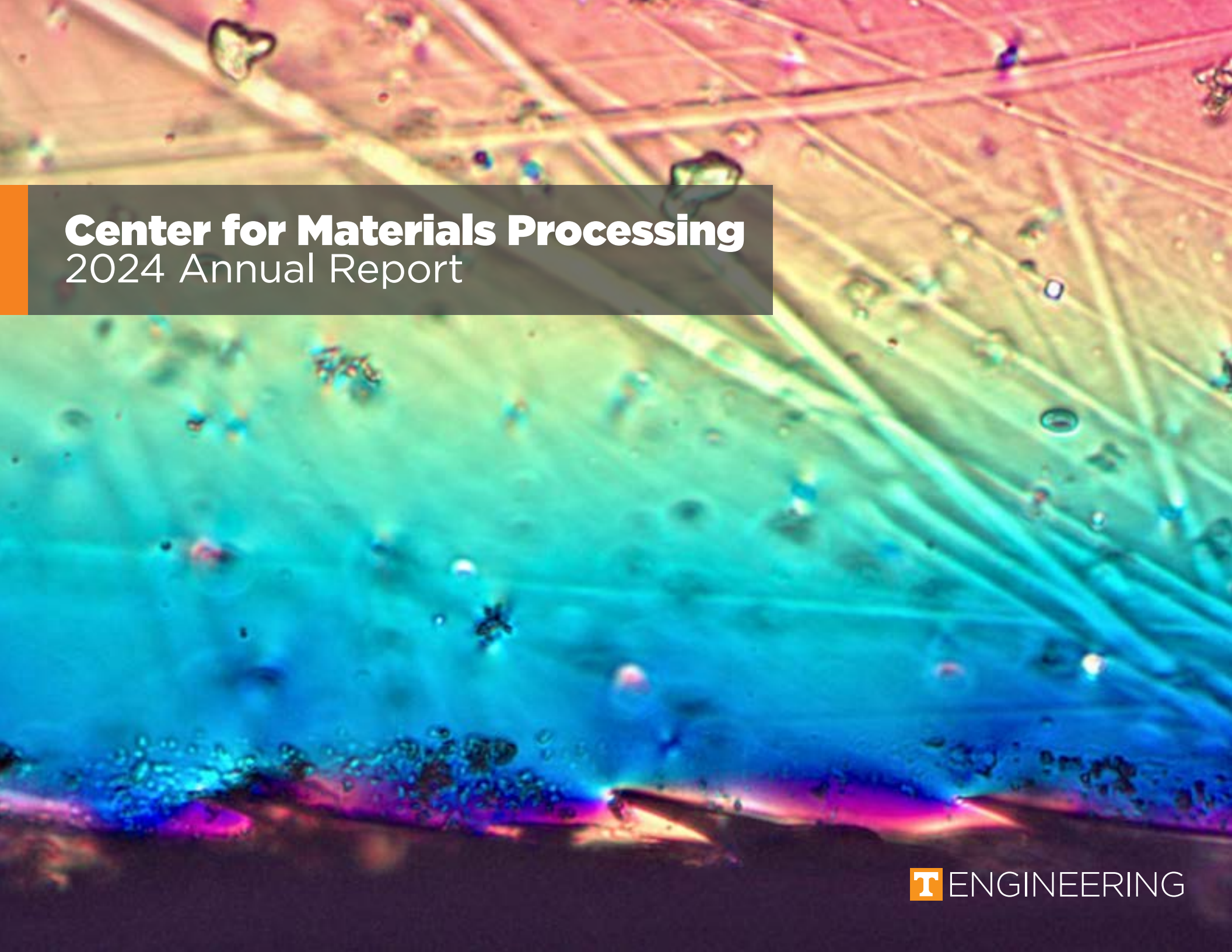

Center for Materials Processing
2024 Annual Report

TENNESSEE ENGINEERING

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Project Manager: Carin Medford | Designer: Wes Baldwin

On the Cover: The Prismatic Bridge; prismatic liquid crystal epoxy bridge synthesized from 4,4'-bis-(2,3-epoxypropoxy) biphenyl and sebacic acid | Photo Credit: Cotton Pekol

Advisory Committee

Established in early 2014, the CMP Advisory Committee works with the CMP director and associate director for industrial partnerships regarding various areas of research that the CMP can advocate for and invest in for the future. The CMP leadership and the Advisory Committee work 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.

William Dunne
Associate Dean, Research and Facilities
Tickle College of Engineering
University of Tennessee, Knoxville

Veerle Keppens
Vice Provost for Faculty Affairs
Professor, Materials Science and Engineering
Tickle College of Engineering
University of Tennessee, Knoxville

Danny Norman
Advanced Manufacturing Consultant
Center for Industrial Services
University of Tennessee

Lilly Tench
Director
Spark Innovation Center
UT Research Park at Cherokee Farm
University of Tennessee

Jon Phipps
Director
Institute for Advanced Materials and Manufacturing
University of Tennessee

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

During FY 24, the Center for Materials Processing (CMP) supported 13 full-time graduate students and 85 undergraduate students, which resulted in 20 peer-reviewed publications, 17 conference papers and presentations, 3 PhD dissertations, 1 patent application, and 5 student best paper or poster awards. Nearly half of these graduate students conduct research in the Center for Advanced Materials & Manufacturing (CAMM), a National Science Foundation funded Materials Research Science and Engineering Center (MRSEC) at the University of Tennessee, Knoxville (UTK). CAMM focuses on the exploration, discovery, and design of new materials with properties of critical societal importance for energy, transport, and security advancements. CMP-supported undergraduate researchers included 68 students working part-time for UTK faculty, in addition to 17 Spark Scholars, who worked with 9 different Spark Innovation Center-affiliated startup companies housed at the Institute for Advanced Materials and Manufacturing (IAMM) on the Cherokee Farm campus or in the Zeanah Engineering Complex on UTK's main campus. This involvement represents approximately 100% growth since FY23 in both the number of participating students and companies. As evidence of its effectiveness, 3 former Spark Scholars have been hired as full-time staff members with Spark companies since 2022. Research topics pursued by CMP-students span diverse areas related to materials processing, including, but not limited to, biomaterial scaffolds for tissue engineering, perovskite nanocrystals for carbon dioxide reduction, transition metal dichalcogenides for semiconductor applications, and porous titanium layers for enhanced hydrogen production. To disseminate CMP-supported research to a larger community, the CMP continued its tradition of sponsoring a research poster session in August 2023 at IAMM. This event provided opportunities for graduate and undergraduate students to present their research to both their peers and to judges from Oak Ridge National Laboratory, research staff from Spark Innovation Center companies, local industry, and faculty from different departments at UTK. The top posters were awarded travel support to enable students to attend larger scientific conferences and present their work to a broader community of researchers. Separately, the CMP also supported travel costs for 4 undergraduate student members of Material Advantage to engage congressional leaders in DC and advocate for federal funding of materials-related research and development and for 1 student to participate in research at a German university through the German Academic Exchange Service's Research Internships in Science and Engineering Program. Beyond its financial support of graduate and undergraduate students, the CMP contributed to materials processing related research by maintaining and operating smaller research equipment necessary for understanding structure-processing-property relationships, supporting the IAMM Diffraction Facility, which is frequently used by many CMP students, and partnering with Industry to address material defects and processing issues. Finally, CMP experienced a change in leadership during FY24. Prof. Claudia Rawn, stepped down from her position as Director of CMP to begin her work as the Deputy Director and the Director of Education, Diversity, Outreach, and Recruitment (EDOR) for CAMM. As a Professor in Materials Science and Engineering (MSE), she is also a researcher in the interdisciplinary group focused on Extreme Materials. Prof. Philip Rack, the Leonard G. Penland Chair Professor in MSE at UTK, was appointed Director of CMP in January 2024. With more than 20 years of experience at UTK, including as a joint faculty with ORNL and in key leadership roles, Philip brings necessary leadership experience and technical expertise to the CMP. His research investigates emergent properties of nanoscale materials and devices, combinatorial thin film processing, fabrication of nanoscale devices, and nanoscale focused electron, ion and photon beam induced processing.

CMP Staff

Philip Rack
Director

Philip Rack has been director of the Center for Materials Processing since January 1, 2024. He is a Professor in the Materials Science and Engineering Department at the University of Tennessee, Knoxville. Philip earned his bachelor's degree in Materials Science and Engineering from the Georgia Institute of Technology and his PhD in Materials Science and Engineering from the University of Florida. Prior to joining the University of Tennessee, Rack worked as a Senior Research Scientist at Advanced Vision Technologies Inc. (AVT) and later taught in the Microelectronic Engineering Department at the Rochester Institute of Technology. His research investigates emergent properties of nanoscale materials and devices, combinatorial thin film processing, fabrication of nanoscale devices, and nanoscale focused electron, ion and photon beam induced processing.

Andy Sarles
Associate Director for Industrial Relations

Andy Sarles started as the CMP Associate Director for Industrial Relations on May 1, 2023. Andy joined the University of Tennessee in 2011 and is currently a Professor and the James Conklin Fellow in the Department of Mechanical, Aerospace, and Biomedical Engineering. Andy received a bachelor's degree in Mechanical Engineering from UTK and MS and PhD degrees in Mechanical Engineering from Virginia Tech. His research is focused on the assembly, characterization, and application of biologically inspired and biomolecular material systems for engineered devices.

Karen Boyce
Business Manager

Karen Boyce is the business manager for the CMP, the Scintillation Materials Research Center, and the Ma2JIC University of Tennessee, Knoxville, site; she also assists the Tickle College of Engineering Finance Office. She has been working within various university systems since 1995 and joined UT in June 2011.

Gerald Egeland
Tech Supervisor/Lab Manager

Gerald Egeland is the CMP laboratory manager and supervises the undergraduate students that perform work on CMP Industrial Facility Membership sponsored research. He has a joint appointment between the CMP and MSE serving as the undergraduate laboratory manager and the departmental safety officer. Egeland has degrees in materials science and engineering from New Mexico Institute of Mining and Technology. Prior to joining UT, he had appointments at both Los Alamos National Laboratory and Idaho National Laboratory focusing on radiation damage of alloys, ceramic powder processing for advanced fuel, and fuel-cladding interactions.

Professor Claudia Rawn

Rawn Made Students the Priority at the CMP

Written by Rhiannon Potkey.

Professor Claudia Rawn always put students first in every decision she made while serving as director of the Center for Materials Processing (CMP). Rawn's commitment to every student's growth is among her lasting legacies in the role.

After more than a decade as the CMP director, Rawn recently stepped down to become the deputy director and director of education, community, outreach, and recruitment of the Materials Research Science Engineering Center (MRSEC) at the University of Tennessee.

"Her guiding light was a commitment to involving students, particularly undergraduates, in the activities of the CMP," said Bill Dunne, associate dean & professor, research & facilities for the Tickle College of Engineering. "Claudia introduced programs that supported recruiting activities for undergrads, supported professional presentations, and featured them in the outcomes of the center. She always cared about students. At a university, that's a super cool thing to have."

Rawn was named associate director of the CMP in January of 2012 and promoted to director in July of 2012. She succeeded Carl McHargue, who became director after a distinguished career at Oak Ridge National Laboratory (ORNL).

"I knew and respected Carl quite a bit. This was his baby, and he was very particular about who he would find to replace him," said Rawn, who was a joint faculty between ORNL and UT before transitioning to UT full time in 2014. "I really appreciate Carl for his belief in me. I know it was very hard for him to turn it over. But his faith in me made me think I could do it."

Professor Claudia Rawn working with a student

Professor Claudia Rawn

Positioning CMP for Success

Rawn is credited with her organizational skills and attention to detail. She helped cut administrative costs for the CMP to enable more funds to be spent directly on the center's activities.

Rawn did her best to make sure CMP was well represented. She upgraded the quality of the annual report required for a Tennessee Higher Education Commission (THEC) Center of Excellence. The report caught the attention of Stacey Patterson, the former vice president of research for the UT System.

"Stacey was so impressed with this report that it got distributed to all the other THEC centers across the UT System, which then got their act together," Dunne said. "Claudia got people to up their game on improving their communication to the UT System and THEC about what they were doing."

Rawn created a poster competition for students to showcase their work on the cover of the annual report. She included other photos from students on the cover and inside the issue. Rawn also helped find a way for the CMP to pay the first year of dues for students to join the Materials Advantage Student Society.

"She was very successful in maximizing the impact of CMP funding on students because of all the programs and activities she implemented," said Andy Sarles, the associate director of industrial relations for the CMP. "The purpose of the THEC funding that's provided to CMP is to support research and education and materials processing, and I know that Claudia was a very good steward of that responsibility."

Passing the Torch

Not only did Rawn help advance the CMP strategically, but she also helped move the office location from East Stadium Hall to its current location in Ferris Hall. Rawn spent many hours cleaning out closets and sorting through old records. She donated some of the items to a public school in Atlanta where the daughter of CEE Professor Richard Bennett taught.

"They were on a shoestring budget, and she was so happy to get all of that for her students," Rawn said. "Every time Dick sees me, he'll still tell me about his daughter's career and how she's doing."

Once her new opportunity at MRSEC emerged, Rawn was ready to pass the torch to new CMP Director Philip Rack. She felt she was leaving CMP in a strong position to build for the future and is confident the center's student-focused mission will endure.

"It was very hard to step away from that role, but I knew it was time," Rawn said. "I think after 10 years you're not adding a lot of fresh ideas, and you really need somebody else to come in with their ideas."

Spark Scholars Program Benefits Students, Start-Ups

Written by Rhiannon Potkey. Photography by Shawn Poynter.

Lucy Moore (BS/CBE, '23) wanted a chance to apply what she was learning in the classroom at the University of Tennessee to what she would be asked to do in a business setting. Moore was eager to gain experience in the field to complement her educational foundation.

Moore didn't have to search far to accomplish her goal.

Through the Spark Scholars program, Moore was selected hired by SkyNano Technologies, a science-based technology company focused on commercializing a free-market solution to carbon pollution.

"I hadn't had such a hands-on work experience before," Moore said. "I absolutely loved it and decided that is what I wanted to continue for a full-time job."

SkyNano offered Moore a full-time position before she began her senior year at UT in the fall of 2022. She graduated last May with a degree in chemical engineering and began work at SkyNano last August.

"It took away a lot of stress from not knowing where I would be working," Moore said. "Starting a new job can be stressful, so it was nice to have already be familiar with everyone and make a really smooth transition."

The Spark Scholars program at UT is a student training program pioneered by the Center for Materials Processing, under the then-direction of Professor Claudia Rawn and Chad Duty, and the Spark Innovation Center, under the direction of Tom Rogers. The program brings together early-stage tech companies located at UT Research Park at Cherokee Farm and UT undergraduate engineering students for jointly sponsored employment related to materials and material processing-related research and development.

The mutually beneficial partnership provides a pipeline of talent for new businesses within the greater Knoxville community while giving students on-the-job education and training in cutting edge technology fields.

The pilot program began in the summer of 2022 with two undergraduates, including Moore, placed with a Spark company. It grew to eight students and five companies in the summer of 2023. The recent cohort included students majoring in chemical engineering, electrical engineering, aerospace engineering, and material science.

The Spark Scholars have worked as research and development assistants on technologies that involve batteries, carbon capture, nanomaterial synthesis, micro-mobility solutions, and more. The students are co-sponsored by CMP and the host company, which enables cost-effective positions for early-stage startups.

"It offers a lot of advantages to some of these young companies, not just in personnel, but with access to facilities on campus to investigate materials and conduct material processing research," said Department of Mechanical, Aerospace, and Biomedoical Engineering Associate Professor and James Conklin Faculty Fellow Andy Sarles, who is the associate director of industrial relations for the CMP. "Many Spark companies have initiated facility membership agreements, which enables them to do more testing or use of instruments or have some quick analysis of material samples done at a university setting at a cost-effective rate."

Philip Stuckey is the founder of FC Renew, a fuel cell manufacturing company that

Lucy Moore

restores degraded hydrogen fuel cells at a lower cost. The work done by the company is performed in the flex-lab space in the Zeanah Engineering Complex or at the Institute for Advanced Materials & Manufacturing on UT's campus, where it utilizes electron microscopy and small-angle X-ray scattering.

"Those types of tools and equipment are cost prohibitive and often access prohibitive for people developing commercialized technologies like we are doing," Stuckey said. "Spark gives us a place to incubate and grow by having access to the facilities and the space we lease from the university."

Stuckey lauded UT for having the foresight to partner with start-up companies to foster technology development while empowering students to develop important technical and professional skills.

"I feel like for the last several centuries the role of academic institutions really hasn't been configured to work the type of relationships we are building and developing with the university to develop technology that really needs that level of understanding and technical capabilities," Stuckey said. "This program is very entrepreneurial and forward thinking with ways to do that and have a lot of success."

Nicole Liu, a sophomore majoring in chemical engineering with a minor in material science and engineering, started her position with FC Renew in June of 2023 and has continued in a part time role during the school year.

"I have definitely learned a lot from it, and I think it furthered my interest in the sustainable energy sector and how it affects the economy," Liu said. "I saw a little bit more of the business side than I was expecting, which was honestly a lot more interesting than I thought it would be. I got a deeper look at how start-up companies function and the trials and errors they go through."

Taking advantage of the Spark Scholars program has been a big benefit to FC Renew.

"The access to faculty and students who know how to use the equipment and the students have really helped us increase our experimental volume," Stuckey said. "It's been a rewarding process on both sides because it puts myself and my colleagues from our company's side in the role of mentor much the way the faculty would be in terms of helping students develop and understand their hands-on and data-processing capabilities."

SkyNano Co-Founder and CEO Anna Douglas was an immediate proponent of the Spark Scholars program when she was first approached about the idea. Through the co-sponsorship with CMP, SkyNano has been able to hire four students and has started looking for more for the upcoming summer.

"For start-up companies, access to talent is one of the main drivers of our success and that applies across the board from technical talent, non-technical, full-time, part-time," Douglas said. "For SkyNano, in particular, we have really benefitted from being able to bring students in during summers and for us to really understand how they work and what their skill set is."

Douglas is an advocate of mentoring and teaching. She thought about becoming a professor before launching SkyNano and carries that mindset into her leadership at work by giving student workers projects that allow them to accomplish a task.

"The projects might be a little bit more straight forward and lower risk, but they still can have a high impact," Douglas said. "I want the students to be able to build confidence that the things they work on can have an impact and that allows them to see their work outcomes."

In her position with SkyNano, Moore built a system that purifies carbon nanotubes when they come out of the growth process to rid them of contamination. She has continued to work on the system since being hired full time.

Moore is grateful for all the opportunities she received at UT and encourages other students to take advantage of the resources the university offers to help build the path to a future career. CMP has been thrilled with the early results of Spark Scholars and hopes more students and companies will take part in the coming year to fuel its continued growth.

"Don't be afraid to work for start-ups. Don't let that intimidate you," Moore said. "I have learned so much more here since I have been exposed to so many different things. Even if the field doesn't pertain exactly to your major, you are able to learn so much that will help you broaden your skills."

Spark Innovation Center Awarded DOE EPIC Funding

Writing by Lilly Tench.

The University of Tennessee Research Park's Spark Innovation Center was awarded an EPIC (Energy Program Innovation Cluster) Round 3 Phase 1 Award in April 2024 from the U.S. Department of Energy Office of Technology Transition. The $150,000 award supports a planning and trial phase for a Spark Prototyping initiative to help startup companies access prototyping resources and facilities in partnership with the UT Tickle College of Engineering, the UT Center for Materials Processing (CMP), Oak Ridge National Lab's Innovation Crossroads program, and the Tennessee Advanced Energy Business Council (TAEBC).

Building on the successful Spark Scholars program that CMP and Spark have developed together, the goal of this project will be to develop a dynamic hub providing Spark startups with access to state-of-the-art facilities and expert guidance, and to empower students through hands-on experience with rapid prototyping, bringing ideas to life swiftly, iterating efficiently, minimizing wasted resources, and interacting with cutting-edge startup companies.

EPIC Round 3 is a competitive funding program aimed at supporting the nation's most innovative incubators nurturing energy startups. With a focus on fostering creativity and impact, EPIC Round 3 awards cash prizes and a three-year cooperative agreement for up to $1,000,000 to regional incubator teams that develop robust programming, connections, and support for energy startups and entrepreneurs. Spark will be eligible to apply to the next round of the program in Fall 2024.

RISE Internship Expanded Jocelyn Hess' Research & Cultural Horizons

Written by Izzie Gall.

While Jocelyn Hess has returned from Europe, her research may be heading for the moon.

Hess, a junior in the Department of Materials Science and Engineering, was awarded a prestigious DAAD Research Internships in Science and Engineering (RISE) internship this spring. The program gave her the opportunity to perform research at Germany's federal aeronautics institute, the German Aerospace Center (DLR).

"I wanted to pursue a research opportunity this summer to better prepare myself for graduate school," Hess said. "DAAD RISE is a one-of-a-kind opportunity for me to perform research while going abroad, giving me new perspectives and experiences."

DAAD is a German organization that funds international exchange programs for students and researchers in North America and the British Isles. Only about 15% of applicants receive RISE internships each year.

Hess's internship was based at the Institute of Materials Physics in Space, where DLR scientists are trying to determine whether infrastructure for a lunar base could be made with native materials rather than supplies shipped from Earth. Her task was to help develop a glass-fiber reinforced ceramic composite made with simulated lunar regolith.

"Working with ceramics was a new experience for me, and I learned a lot," said Hess. "I was able to successfully sieve and sinter different fractions of lunar regolith simulant, then compression-test the sintered samples to determine the optimal sintering temperature and time."

By the end of her stay, Hess and her team had started using the simulant in a newly fabricated regolith composite manufacturing machine, investigating the relationship between input parameters and output quality.

"This work expanded my knowledge of composites and their manufacturing techniques, which I will apply as I continue doing research on composites at UT," Hess said. During the academic year, Hess performs research on polymer-carbon fiber and polymer-glass fiber composites with Uday Vaidya, a professor in the Department of Mechanical, Aerospace, and Biomedical Engineering.

Jocelyn Hess

Overcoming Culture Shock

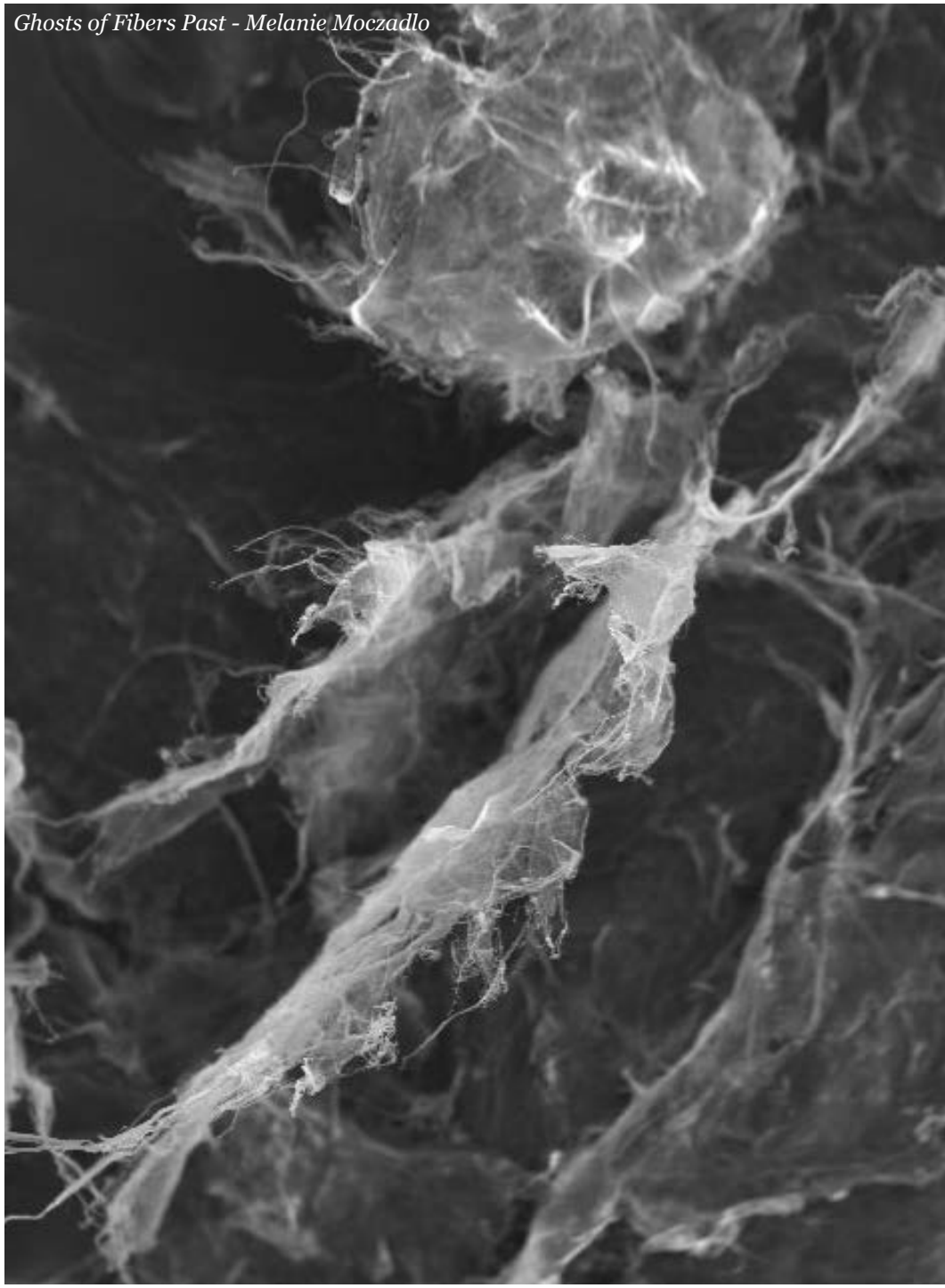
While Hess eagerly dove into the ceramics side of composites research, she had more trouble adjusting to the unfamiliar interpersonal dynamics at the DLR.

"Workplace relationships are shaped by culture, so they vary greatly between Germany and the United States," she said. "Constructive criticism is given more freely there, and the humor is very different. I did a lot of research on the culture and practiced very basic German before I went, but it was still a large culture shock, and the complete immersion meant that I had to face it head-on."

Hess challenged herself to commit to the immersion, speaking German whenever possible and navigating without using her phone. By the end of her trip, she was talking more freely with her fellow researchers and had confidently made her way around the country—attending an organ concert at the Cologne Cathedral, touring castles, boating down the Neckar River, and hiking around Eibsee Lake at the base of the Bavarian Alps.

Though she misses the schnitzel at the 16th-century Hofbräuhaus, continuing her research on composites in Knoxville lets Hess feel connected to the work and culture she experienced this summer.

"The study of materials is exciting because it allows you to study the building blocks and foundations of the world," said Hess. "I love being able to create and research materials I can see and touch. I feel it brings my research to life."



Ghosts of Fibers Past - Melanie Moczadlo

CMP Supported and Associated Graduate Students

In FY24, through its competitive application process, the CMP financially supported a cohort of seven graduate students working in areas of materials processing research. Current students, featured below, are from a variety of disciplines including comparative and experimental medicine, materials science and engineering, and mechanical engineering. These students along with CMP supported graduate students who graduated last year are the force behind many of publications and dissertations listed in this report.

Jack Lasseter, MSE

What is your thesis topic? My work studied the use of focused energy, like photon, electron, or ion beams, to manipulate matter in visible and controllable ways. This allows for directing chemical vapor deposition onto nanostructures and patterning 2D transition metal dichalcogenides (TMDs).

How is materials processing involved in your research? Materials processing is fundamental to the research as the growth, transfer, and device fabrication methods strongly impact the beam intensity utilized in our processing methods.

Provide an example of where the material, process, or properties you are studying might find an application. TMD's are promising for optoelectronic properties and light sensing applications, including ultra-thin solar cells, photodetectors, and light emitters. 2D TMD's allow the integration of these capabilities into wearable, transparent next-generation devices.

Meaghan Harley-Troxell, Comparative and Experimental Medicine

What is your thesis topic? My research aims to print a novel, biocompatible, and biodegradable construct that can be implanted to treat traumatic brain injuries.

How is materials processing involved in your research? The type of polymer, material modifications, and fabrication methods can alter a material's properties, which changes how cells in the body or implanted cells will interact with the material. My research uses synthetic polymers, carbon-based nanoparticles, and graphene oxide, to develop an implantable construct that can alter the injured tissue environment to support nerve repair and regeneration.

Provide an example of where the material, process, or properties you are studying might find an application. The composite resin will allow for 3D printing of precise, delicate, and complex structures for a variety of biomedical applications, such as those of the eye or the brain.

Weitian Wang, ME

What is your thesis topic? My research investigates the role of porous transport electrodes in water electrolysis systems, including their mechanisms, design, and manufacturing.

How is materials processing involved in your research? Porous transport electrodes require micro- to nano-scale features, which are critical for efficient electrochemical reactions. Material processing helps me to develop reliable manufacturing methods to realize high-performing porous transport electrodes from theoretical designs.

Provide an example of where the material, process, or properties you are studying might find an application. The porous transport electrodes I am developing can be applied in water electrolyzers for “green hydrogen” production, which is promising to address the challenge of high costs and low efficiency of water electrolyzers.

Weitian's project contributes to the decarbonization of the whole energy system via decreasing the capital costs of green hydrogen production. His research will help CMP community to seek potential funding and application opportunity about clean hydrogen.

Advisor: **Feng-Yuan Zhang**
Professor (MABE)

CMP Supported and Associated Graduate Students

Hugh Schortt, MSE

What is your thesis topic? I am studying the extreme mechanical properties of a medium entropy alloy with chemical short-range order.

How is materials processing involved in your research? Changing the grain size of the alloy affects its yield strength. Plus, annealing is used to alter the chemical short-range order of the material, which affects the anisotropic nature of the material.

Provide an example of where the material, process, or properties you are studying might find an application. Potential applications include its use in fatigue-resistance structures, extreme mechanical environments, such as high-pressure torsion loading in deep ocean water or in mining, and as a corrosion- and embrittlement-resistance material for hazardous waste containment.

Cotton Pekol, MSE

What is your thesis topic? My research studies how changing the morphology of liquid crystal epoxies affects their functional properties. For example, this work asks, how can a system capable of shape memory be modified so that things like 3D printability, self-healing, and adjustable degrees of shape memory actuation can all be controlled?

How is materials processing involved in your research? Processing is at the heart of this work in a significant way. Epoxy formulation, rheological modification, and introduction of dynamic covalent bonding are all directly related to adjusting the processability of a shape memory epoxy, including in 3D printing and recycling.

Provide an example of where the material, process, or properties you are studying might find an application. This material system shows promise for "smart" applications such as two-way actuators, self-healing protective coatings, and sensors, all of which can possess customized behaviors dependent on the implemented processing technique.

Cotton explains complex problems as simple concepts and stories that relate to broad audiences. This is an exceptional skill for a young researcher. His work is addressing long standing challenges in recycling thermosets and while maintaining material functionalities. Cotton's work is impactful and will have broad applicability in many areas.

Advisor: **David Harper**
Professor (MSE)

Sheryl Sanchez, MSE

What is your thesis topic? My research explores lead-free perovskite nanocrystals (PNCs), particularly $Cs_3Sb_2X_9$, synthesized using a high-throughput ligand-assisted reprecipitation method. This work aims to address environmental concerns and stability issues in perovskites, focusing on photocatalysis for sustainable energy applications.

How is materials processing involved in your research? Materials processing is integral to my research, as I utilize high-throughput, automated synthesis methods to systematically vary ligand ratios, solvent polarities, and precursor concentrations. This process allows for precise control over the size, shape, and optoelectronic properties of the PNCs, optimizing them for photocatalytic performance.

Provide an example of where the material, process, or properties you are studying might find an application. Lead-free $Cs_3Sb_2X_9$ PNCs could find applications in photocatalytic CO_2 reduction, which uses solar energy to convert CO_2 into useful fuels or chemicals, contributing to green energy solutions and helping address climate change challenges.

CMP Supported and Associated Graduate Students Cont.

Katie Loughlin, MSE

What is your thesis topic? My thesis topic focuses on the synthesis, characterization, and modelling of the mineral mayenite ($Ca_{12}Al_{14}O_{33}$) and related materials, including $Sr_{12}Al_{14}O_{33}$.

How is materials processing involved in your research? Both my sample synthesis method, polymeric steric entrapment, and in-situ high-temperature X-ray diffraction, which we use to understand phase changes during synthesis, involve materials processing.

Provide an example of where the material, process, or properties you are studying might find an application. Mayenite and related materials show promise as electrides, catalysts, and ion conductors.

Katie is one of those students that is really fearless when it comes to programming. She has completed the challenging classes for the Interdisciplinary Graduate Minor in Computational Science (IGMCS) and is putting her talents towards computational problems related to better understanding atomic details of complicated oxide structures.

Advisor: **Claudia Rawn**
Professor (MSE)

Thesis/Dissertation Titles

Jack Lasseter, PhD (MSE)
"In Situ Direct-Write Nanoscale Synthesis in the Electron Microscope"

ADVISOR: Prof. Philip Rack

Yao Li, PhD (NE)
"Temperature and Cr effect on dislocation loop formation in ion irradiated Fe and Fe-Cr model alloys"

ADVISOR: Prof. Steve Zinkle

Sreya Paladugu, PhD (MSE)
"Structure-property relationships in compositionally complex and nanostructured catalysts"

ADVISOR: Prof. Katharine Page

Industry Partners

- American Nanotechnologies, Inc.
- Analysis and Measurement Services Corporation
- ARC Automotive, Inc.
- Daylyte Batteries
- Eagle Alloys
- Electro-Active Technologies, Inc.
- Eonix
- FC Renew
- Fulton Bellows LLC
- Greentech Environmental
- Holocene Climate Corporation
- Novonix
- Perseus Materials
- Proton Power, Inc.
- RAEV
- Safire Technology Group
- SkyNano LLC
- Takahata Precision Tennessee, Inc.
- ThermoVerse
- TPR Federal-Mogul Tennessee, Inc.
- TreisD Corporation
- Tsubaki Nakashima Co., Ltd
- UT Center for Industrial Services
- Zeiss Semiconductor Manufacturing Technology

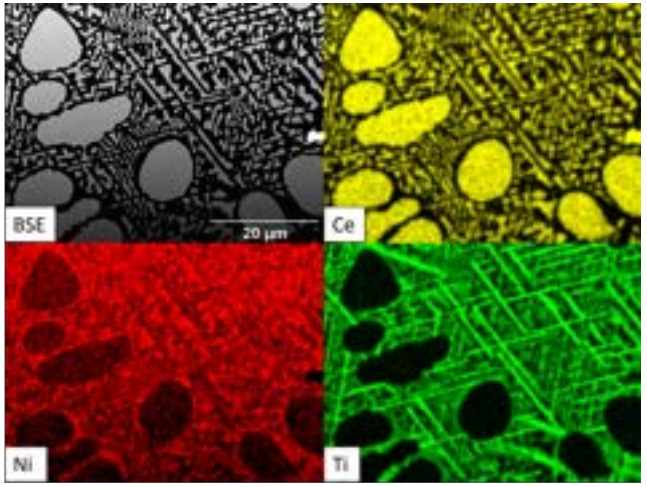
Program Accomplishments and Overview

Accomplishments

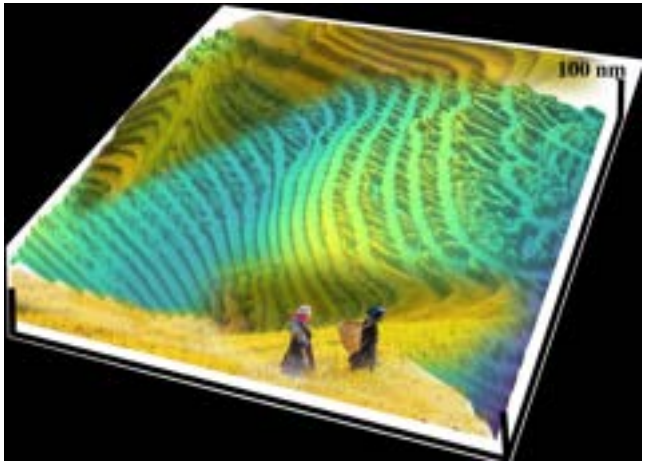
- **(7)** graduate students received PhD dissertation support packages
- **(6)** UTK MRSEC students received supplemental funding
- **(17)** Spark Scholars and 9 Startup companies supported through the Spark Scholars Program
- **(3)** Spark Scholar alumni hired as full-time staff at host companies
- **(>65)** undergraduate researchers supported
- **(>25)** faculty supported
- Assisted **(>15)** external companies
- Partnered with Spark Innovation Center to grow Spark Scholars program and develop shared-access prototyping hub

Central to the mission of the CMP, we provided a cohort of seven senior PhD students with graduate support packages that help fund the final stretches of their dissertation research. Students receiving CMP support conduct research on diverse aspects of materials processing, including, but not limited to, biomaterial scaffolds for tissue engineering, perovskite nanocrystals for carbon dioxide reduction, transition metal dichalcogenides for semiconductor applications, and porous titanium layers for enhanced hydrogen production. The awarded students were selected through a competitive proposal and presentation process and represent a variety of technical disciplines including comparative and experimental medicine, materials science and engineering, and mechanical engineering. The CMP also supported 6 graduate students within the Center for Advanced Materials and Manufacturing (CAMM), UTK's Materials Research Science and Engineering Center funded by the NSF. Interdisciplinary research thrusts of the CAMM include accelerating understanding and design of quantum materials and systems and developing materials able to withstand extreme pressure and temperatures needed for nuclear fusion and hypersonics applications. 3 PhD students supported by the CMP successfully defended their dissertations in the past year.

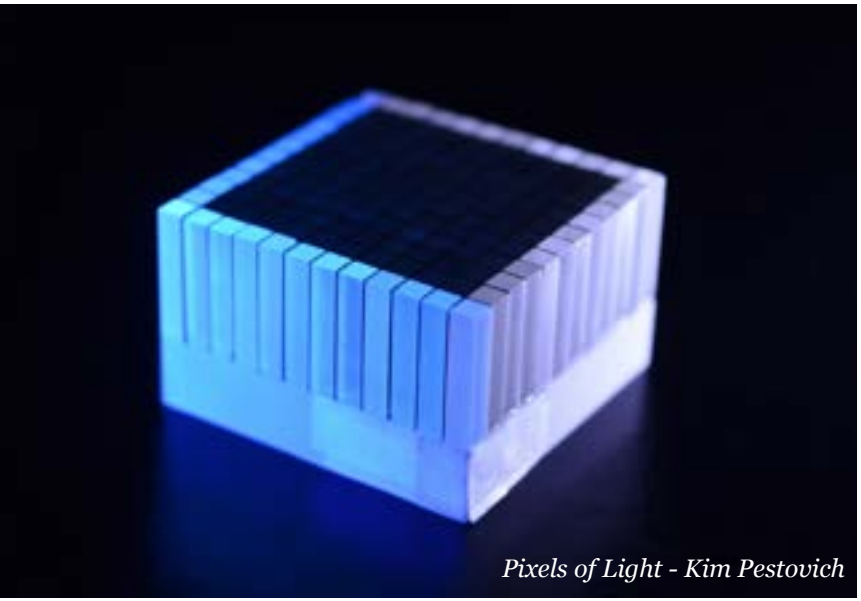
Additionally, 68 researchers in more than 23 research groups at UTK received financial support for their research efforts. Collectively, these students gained valuable research experience in material synthesis, characterization, processing, modeling, and machine learning. Types of material systems studied included perovskites, fiber-reinforced composites, metal alloys and oxides, polymers, emulsions, liquid crystals, biomaterials, quantum dots, and ceramics,



Adding Titanium...Lucky or unlucky?
- Syeda Bushra Haider



Rice Fields on Nanoterraces - Bogdan Dryzhakov


Pixels of Light - Kim Pestovich

with applications in scintillators, catalysts, smart materials, batteries and fuel cells, structural materials, additive manufacturing, and automotive, to name a few.

Separately, sixteen undergraduate engineering students and 1 graduate engineering student at UTK worked off-campus as Spark Scholars with local startup companies. CMP provided cost-matching to the companies for the students' hourly wages. Spark Scholars ranged from undergraduate sophomores to Master's degree level, and they represented 5 different engineering departments within the Tickle College of Engineering. In FY 24, three alumni from the Spark Scholars program were hired into full-time staff positions at these companies upon graduating from the University of Tennessee.

The CMP also invested in broadening student exposure to materials research and advocacy. This was accomplished in part by supporting an international research internship for 1 MSE undergraduate student who was accepted into the German Academic Exchange Service's Research Internships in Science and Engineering (DAAD RISE) program. The student, Jocelyn Hess, performed materials research at the German Aerospace Center during Summer 2024. CMP also supported four student members of the UTK chapter of Material Advantage, who travelled to Congressional Visits Day in Washington DC in April 2024, an annual event that brings together members of Material Advantage from around the U.S. to advocate for increased federal funding for science, technology, and R&D. Material Advantage student members held meetings with members of Congress and their staffs representing 2 different Tennessee districts and 1 Missouri district to communicate to legislators to vote for funding related to NSF, DOE Office of Science, ARPA-E, NIST, and other critical research funding programs. Students shared their stories of how federal funding has impacted them as students, attended the Material Advantage CVD opening reception where they received some advocacy tips, and visited several national museums and landmarks in DC.

The CMP supported UTK faculty in several ways during the past year too, including through providing financial support of undergraduate and graduate researchers, cost-sharing purchases of state-of-the-art equipment, and providing targeted funding to seed new research collaborations. CMP investments in new equipment include a 4-dimension scanning transmission electron microscopy housed in the Tennessee Ion Beam Materials Laboratory, an X-Ray Diffractometer located at the Institute for Advanced Materials and Manufacturing, and electrochemical potentiostats for corrosion research performed by UT-Oak Ridge Innovation Institute faculty. During FY 24, more than 25 UTK faculty representing many TCE departments and multiple colleges at UTK received financial support of students pursuing research in their labs. With CMP support, these groups generated 20 journal publications, 17 conference papers and presentations, 1 patent application, and 5 student best paper or poster awards.

With the goal to stimulate research and development in emerging areas of materials processing that lead to new extramural funding, the CMP introduced a new Collaboration Seed funding program. The call for proposals was distributed in Spring 2024 and the first awardees, Prof. Ahmed Aziz (EECS) along with collaborator Dr. Steven Randolph (Oak Ridge National Laboratory), were selected to research Thin Film Processing and Nanomachining of Superconducting Materials for applications in New Computing Paradigms. Their CMP seed project started on July 1, 2024.

During FY24, the CMP also strategically partnered with the Spark Innovation Center at the UT Research Park and other TN businesses to develop a student talent pipeline, foster technology development at TN small businesses, and provide technical solutions to industry challenges related to materials processing.

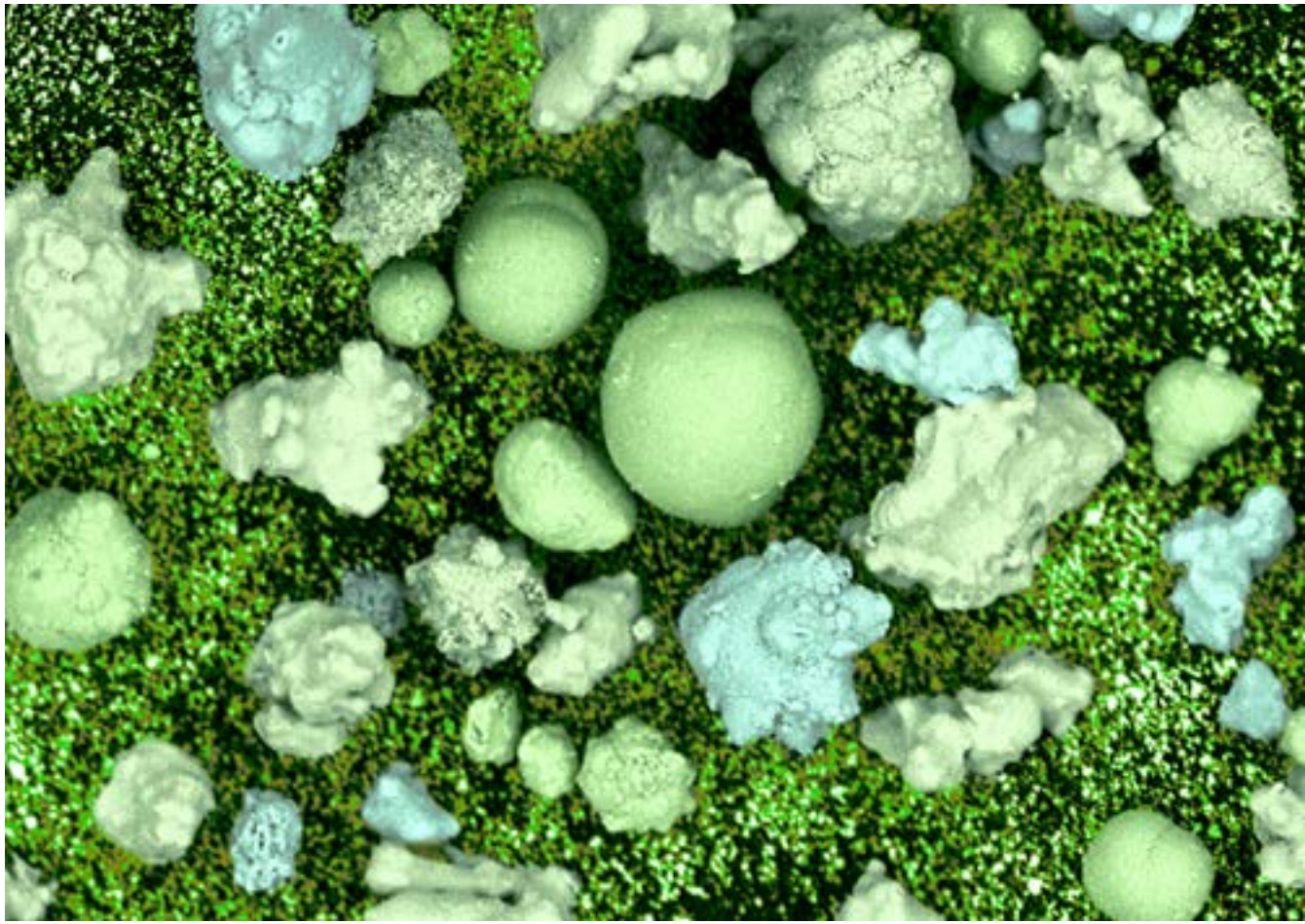
The CMP grew the Spark Scholars program from 2 companies and 2 students in FY22 and 5 companies and 8 students in FY23 to 9 companies and 17 students during FY24. As part of the program, CMP cost-matched Spark Scholars wages, significantly reducing the cost to the employer, providing them


Glowing Garnet Crystals - Matheus Pianassola

cost-effective employees with technical backgrounds in materials, engineering, and physics. Responses received from companies participating in the program have been extremely positive, and their willingness to hire Spark Scholars alumni into full-time positions after graduation demonstrates their appreciation for the students and the program. Participating companies include Spark Innovation Center Incubator companies as well as startups participating in the ORNL Innovation Crossroads and Spark CleanTech Accelerator programs.

Additionally, Spark Innovation Center obtained Department of Energy (DOE) EPIC (Energy Program Innovation Cluster) Round 3 Phase 1 funding to develop a plan for a new university-industry prototyping hub that seeks to leverage UTK facilities and will be accessible to Spark Startup Companies and UTK students. The CMP actively participated in this planning grant. Building on the successes of the Spark Scholars plan, CMP will also support Spark's Phase II grant proposal for implementing the plan to be submitted in Fall 2024.

The CMP, through its active facility membership program, also offered low-cost access to UTK facilities and equipment and technical expertise to more than 15 external companies during FY24. Through this program and other informal interactions with industry, CMP staff and students performed materials characterization and testing for multiple companies looking to improve their manufacturing or assembly processes, understand material variations across vendors, and identify the causes for production defects. These activities are a key outreach service of the CMP to TN manufacturers.



Particle Park - Raymond Wysmierski

Goals and Future Plans

In FY25, the CMP aims to deliver on its core mission, build on its recent accomplishments and successful partnerships, and invest in new activities. Specifically, the CMP will continue to invest in research and education on diverse topics related to materials processing for both students and faculty at UTK. The current cohort of senior PhD students will receive support through the end of 2024, at which point a new round of PhD students doing research on materials processing will be selected.

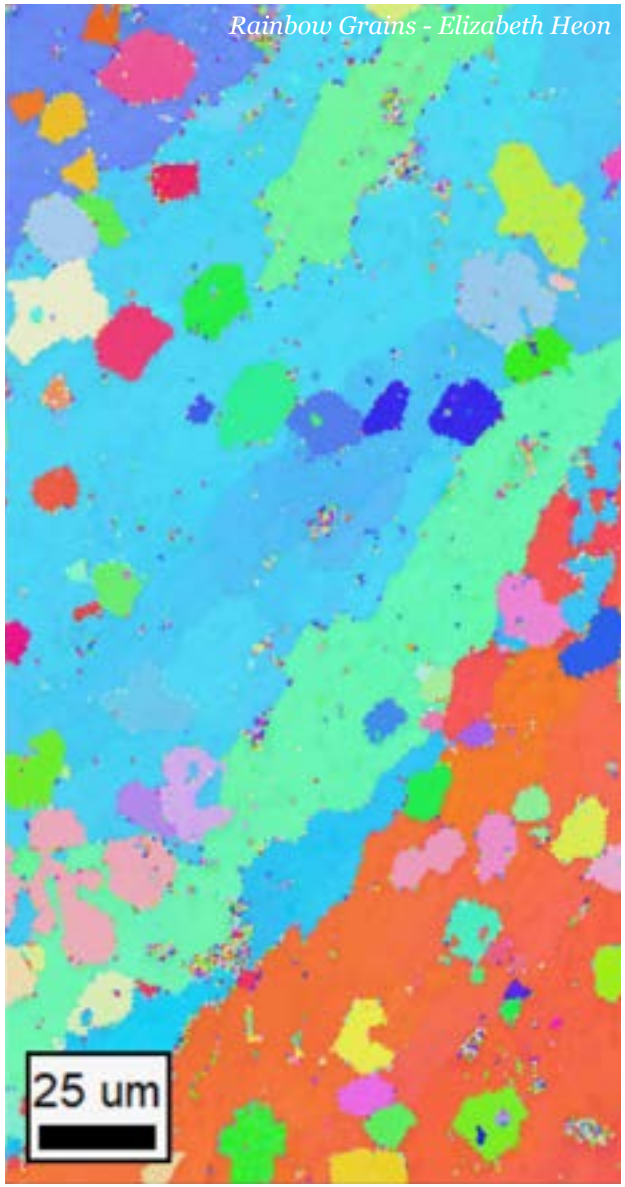
The CMP will also pursue new ways to support students and faculty in FY25. First, the new cohort of graduate students supported by the CMP in FY25 will include support packages for 2 first-year PhD students in the Materials Science and Engineering and Mechanical Aerospace and Biomedical Engineering departments. The intention of this funding strategy is to help departments recruit top students before faculty researchers may have specific project funding secured to support them.

The second mechanism that will be implemented is a new University-Industry Partnership Seed Grant that seeks to foster research collaborations between full-time university researchers and industry partners. The goals of this funding strategy are to strengthen ties between university researchers and outside businesses, with the aim of establishing enduring collaborations that translate UTK-related and/or industry-related research to society, and assist faculty members in growing the translational impact of their research programs and broadening their expertise. The call for proposals was distributed in June 2024, with the goal to award funding by January 1, 2025.

Additionally, the CMP seeks to increase participation by and support of faculty who are mentoring undergraduate researchers in their labs. This will be accomplished through wider advertising of CMP support for undergraduate researchers and limiting support to a maximum of 3 students per lab per year. Similarly, the CMP aims to increase participation of students and host companies participating in the Spark Scholars Program. This will be done by committing a larger percent of the CMP's budget to matching student wages and prioritizing a broader involvement of companies hosting students. Associate Director Andy Sarles will work with Spark Innovation Center Director, Lilly Tench, to grow and improve this exciting program.

Finally, the CMP will work with partners in the Spark Innovation Center, UT Center for Industrial Services, the Tickle College of Engineering, and the Office of Research Innovation and Educational Development at UTK to engage, serve, and train external companies who are seeking to develop materials processing knowledge and solutions to industry challenges.

Through these parallel efforts, the CMP aims to maximize the impact of THEC investment by further strengthening the pipeline of qualified engineering graduates with state-of-the art materials processing and research knowledge, showcasing faculty expertise and providing technical solutions needed to solve industrial problems, and supporting technology development and transfer to industry.



Rainbow Grains - Elizabeth Heon

CMP 2023–24 Publications

Journal Papers:

1. Lasseter, J., P.D. Rack, and S.J. Randolph Selected Area Deposition of High Purity Gold for Functional 3D Architectures. Nanomaterials, 2023. 13.

2. Vlassiouk, I., et al., Armor for Steel: Facile Synthesis of Hexagonal Boron Nitride Films on Various Substrates. Advanced Materials Interfaces, 2024. 11(1): p. 2300704.

3. Lasseter, J., et al., Selected Area Manipulation of MoS2 via Focused Electron Beam-Induced Etching for Nanoscale Device Editing. ACS Applied Materials & Interfaces, 2024. 16(7): p. 9144-9154.

4. Patel, B.K., et al., Large magnetic anisotropy of a decorated spin-chain system K2Co3(MoO4)3(OH)2. Dalton Transactions, 2024. 53(15): p. 6592-6600.

5. O'Quinn, E. C. Sprouster, D.J., Lang, M.K., Trelewicz, J.R., MgO Waste Form Irradiation Damage and Stability ANS Trans. 130, 111–114 (2024).

6.Evan Williams, Jacob Minnette, Eric O'Quinn, Cale Overstreet, William F. Cureton, Ina Schubert, Christina Trautmann, Changyong Park, Maxim Zdorovets, Maik Lang, Swift Heavy Ion Irradiation Effects in Zirconium and Hafnium Carbides, Nucl. Instruments Methods Phys. Res. Sect. B Beam Interact. with Mater. Atoms 548 (2024) 165248

7. Jacob Minnette, Evan Williams, William Cureton, Alexandre Solomon, Eric O'Quinn, Matthew Kurley, Rodney D. Hunt, Changyong Park, Ina Schubert, Christina Trautmann, Maik Lang, Response of ZrC to Swift Heavy Ion Irradiation, J. Appl. Phys. 134 (2023) 185901

8. Wang, W., et al., An ink-free integrated dual electrode assembly for economical proton electrolyzer membrane water electrolysis at ultrahigh current densities. Chemical Engineering Journal, 2024. 494: p. 153015.

9. Wang, W., et al., Innovative design and manufacturing of a reaction-enhanced liquid/Gas diffusion layer with boosted catalyst utilization for green hydrogen production. Applied Energy, 2024. 373: p. 123915.

10. Ding, L., et al., Enhancing reaction interface with modified microporous layers for high-efficiency hydrogen production in PEM water electrolysis. Electrochimica Acta, 2024. 502: p. 144757.

11. Broud, M.T., et al., Selective Carbon Dioxide Binding on Carbon Quantum Dots. The Journal of Physical Chemistry C, 2023. 127(28): p. 13639-13650.

12. Yu, L., et al., Tailored mesoporous structures of lignin-derived nano-carbons for multiple applications. Carbon, 2023. 213: p. 118285.

13. Dubey, A., et al., Lead-Free Halide Perovskites for Photocatalysis via High-Throughput Exploration. Chemistry of Materials, 2024. 36(5): p. 2165-2176.

14. Sanchez, S.L., et al., Physics-driven discovery and bandgap engineering of hybrid perovskites. Digital Discovery, 2024. 3(8): p. 1577-1590.

15. Li, Y., et al., Flash electropolishing of BCC Fe and Fe-based alloys. Journal of Nuclear Materials, 2023. 586: p. 154672.

16. Fieser, D., et al. Synthesis and Unique Behaviors of High-Purity HEA Nanoparticles Using Femtosecond Laser Ablation. Nanomaterials, 2024. 14.

17. Zhu, P., et al., Defect-specific strength factors and superposition model for predicting strengthening of ion irradiated Fe18Cr alloy. Journal of Nuclear Materials, 2024. 588: p. 154823.

18. Paladugu, S., et al., Tailored (La0.2Pr0.2Nd0.2Tb0.2Dy0.2)2Ce2O7 as a Highly Active and Stable Nanocatalyst for the Oxygen Evolution Reaction. Small, 2024. 20(23): p. 2305789.

19. Paladugu, S., et al., Mesoporous RE0.5Ce0.5O2–x Fluorite Electrocatalysts for the Oxygen Evolution Reaction. ACS Applied Materials & Interfaces, 2024. 16(6): p. 7014-7025.

20. Edaugal, J.P., et al., Digital Light Processing (DLP): 3D printing of polymer-based graphene oxide nanocomposites—Efficient antimicrobial material for biomedical devices. MRS Communications, 2023. 13(4): p. 594-602.

Conference Papers and Presentations:

1. Wheeler, K., et al., He Bubble Evolution in LiAlO2: A Comparison of Human and Artificial Intelligence Based Analysis. Microscopy and Microanalysis, 2024 Proceedings. 30(Supplement_1): p. ozae044.816.

2. Buchanon, C., and Gilbert, D. "Investigation of Multi-Dimensional Chiral Soliton Lattices in Multilayer FeGd Thin Films," 2024 American Conference on Neutron Scattering Conference, Knoxville, TN, June 2024.

3. K. Stevens, C. Ang, B. Shaver, Effect of Particles in a Ceramic Matrix as a Rapid Investigation of "Cer-Cer" Composite Fuels, Nuclear Technology. Transactions of the American Nuclear Society. 2023.

CMP 2023-24 Publications Cont.

4. Phillips M, Ang C and Shaver B. Fabrication and metrology of SiC cladding and seals for containment and heat transfer applications. Nucl Sci Technol Open Res 2023, 1:22 (https://doi.org/10.12688/nuclscitechnolopenres.17457.1).

5. K. Karl, C. Ang, B. Shaver, Feasibility and Mechanics of SiC Flow for Fabrication of Containment Structures, Nuclear Science and Technology Open Research (2023).

6. C. Ang, K. Stevens, M. Koehler, T. Hinklin, Zirconium Carbide Matrix Materials for Composite / Inert Matrix Fuels, Proceedings of the 46th Annual Conference on Composites, Materials and Structures, St. Augustine, FL, 2023.

7. C. Ang, M. Phillips, K. Karl, T. Hinklin, B. Shaver, Ceramic Encapsulation for Commercial Non-plutonium Radioisotope Fuels, Proceedings of the 46th Annual Conference on Composites, Materials and Structures, St. Augustine, FL, 2023.

8. Weitian Wang, et al. "Design and Manufacturing of Cost-Effective Water Electrolyzers at Industrial Current Densities Via an Ink-Free Integrated Dual Electrode Assembly" Electrochemical Society PRiME Meeting, 2024, Honolulu, US.

9. Weitian Wang, et al. "A general design to cost-effective water electrolyzers at industrial current densities via an ink-free integrated dual electrode assembly" Center for Nano Material Science (CNMS) User Meeting 2024, Knoxville, US.

10. Weitian Wang, et al. "Boosting the energy conversion efficiency of power-to-hydrogen via developing a novel porous transport material", North American Thermal Society (NATAS) Meeting 2024, Knoxville, US.

11. Maeser, H. L. & Penumadu, D. “Non-invasive characterization of fiber reinforced automotive composites through thermography.” Proceedings of 2023 Composites and Advanced Materials Expo (CAMX 2023). 2023.

12. Maeser, H., Blessing, C., Young, S., & Penumadu, D. "SmartJoints for Materials Joining." Poster presented at Composite and Hybrid Materials Interfacing (CHMI) August 2023 Members Meeting. 2023. Atlanta, GA.

13. Maeser, H., Blessing, C., Chang, K., Young, S., & Penumadu, D. "SmartJoints for Materials Joining: Affect of Plasma Treatment and Analysis of Residual Stress." Poster presented at Composite and Hybrid Materials Interfacing (CHMI) March 2024 Members Meeting. 2024. Knoxville, TN.

14. Sanchez, S., et al. Accelerating Bandgap Discovery in Hybrid Perovskites with Advanced Modeling Techniques, Proceedings of the MRS Fall 2024 Meeting, Boston, MA, accepted.

15. Sanchez, S., et al. Unlocking the Potential of Cesium Lead Bromide Nanocrystals: Stability and Growth Insights from High-Throughput Synthesis, Proceedings of the MRS Fall 2024 Meeting, Boston, MA, accepted.

16. Y. Li, A. Houston, Y. Zhao, J. Poplawsky, G. Duscher, and S.J. Zinkle, “On self-organized dislocation loops in ion irradiated BCC Fe and Fe-Cr alloys”, Materials in Nuclear Energy Systems (MiNES) New Orleans, LA, Dec. 11-14, 2023.

17. Y. Zhao, A. Bhattacharya, J.D. Poplawsky, J. Henry, S. Chen, and S.J. Zinkle, “Kinetics and stability of nano-scale precipitates in Fe-based alloys during ion irradiations” (invited), Materials in Nuclear Energy Systems (MiNES) New Orleans, LA, Dec. 11-14, 2023.

Student Awards:

1. Charlotte Buchanon (MSE, pictured), 2024 “Outstanding Student Poster Presentation” Award, Citation: Buchanon, C., and Gilbert, D. “Investigation of Multi-Dimensional Chiral Soliton Lattices in Multilayer FeGd Thin Films,” 2024 American Conference on Neutron Scattering Conference, Knoxville, TN, June 2024.

2. Hugh Schortt, The Minerals, Metals & Materials Society, TMS Best Paper Contest – Graduate – Worldwide 1st Place recipient (TMS 2025 Annual Meeting). Awarded in June 2024.

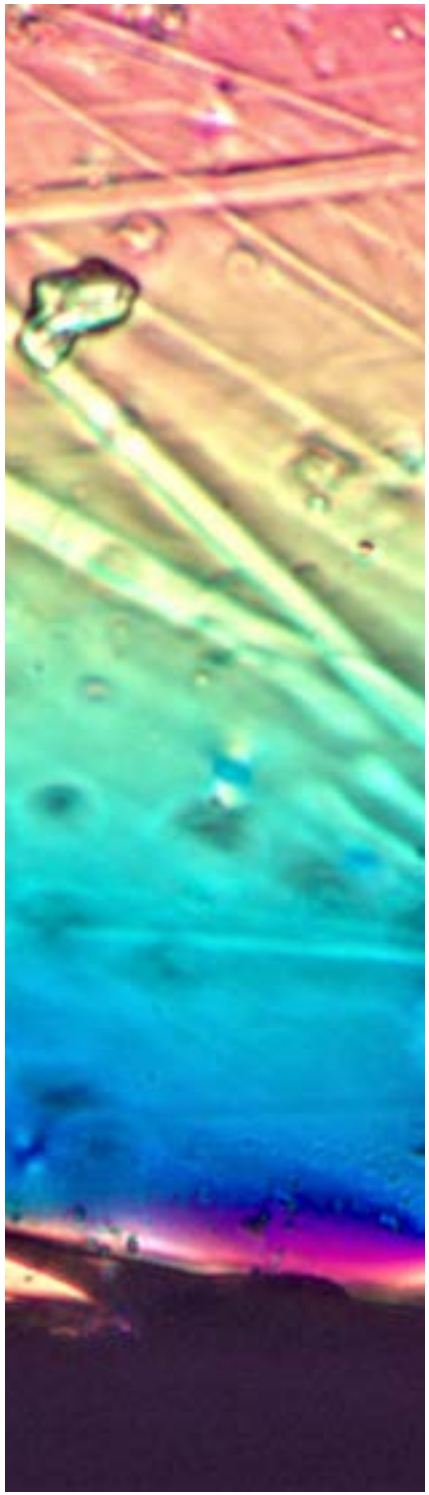
3. Sreya Paladugu, Graduate Researcher Poster Prize, Materials Research Society Spring Meeting, San Francisco, CA, Spring 2023.

4. Sreya Paladugu, Poster Prize, Neutron Sciences User Meeting, Oak Ridge, TN, Summer 2023

5. Justin Edaugal, "Digital Light Processing (DLP): 3D printing of polymer-based graphene oxide nanocomposites—Efficient antimicrobial material for biomedical devices". 1st Prize Undergraduate Research POLY Division, 2023 ACS National Meeting, Indianapolis, IN, March 2023.

Intellectual Property:

1. Ibrahim Abdullahi, Palani Jothi, Manashi Nath, Katharine Page, Sreya Paladugu, “Mesoporous rare earth catalysts for water splitting and carbon dioxide reduction,” United States Provisional Patent Application: 63/529,286, Filing Date: July 27, 2023.



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