hu, MSE
CURRENT EMPLOYER: Center for Nanophase Materials Science, Oak Ridge National Laboratory

Robert Minneci, PhD
"Microstructural Characterization and Analysis of Laser-Powder Bed Fusion GRCop-84 by Metallurgical and Neutron Scattering Methods"

ADVISOR: Claudia Rawn, MSE
CURRENT EMPLOYER: BWX Technologies (Lynchburg, Virginia)

Brianna Musico, PhD
"Synthesis and Physical Properties of High Entropy Oxide Ceramics"

ADVISOR: Veerle Keppens, MSE
CURRENT EMPLOYER: Los Alamos National Laboratory (New Mexico)

Lauren Nuckols, PhD
"Ion Irradiation Effects on Damage Annealing and Dopant Activation in Single Crystal SiC"

ADVISOR: William Weber, MSE
CURRENT EMPLOYER: Oak Ridge National Laboratory

R. Cody Pack, PhD
"3D Printing of Hybrid Architectures via Core-shell Material Extrusion Additive Manufacturing"

ADVISOR: Brett Compton, MSE/MABE
CURRENT EMPLOYER: University of Tennessee, MABE

Tyler Smith, PhD
"Exploring Structural and Electronic Properties of Triangular Adatom Layers on the Silicon Surface Through Adsorbate Doping"

ADVISOR: Hanno Weitering, Physics
CURRENT EMPLOYER: Defense Contractor (Indiana)

Maiosheng Wang, PhD
"Spin Effects of Excited States in Organic Semiconductors and Hybrid Perovskites for Optoelectronics and Spintronics"

ADVISOR: Bin Hu, MSE
CURRENT EMPLOYER: Lam Research Corporation (California)

Xue Wang, PhD
"Mechanics of the solid-state bonding under severe thermomechanical processes"

ADVISOR: Yanfei Gao
CURRENT EMPLOYER: Corning (New York)

Undergraduate Research Spotlight

Undergraduates funded by the CMP are actively engaged in research and expected to participate in events showcasing their research. The students perform research in labs, analyze data, perform calculations, and run models; unsurprisingly, the majority of the CMP funds are support for the students in the forms of stipends, hourly wages, and access to the state-of-the-art characterization equipment housed on the Cherokee campus.

For the majority of the students participating in research positions, their financial support was jointly shared between a faculty member and the CMP. Several of these students were recognized at the Exhibition of Undergraduate Research and Creative Achievement (EURēCA). This was the 25th EURēCA, an annual event showcasing research and creative activities across all disciplines by currently enrolled undergraduate students in collaboration with a faculty member. Due to the pandemic both in FY20 and FY21, the events associated with EURēCA were held virtually. The various disciplines recognize the top posters, and CMP-funded students were recognized in both College of Arts & Sciences natural sciences and Tickle College of Engineering categories. Recognized students from the disciplines were advanced as a group to compete for recognition from the Office of Undergraduate Research and Fellowships (OURF). CMP-supported students Kelsey Uselton (chemical and biomolecular engineering and mentored by Senior Research Associate Gabriel Goenaga) was recognized with an OURF Bronze Award and Second Place in the TCE research category, and Kate Eikel (MSE and mentored by Professor Bin Hu) was recognized with an OURF Gold Award and first place in the TCE research category. Eikel graduated in May and started as an engineer at Honeywell Federal Manufacturing & Technologies, LLC.

Top: Samantha Maness, Bottom: Jackson Spurling

Two students, Samantha Maness and Jackson Spurling receiving scholarship funds from the CMP graduated in May of 2021. In addition to the CMP scholarship, both Maness and Spurling participated in undergraduate research with Associate Professor Brett Compton, and Maness was recognized with a TCE Award of Merit at the 2021 EURēCA. This fall, Maness is heading to the Luxembourg Institute of Science and Technology to participate in research as a Fulbright Visiting Researcher and plans to start the PhD program at Northwestern University in the fall of 2022. Spurling plans to pursue his PhD in materials science and engineering at Pennsylvania State University. He earned a prestigious National Science Foundation (NSF) Graduate Research Fellowship in 2021 that includes a $34,000 annual stipend for three years, $12,000 toward tuition and fees, increased chances to take part in international research, and other benefits. Logan White, who also graduated in May 2021 and participated in undergraduate research partially supported by the CMP under the direction of Hu, applied for and was granted a Fulbright Visiting Researcher position and will be heading to the Czech Republic and Northwestern University in the fall of 2022. These CMP-supported undergraduates were also recognized at the 2021 Chancellor's Honors Banquet as top collegiate scholars in the Tickle College of Engineering (Maness and White) and one of two undergraduate researchers of the year (Spurling).

These top performing undergraduate students that either join the workforce or continue their education at universities are the best ambassadors for the CMP, their home departments, and the University of Tennessee. This holds true for our supported graduate students that graduated over the last year and are now employed at a variety of locations, including Oak Ridge National Laboratory, Y12, Los Alamos National Laboratory, BWX Technologies, Lam Corporation, and Corning. •

Program Accomplishments and Overview

Accomplishments

- Two full- and nine facility-level memberships supporting local industry while engaging students in the work and outcomes
- Support packages for sixteen graduate students
- Generated 55 publications
- Funded close to seventy undergraduates participating in research activities, including:
    - Samantha Maness and Logan White awarded Fulbright Scholarships
    - Jackson Spurling awarded an NSF Graduate Research Fellowship
    - Exhibition of Undergraduate Research and Creative Achievement
        - CMP-funded students recognized in both the College of Arts & Sciences Natural Sciences and Tickle College of Engineering categories. These students were advanced as a group to compete for recognition from the Office of Undergraduate Research and Fellowships (OURF) and received gold and bronze awards.
- Co-sponsored and co-hosted a virtual student night to showcase CMP-funded student research with 40 poster entries.

Overview

As the pandemic with its extraordinary circumstances added levels of complexity to both work and everyday life, the Center for Materials Processing (CMP) embraced the message from Chancellor Donde Plowman to be creative, compassionate, and flexible. In doing so, the CMP increased the number of both facility level and full memberships, graduate and undergraduate students supported, and more than doubled the publications from the previous year.

As in past years, the bulk of the technical accomplishments are attributed to the CMP-associated graduate and undergraduate students. Support comes in a variety of ways, including graduate stipends, paid undergraduate research opportunities, undergraduate scholarships, funds for using state of the art instruments housed in core facilities, travel support for students to present their research at professional conferences (all virtual in during FY21), smaller-scale instrument purchases that support materials processing activities, and the cost sharing of larger-scale instruments. As in past years, the majority of the CMP funds go to directly supporting the stipends of graduate students, hourly wages for undergraduate students participating in research, and salary support for CMP administration and technical activities.

Through gained experience, the CMP continues to improve the competitive process for graduate students to be awarded support tied to distinct processing projects. Calls are issued in the fall and spring, and applicants submit a written white paper type proposal.

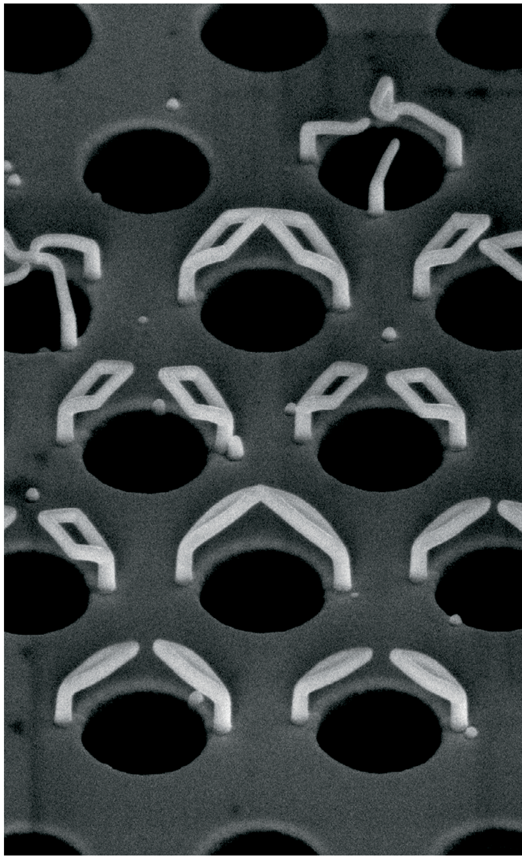


Photo Credit: Grace Pakeltis
Scanning Electron Micrograph (SEM) of a field of 3D nanoprinted plasmonic structures.

Those who authored the top ranked proposals are then asked to make oral presentations to selection committee members Associate Dean for Research and Facilities Bill Dunne, CMP Associate Director of Industrial Relationships Chad Duty, Interim Executive Director, Institute for Advanced Materials and Manufacturing Director, UT Core Facilities Program Jon Phipps, CMP Director Claudia Rawn, and MSE Department Head Veerle Keppens.

The students are also asked to include a budget and are encouraged to request funds for partially supporting their stipend, core facility instrument charges, and for covering travel to a professional conference for reporting their results. CMP supported students were involved in a vast array of research topics including: binder jet additive manufacturing, preparation of scintillator materials, thinning of PdSe2 flakes for field effect transistors, bulk metallic glasses, high entropy oxides, hybrid organic-inorganic perovskites for optoelectronic devices, metallic glass composites, modeling processing conditions of friction stir welding of lightweight Al alloys, failure in welds, and failure mechanisms in Li-ion batteries. Nine CMP-supported students graduated in FY21 and found employment in industry, academia, and federal government related positions that include Oak Ridge National Laboratory (ORNL), Y12, and the National Nuclear Security Administration in Washington, DC.

Chris Wetteland headed back to Los Alamos National Laboratory in December 2020. The CMP wishes to recognize Wetteland for the outstanding job he did as the CMP associate director of industrial relationships in getting the facilities level memberships off the ground and working with faculty to lay the groundwork for the two new full industrial memberships with Fulton Bellows (MSE Assistant Professor Eric Lass as lead) and Mitsubishi (Governor's Chair for Advanced and Nanostructured Materials Rigoberto Advincula as lead). Upon Wetteland's departure, Safety Officer Gerald Egeland, a jointly supported MSE/CMP staff member that joined in FY20, stepped up and continued to perform the experiments needed for the CMP Facility-level memberships with the help of undergraduate students Vincenzo Musico, Sarah Lantzy, and Dov Polsky. These students have become experts in conducting a variety of mechanical property tests, characterizations using a scanning electron microscope, and have learned much about interacting with industrial representatives. On April 1, 2020, the CMP welcomed a new associate director of industrial relationships, Duty from the Department of Mechanical, Aerospace, and Biomedical Engineering (MABE). Since joining the CMP, Duty has been working closely with UT Research Park team members Tom Rogers, Rickey McCallum, and John Bruck to establish relationships with the Spark Innovation companies. Duty is continuing the vision that our industry partners leverage our advanced microscopy techniques, mechanical testing, and undergraduate student eagerness to participate in research opportunities. In addition, he continues the efforts to establish new partnerships formerly led by Wetteland, working with representatives from the Center for Industrial Services (CIS) and previously established members.

The CMP has continued to support JIAM activities by providing partial support to JIAM Diffraction (XRD) Facility laboratory manager, Michael Koehler, who is in charge of the day-to-day operations of the laboratory, which includes helping students and industry members in the collection and analysis of X-ray diffraction data. The JIAM Diffraction (XRD) Facility is part of the University of Tennessee's Core Facilities Program that is intended to provide access to high-end instrumentation, technical support, and expert consultation to both users from across the university and external customers for a fee. As part of the graduate student support packages, some of the funds are used to cover instrument charges. The most frequent instrument charges are from students using both the XRD and microscopy core facilities. Equipment that CMP helped to support the purchase of in FY21 included a benchtop single crystal X-ray diffractometer to complement the suite of X-ray powder diffractometers. The new instrument, delivered just before the end of the fiscal year, is already seeing heavy usage from several research groups in MSE, including the Scintillator Materials Research Center.

Along with the lead university site, Ohio State University and other site universities Colorado School of Mines and Penn State, the UT site of the Manufacturing and Materials Joining Innovation Center (Ma2JIC) submitted a proposal to the National Science Foundation's (NSF) Industry/University Collaborative Research Center (I/UCRC) program for Phase III funding in FY21. The proposal was favorably reviewed, and Ma2JIC was funded for an additional five years. Rawn and staff member Karen Boyce are both partially supported by the funds allocated for the administration of the UTK site of Ma2JIC. Ma2JIC research interests are an important subset of materials processing and are focused on materials joining, including traditional welding, friction stir welding techniques, and additive manufacturing. Industrial support of the UT Ma2JIC site comes from EPRI, Miller Electric, NASA, U.S. Army Combat Capability Development Center (CCDC), and UT-Battelle. Several of the faculty associated with Ma2JIC, including Associate Professor Bradley Jared (MABE), Lass, and Professor Tony Schmitz (MABE), work closely with staff members at the Manufacturing Demonstration Facility.

Goals/Future Plans

The CMP goals for FY22 are to continue to provide outstanding services to our current industrial partners while also increasing our industrial memberships and continually improving the experiences of CMP supported students. The CMP will continue to leverage our graduate support packages, scholarships, and undergraduate research assistants with syngerestic programs. The CMP is refining and improving the application and award processes for attaining CMP graduate support packages that provide important professional development activities for students who will soon graduate and begin their professional careers. The support of undergraduate research that provides students with the skills needed to succeed in the technical workforce continues to be an important aspect of the CMP. The CMP will continue to host events, now using a variety of in-person and virtual platforms, to showcase both graduate and undergraduate students and their research. •

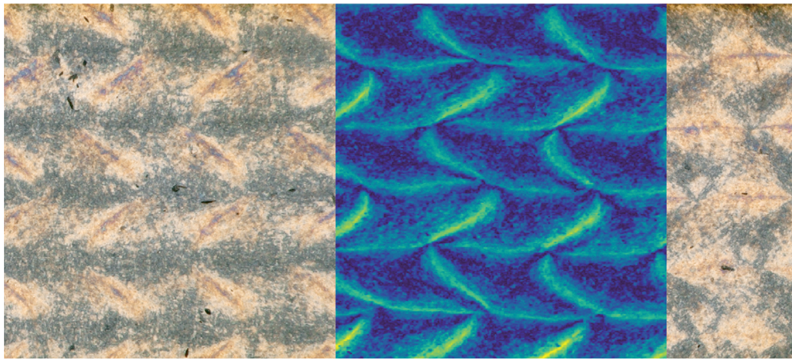


Photo Credit: Nadim Hmeidat
Polarized light microscopy vs micro-SAXS Hermans orientation of a 3D printed epoxy-filled nanoclay platelets.

Budget

	FY 2020–21 Actual			FY 2021–22 Proposed			FY 2022–23 Requested		
EXPENDITURES	**Matching**	**Appropr.**	**Total**	**Matching**	**Appropr.**	**Total**	**Matching**	**Appropr.**	**Total**
SALARIES									
Faculty	$220,907	$108,065	$328,972	$231,952	$130,000	$361,952	$255,148	$136,500	$391,648
Other Professional	$68,813	$45,735	$114,548	$72,254	$50,000	$122,254	$79,479	$52,500	$131,979
Clerical/Supporting	$116,937	$61,701	$178,638	$122,784	$65,000	$187,784	$135,063	$68,250	$203,313
Assistantships	$320,549	$217,773	$538,321	$336,576	$250,000	$586,576	$370,234	$250,000	$620,234
TOTAL SALARIES	$727,206	$433,273	$1,160,479	$763,566	$495,000	$1,258,566	$839,923	$507,250	$1,347,173
Longevity (Excluded from Salaries)	$4,514	$2,186	$6,700	$4,740	$3,000	$7,740	$5,214	$3,150	$8,364
Fringe Benefits	$189,971	$77,798	$267,769	$199,469	$99,600	$299,069	$219,416	$101,450	$320,866
TOTAL PERSONNEL	$921,691	$513,258	$1,434,948	$967,775	$597,600	$1,565,375	$1,064,553	$611,850	$1,676,403
NON-PERSONNEL	**Matching**	**Appropr.**	**Total**	**Matching**	**Appropr.**	**Total**	**Matching**	**Appropr.**	**Total**
Travel	—	—	$0	$30,000	$15,000	$45,000	$33,000	$10,000	$43,000
Other Supplies	$40,428	$26,761	$67,189	$42,450	$25,000	$67,450	$46,695	$15,000	$61,695
Equipment	$240,398	$61,709	$302,107	$300,000	$56,025	$356,025	$350,000	$35,048	$385,048
Maintenance	$23,056	$21,544	$44,601	$24,209	$25,000	$49,209	$26,630	$10,000	$36,630
Scholarships	$37,550	$7,750	$45,300	$39,428	$10,000	$49,428	$43,370	$10,000	$53,370
Other (Specify)									
Media Processing	$984	$945	$1,929	$1,033	$1,500	$2,533	$1,136	$3,000	$4,136
Communication	$852	$169	$1,021	$895	$500	$1,395	$984	$500	$1,484
Computer Services	$576	$73	$648	$604	$250	$854	$665	$250	$915
Grants and Subsidies	$19,731	$1,974	$21,705	$20,717	$5,000	$25,717	$22,789	$5,000	$27,789
Contractual & Special Services	$30,344	$11,608	$41,952	$31,862	$25,000	$56,862	$35,048	$25,000	$60,048
TOTAL NON-PERSONNEL	$393,920	$132,533	$526,453	$491,198	$163,275	$654,473	$560,317	$113,798	$674,115
TOTAL EXPENDITURES	**$1,315,610**	**$645,791**	**$1,961,401**	**$1,458,973**	**$760,875**	**$2,219,848**	**$1,624,870**	**$725,648**	**$2,350,518**
REVENUE	**Matching**	**Appropr**	**Total**	**Matching**	**Appropr.**	**Total**	**Matching**	**Appropr.**	**Total**
New State Appropriation	—	$673,670	$673,670	—	$691,094	$691,094	—	$725,648	$725,648
Carryover State Appropriation	—	$41,901	$41,901	—	$69,781	$69,781	—	—	$0
New Matching Funds	$1,315,610	—	$1,315,610	$1,458,973	—	$1,458,973	$1,624,870	—	$1,624,870
Carryover from Previous Matching Funds	—	—	$0	—	—	$0	—	—	$0
TOTAL REVENUE	**$1,315,610**	**$715,571**	**$2,031,181**	**$1,458,973**	**$760,875**	**$2,219,848**	**$1,624,870**	**$725,648**	**$2,350,518**

CMP 2020–21 Publications

R.C. Advincula, J.R.C. Dizon, Q. Chen, I. Niu, J. Chung, L. Kilpatrick, R. Newman, “Additive manufacturing for COVID-19: devices, materials, prospects, and challenges”, MRS Communications, 10, 413-427 (2020).

W.L. Boldman, D.A. Garfinkel, R. Collette, C.S. Jorgenson, D.K. Pradhan, D.A. Gilbert, P.D. Rack, “ Exploring the composition, phase separation and structure of AgFe alloys for magneto-optical applications”, Materials Science and Engineering B-Advanced Functional Solid-State Materials, 266, 115044 (2021).

J. Brechtl, S.Y. Chen, X. Xie, Y. Ren, J.W. Qiao, P.K. Liaw, and S.J. Zinkle, “Towards a greater understanding of serrated flows in al Al-containing high-entropy-based alloy”, International Journal of Plasticity, 115, 71-92 (2019).

X. Cai, Y. Gao, X. Wang, W. Zhang, W. Liu, X. Shen, W. Zhang, Z. Yu, Z. Feng, “Triaxial constraint and tensile strength enhancement in brazed joints”, Metallurgical and Materials Transactions A, 51, 5587-5596 (2020).

S. Chen, K.-K. Tseng, Y. Tong, W. Li, C.-W. Tsai, J.-W. Yeh, P.K. Liaw, “Grain growth and Hall-Petch relationship in a refractory HfNbTaZrTi high-entropy alloy”, J. Alloy and Comp., 795, 19-26 (2019).

S.Y. Chen, Y. Tong, K.-K. Tseng, J.-W. Yeh, J.D. Poplawsky, J.G. Wen, M.C. Gao, G. Kim, W. Chen, Y. Ren, R. Feng, W.D. Li, P.K. Liaw, “Phase Transformations of HfNbTaTiZr high-entropy alloy at intermediate temperatures”, Scripta Materialia, 158, 50-56 (2019).

H. Choo, M.R. Koehler, L.P. White, Y. Ren, D. Morin, E. Garlea, “Influence of defect characteristics on tensile deformation of an additively manufactured stainless steel: Evolutions of texture and intergranular strain”, Materials Science and Engineering A, 791, 139637 (2020).

B.R. Cladek, S.M. Everett, M.T. McDonnell, M.G. Tucker, D.J. Keffer, C.J. Rawn, “Local structure and distortions of mixed methane-carbon dioxide hydrates”, Communications Chemistry, 4, 6 (2021).

B.G. Compton, J.K. Wilt, J.W. Kemp, N.S. Hmeidat, S,R. Maness, M. Edmond, S. Wilcenski, J. Taylor, “Mechanical and thermal properties of 3D-printed epoxy composites reinforced with boron nitride nanobarbs”, MRS Communications, (2021).

H. Diao, D. Ma, R. Feng, T. Liu, C. Pu, C. Zhang, W. Guo, J.D. Poplawsky, Y. Gao, P.K. Liaw, “Novel NiAl-strengthened high entropy alloys with balanced tensile strength and ductility”, Materials Science and Engineering A-Structural Materials Properties Microstructure and Processing, 742, 636-647 (2019).

Y. Dou, M. Wang, J. Zhang, H. Xu, B. Hu, “Identifying photoinduced dipolar polarization and orbit-orbit interaction between excitons in organic-inorganic hybrid berovskites”, Advanced Functional Materials, 30, 2003476 (2020).

C. Foster, Y. Wu, L. Stand, M. Koschan, C.L. Melcher, “Czochralski growth and scintillation properties of Li+, Na+, and K+ codoped (Lu0.75Y0.25)3Al5O12: Pr3+ single crystals”, Journal of Crystal Growth, 532, 125408 (2020).

N.C. Harms, H.-S. Kim, A.J. Clune, K.A. Smith, K.R. O'Neal, A.V. Haglund, D.G. Mandrus, Z. Liu, K. Haule, D. Vanderbilt, J.L. Musfeldt, “Piezochromism in the magnetic chalcogenide MnPS3”, NPJ Quantum Materials, 5, 56 (2020).

A. Heimbrook, K. Higgins, S. V. Kalinin, M. Ahmadi “Exploring the physics of cesium lead halide perovskite quantum dots via bayesian inference of the photoluminescence spectra in automated experiment”, Nanophotonics (2021).

K. Higgins, M. Lorenz, M. Ziatdinov, R.K. Vasudevan, A.V. Ievlev, E.D. Lukosi, O.S. Ovchinnikova, S.V. Kalinin, M. Ahmadi, “Exploration of electrochemical reactions at organic-inorganic halide perovskite interfaces via machine learning in in situ time-of-flight secondary ion mass spectrometry”, Advanced Functional Materials, 30, 2001995 (2020).

K. Higgins, S. Valleti, M. Ziatdinov, S.V. Kalinin, M. Ahmadi, “Chemical robotics enabled exploration of stability in multicomponent lead halide perovskites via machine learning”, ACS Energy Letters, 5, 3426-3436 (2020).

N.S. Hmeidat, R.C. Pack, S.J. Talley, R.B. Moore, B.G. Compton, “Mechanical anisotropy in polymer composites produced by material extrusion additive manufacturing”, Additive Manufacturing, 34, 101385 (2020).

P.J. Hou, Y. Li, D. Chae, Y. Ren, K. An, H. Choo, “ Lean duplex TRIP steel: Role of ferrite in the texture development, plastic anisotropy, martensitic transformation kinetics, and stress partitioning”, Materialia, 15, 100952 (2021).

CMP 2020–21 Publications

N. Hua, Z. Liao, Q. Wang, L. Zhang, Y. Ye, J. Brechtl, P.K. Liaw, “Effects of crystallization on mechanical behavior and corrosion performance of a ductile Zr68Al8Ni8Cu16 bulk metallic glass”, Journal of Non-Crystalline Solids, 529, 119782 (2020).

D.G Kizzire, A.M. Richter, D.P. Harper, D.J. Keffer, “Lithium and sodium ion binding in nano-structured carbon composites”, Molecular Simulation, (2020).

C. Lee, G. Kim, Y. Chou, B.L. Musico, M.C. Gao, K. An, G. Song, Y.-C. Chou, V. Keppens, W. Chen, P.K. Liaw, “Temperature dependence of elastic and plastic deformation behavior of a refractory high-entropy alloy”, Science Advances, 6, eaaz4748 (2020).

J.T. Li, T. Wu, J. Zhang, S. Haacke, F. Teng, B. Hu, “Exploring light polarization effects of photovoltaic actions in organic-inorganic hybrid perovskites with asymmetric and symmetric unit structures”, ACS Applied Materials & Interfaces, 12, 38054-38060 (2020).

W.D. Li, D. Xie, D.Y. Li, Y. Zhang, Y.F. Gao, P.K. Liaw, “Mechanical behavior of high-entropy alloys”, Progress in Materials Science, 118, 100777 (2021).

Y. Lin, A. Bhattacharya, D. Chen, J.-J. Kai, J. Henry, S.J. Zinkle, “Temperature-dependent cavity swelling in dual ion irradiated Fe and Fe-Cr ferritic alloys”, Acta Materialia, 207, 116660 (2021)

Y. Lin, W. Chen, M. Li, J. Henry, S.J. Zinkle, “Dynamic observation of dual-beam irradiated Fe and Fe-10Cr alloys at 435 °C”, Acta Materialia, 210, 116793 (2021).

Y. Liu, A.V. Ievlev, N. Borodinov, M. Lorenz, K. Xiao, M. Ahmadi, B. Hu, S.V. Kalinin, O.S. Ovchinnikova, “Direct observation of photoinduced ion migration in lead halide perovskites”, Advanced Functional Materials, 31, 2008777 (2020).

S.E.A. McCoy, J.R. Salasin, S.M. Everett, C.J. Rawn, “Synthesis and structural characterization of Ca12Ga14O33”, Scientific Reports, 10, 16311 (2020).

B.L. Musico, Q. Wright, C. Delzer, T.Z. Ward, C.J. Rawn, D.G. Mandrus, V. Keppens, “Synthesis method comparison of compositionally complex rare earth-based Ruddlesden-Popper n=1 T '-type cuprates”, Journal of the American Ceramic Society, 104, 3750-3759 (2021).

S.N. Neal, H.-S. Kim, K.R. O'Neal, A.V. Haglund, K.A. Smith, D.G. Mandrus, H.A. Bechtel, G.L. Carr, K. Haule, D. Vanderbilt, J.L Musfeldt, “Symmetry crossover in layered MPS3 complexes (M=Mn, Fe, Ni) via near-field infrared spectroscopy”, Physical Review B, 102, 85408 (2020).

S.N. Neal, K.R. O'Neal, A.V. Haglund, D.G. Mandrus, H.A. Bechtel, G.L. Carr, K. Haule, D. Vanderbilt, H.S. Kim, J.L. Musfeldt, “Exploring few and single layer CrPS4 with near-field infrared spectroscopy”, 2D Materials, 8, 035020 (2021).

R.C. Pack, B.G. Compton, “Material extrusion additive manufacturing of metal powder-based inks enabled by carrageenan rheology modifier”, Advanced Engineering Materials, 22, 2000880 (2020).

R.C. Pack, S.K. Romberg, A.A. Badran, N.S. Hmeidat, T. Yount, B.G. Compton, “Carbon fiber and syntactic foam hybrid materials via core-shell material extrusion additive manufacturing”, Advanced Materials Technologies, 5, 2000731 (2020).

G. Pakeltis, E. Rotunno, S. Khorassani, D.A. Garfinkel, R. Collette, C.A. West, S.T. Retterer, J.C. Idrobo, D.J. Masiello, P.D. Rack, “High spatial and energy resolution electron energy loss spectroscopy of the magnetic and electric excitations in plasmonic nanorod oligomers”, Optics Express, 29, 4661-4671 (2021).

M. Pianassola, M. Loveday, B.C. Chakoumakos, M. Koschan, C.L. Melcher, M. Zhuravleva, “Crystal growth and elemental homogeneity of the multicomponent rare-earth garnet (Lu1/6Y1/6Ho1/6Dy1/6Tb1/6Gd1/6)3Al5O12”, Crystal Growth & Design, 20, 6769-6776 (2020).

M. Pianassola, M. Loveday, J.W. McMurray, M. Koschan, C.L. Melcher, M. Zhuravleva, “Solid-state synthesis of multicomponent equiatomic rare-earth oxides”, J. Am. Ceramic Soc., 103, 2908-2918 (2020).

D. Rutstrom, L. Stand, B. Dryzhakov, M. Koschan, C.L. Melcher, M. Zhuravleva, “Crystal growth and scintillation properties of new ytterbium-activated scintillators Cs4CaI6:Yb and Cs4SrI6:Yb”, Optical Materials, 110, 110536 (2020).

Y. Sharma, A. Mazza, B. Musico, E. Skoropata, R. Nepal, R. Jin, A. Ievlev, L. Collins, Z. Gai, A. Chen, M. Brahlek, V. Keppens, T.Z. Ward, “Magnetic texture in insulating single crystal high entropy oxide spinel films”, ACS Applied Materials & Interfaces, 13, 17971 (2021).

R. Sherrod, E.C. O'Quinn, I.M. Gussev, C. Overstreet, J. Neuefeind, M.K. Lang, "Comparison of short-range order in irradiated dysprosium titanates", NPJ Materials Degradation, 5, 19 (2021).

J.P. Smith, K.E. Sickafus, C.J. Rawn, C. Delzer, C.F. Chen, C. Melcher, "Thermal processing conditions for the synthesis of near theoretical density $Li_5La_3Ta_2O_{12}$ ceramics for ceramic dual-mode detectors", Journal of Alloys and Compounds, 872, 159714 (2021).

J.T. Tisdale, B. Musicó, B. Dryzhakov, M. Koehler, D. Mandrus, V. Keppens, B. Hu, "Optomechanical effects occurring in a hybrid metal–halide perovskite single crystal based on photoinduced resonant ultrasound spectroscopy", J. Phys. Chem. Lett., 11, 5407–5411 (2020).

L. Wang, D. Martin, W.-Y. Chen, P.M. Baldo, M. Li, B.D. Wirth, S.J. Zinkle, "Effect of sink strength on coherency loss of precipitates in dilute Cu-base alloys during in situ ion irradiation", Acta Materialia, 210, 116812 (2021).

L. Wang, C. Zheng, B. Kombaiah, L. Tan, D.J. Sprouster, L.L. Snead, S.J. Zinkle, Y. Yang, "Contrasting roles of Laves_Cr2Nb precipitates on the creep properties of novel CuCrNbZr alloys", Materials Science and Engineering: A, 779, 139110 (2020).

M. Wang, L. Hao, F. Yin, X. Yang, S.C. Shen, N.L. Zou, H. Cao, J.Y. Yang, N.P. Lu, Y.S. Wu, J.B. Zhang, H. Zhou, J. Li, J. Liu, P. Yu, "Manipulate the electronic state of Mott iridate superlattice through protonation induced electron-filling", Advanced Functional Materials, 2100261 (2021).

M.S. Wang, H.X. Xu, T. Wu, H. Ambaye, J.J. Qin, J. Keum, I.N. Ivanov, V. Lauter, B. Hu, "Optically induced static magnetization in metal halide perovskite for spin-related optoelectronics", Advanced Science, 2004488 (2021).

M.S. Wang, J. Zhang, X.X. Zhu, H.X. Xu, B. Hu, "Revealing long-range orbit-orbit interaction between coherent light-emitting excitons occurring in amplified spontaneous emission in $CsPbBr_3$ microstructures", Journal of Materials Chemistry C, early access (2021).

C.A. West, A. Olafsson, G. Pakeltis, D.A. Garfinkel, P.D. Rack, D.J. Masiello, J.P. Camden, J.C. Idrobo, "Plasmon hybridization in nanorhombus assemblies", Journal of Physical Chemistry C, 124, 27009-27016 (2020).

X. Wu, F.F. Ming, T.S. Smith, G.W. Liu, F. Ye, K.D. Wang, JS. Johnston, H.H. Weitering, "Superconductivity in a hole-doped Mott-insulating triangular adatom layer on a silicon surface", Physical Review Letters, 125, 117001 (2020).

D. Xie, Z.Y. Lyu, Y. Li, P.K. Liaw, H.B. Chew, Y. Ren, Y, Chen, K. An, Y.F. Gao, "In situ monitoring of dislocation, twinning, and detwinning modes in an extruded magnesium alloy under cyclic loading conditions", Materials Science and Engineering A-Structural Materials Properties Microstructure and Processing, 806, 140860 (2021).

X.D. Xu, S.Y. Chen, Y. Ren, A. Hirata, T. Fujita, P.K. Liaw, M.W. Chen, "Temperature-dependent compression behavior of an $Al_{0.5}CoCrCuFeNi$ high-entropy alloy", Materialia, 5, 100243 (2019).

Y.X. Ye, B. Ouyang, C.Z. Liu, G.J. Duscher, T.G. Nieh, "Effect of interstitial oxygen and nitrogen on incipient plasticity of NbTiZrHf high-entropy alloys", Acta Materialia, 199, 413-424 (2020).

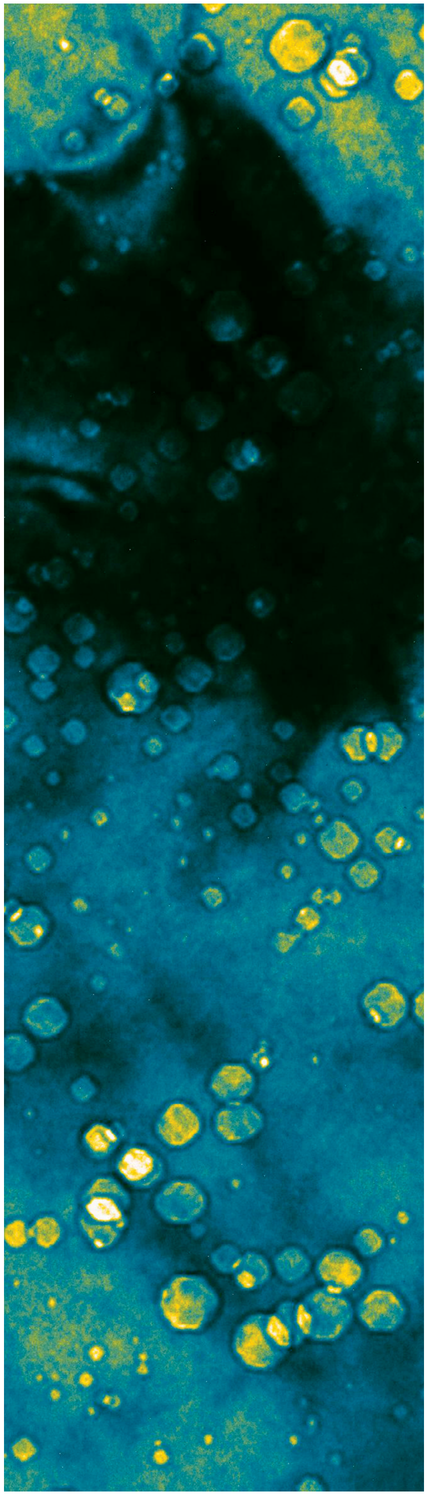
H. Zhang, L. Hao, J. Yang, J. Mutch, Z. Liu, Q. Huang, K. Noordhoek, A. May, J.-H. Chu, J.-W. Kim, P.J. Ryan, H. Zhou, J. Liu, "Comprehensive electrical control of metamagnetic transition of a quasi-2D antiferromagnet by in situ anisotropic strain", Advanced Materials, 32, 2002451 (2020).

H. Zhang, Q. Huang, L. Hao, J. Yang, K. Noordhoek, S. Pandey, H. Zhou, J. Liu, "Anomalous magnetoresistance in centrosymmetric skyrmion-lattice magnet Gd_2PdSi_3", New Journal of Physics, 22, 83056 (2020).

J. Zhang, J. Qin, T. Wu, B. Hu, "Doping induced orbit-orbit interaction between excitons while enhancing photovoltaic performance in tin perovskite solar cells", Journal of Physical Chemistry Letters, 11, 6996-7001 (2020).

W. Zhang, A.R. Mazza, E. Skoropata, D. Mukherjee, B. Musico, J. Zhang, V. M. Keppens, L. Zhang, K. Kisslinger, E. Stavitski, M. Brahlek, J.W. Freeland, P. Lu, and T. Z. Ward, "Applying configurational complexity to the 2D Ruddlesden–Popper crystal structure", ACS Nano, 14, 13030–13037 (2020).

X. Zhu, H. Wang, S. Allu, Y. Gao, E. Cakmak, E.J. Hopkins, G.M. Veith, Z. Wang, "Investigation on capacity loss mechanisms of lithium-ion pouch cells under mechanical indentation conditions", Journal of Power Sources, 465, 228314 (2020).



TICKLE
COLLEGE OF ENGINEERING

CENTER FOR MATERIALS
PROCESSING

423 Ferris Hall
1508 Middle Drive
Knoxville, TN 37996
Phone: 865-974-9554
Email: *crawn@utk.edu*