CENTER FOR MATERIALS PROCESSING

2016 - 2017 Annual Report

TICKLE COLLEGE OF ENGINEERING

CENTER FOR MATERIALS PROCESSING

Center for Materials Processing
Annual Report 2017

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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.

THE UNIVERSITY OF TENNESSEE KNOXVILLE

CENTER FOR MATERIALS PROCESSING

Executive Summary

A key component of the CMP Mission is the support of teaching and research in areas where materials processing plays a significant role. One of the cornerstones of Materials Science and Engineering is the relationship between processing, structure on various scales, and resulting properties including electronic, magnetic, mechanical, optical, physical, and thermal. CMP funds are focused on supporting graduate and undergraduate students in several disciplines who undertake research in the various aspects of the processing, structure, and properties relationships. The CMP works as an advocate for the field of materials processing on many levels, including recruiting outstanding future students to study and work in materials processing related fields.

In addition to partially or fully supporting student assistantships through stipends, the CMP sponsors several poster competitions throughout the year where awards are in the form of travel support allowing students to present research and represent Tennessee at professional conferences. Matching funds are provided for supporting ongoing or developing new programs and making state-of-the-art instruments and equipment that relate to materials processing available to university and industrial partners.

Current areas of specific interest to the CMP include additive manufacturing, crystal growth, scintillation detectors, nuclear materials, energy related materials, and micro- and nano-fabrication of electronic devices. Another important component of the CMP mission is transferring improvements to the applied sector. During the last year, the work of the CMP Industrial Advisory Subcommittee and the CMP Administration was realized with the new CMP Facilities Level Membership agreement. We are looking forward in the future to improving and making the CMP full and associate level industrial memberships more attractive to potential industrial members. One of the exciting events of the year was the CMP's participation in the Oak Ridge Chapter of ASM's Industry Night, featuring small technical businesses from around East Tennessee and beyond.

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Dr. Claudia J. Rawn

CMP Director

Dr. Claudia Rawn joined the Center for Materials Processing (CMP) in early January 2012 as the associate director and replaced Dr. Carl McHargue as the director in July of 2012 upon his retirement.

Claudia Rawn received her B.Sc. in Materials Engineering from Virginia Polytechnic Institute and State University (Virginia Tech), her M.Sc. in Chemistry from George Mason University, and her Ph.D. in Materials Science and Engineering from the University of Arizona. Prior to starting her graduate studies, she worked as a materials engineer in the Ceramics Division of the National Institute of Standards and Technology (NIST) performing experimental phase equilibria studies. After obtaining her Ph.D., she moved to Ljubljana, Slovenia, and became a postdoctoral research associate in the Ceramics Department at the "Jožef Stefan" Institute where she used both solid-state techniques and single crystal growth to synthesize a variety of oxide materials as candidate materials for wireless communications applications. In addition to synthesizing the materials, she used X-ray and neutron powder diffraction data to determine details of the atomic structure and correlate those details with improvements of key physical properties. Dr. Rawn returned to the United States and joined the Materials Science and Technology Division (MSTD) at Oak Ridge National Laboratory (ORNL) as a postdoctoral fellow of the Oak Ridge Associated Universities (ORAU). She was promoted to a research staff member and senior research staff member during her years at ORNL. In 2001, she became a joint faculty member with the Department of Materials Science and Engineering (MSE) at the University of Tennessee, Knoxville. In December of 2013, Dr. Rawn retired from ORNL and began concentrating all of her efforts at the University of Tennessee as an associate professor in the Materials Science and Engineering Department and director of the Center for Materials Processing.

Since joining the MSE Department, she 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 the MSE Department in 2005. For the last five years, she has been an instructor for Tennesssee's Governor's School for Engineering. She has served as the Chair of the Undergraduate Affairs Committee in the MSE Department and is on the University of Tennessee's Undergraduate Research Advisory Committee. Dr. Rawn's 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. She has co-authored over 90 technical publications. Dr. Rawn is a fellow of ASM International and served on the United States National Committee for Crystallography from January 2009 to December 2015, for the last three years serving as the secretary. She is a member of several professional societies including ASM International, the American Crystallographic Association, the Neutron Scattering Society of America, and the American Ceramic Society. She has also held several positions in the Executive Committee of the Oak Ridge Chapter of ASM (ORCASM), including chairperson. Under her direction, ORCASM started hosting their local Materials Camps. In 2010, ORCASM started hosting Teacher Materials Camps, and she has served as co-chair for both the student and teacher materials camps. Dr. Rawn is the director of the Research and Instructional Strategies for Engineering Retention (RISER) at the University of Tennessee that focuses on engineering retention through offering research opportunities and emphasizing engineering applications or mathematics. She is also the PI and site director of the UTK site of the Manufacturing and Materials Joining Innovation Center (Ma^2JIC), funded by the National Science Foundation (NSF) and industrial memberships. In April 2016, Dr. Rawn was honored with the Nancy and Leon Cole Outstanding Teacher Award, an annual teaching award presented to an outstanding engineering faculty member in the UTK College of Engineering. The award has been awarded annually for over 20 years with the intent to reward outstanding teaching in engineering and to encourage teaching at a high level of excellence so future engineers have the necessary skills to solve the world's major problems. Dr. Rawn was also recognized with the Tickle College of Engineering (TCE) Outstanding Faculty Advisor Award in 2017.

CMP Supporting Staff

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 (Ma^2JIC) University of Tennessee, Knoxville site. Ms. Boyce has been working within various university systems since 1995 and joined the University of Tennessee, Knoxville in June 2011.

Chris Moore is the communications specialist for the CMP and the RMC. Mr. Moore attended Middle Tennessee State University (MTSU) and joined the University of Tennessee, Knoxville in September of 2013.

Amber White is 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.

2016 – 2017 CMP Advisory Committee Members

Established in early 2014, the CMP Advisory Committee works with the CMP Director to identify various areas of research that the CMP can advocate for and invest in for the future. In early 2016, a second CMP Advisory Committee, smaller in size and made up entirely of industrial members, was established. Both CMP Advisory Committees and the CMP Director 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.

Dr. Khalid Alshibli
Professor – Civil and Environmental Engineering
College of Engineering
University of Tennessee, Knoxville

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

Dr. William Dunne
Associate Dean – Research and Technology
College of Engineering
University of Tennessee, Knoxville

Dr. Roger England
Industrial Committee
Director – Advanced Manufacturing Technology and Materials Engineering
Cummins, Inc.

Dr. Neal Evans
Industrial Committee
Senior Materials Scientist
Proton Power, Inc.

Dr. Veerle Keppens
Professor and Head, Materials Science and Engineering
Director – Joint Institute for Advanced Materials
College of Engineering
University of Tennessee, Knoxville

Ms. Beth Matlock
Senior Materials Engineer
Technology for Energy Corporation (TEC)

Dr. Charles Melcher
Director – Scintillation Materials Research Center
College of Engineering
University of Tennessee, Knoxville

Dr. Andrew Payzant
Engineering Materials Group Leader
Chemical and Engineering Materials Division
Neutron Sciences Directorate
Oak Ridge National Laboratory

Dr. Kurt Sickafus
Professor – Materials Science and Engineering
College of Engineering
University of Tennessee, Knoxville

Mr. Trevor Toll
Research Engineer
Analysis and Measurement Services (AMS) Corporation

Dr. Peter Tortorelli
Acting Director – Materials Science and Technology Division
Physical Sciences Directorate
Oak Ridge National Laboratory

Dr. Steven Zinkle, Chairperson
Governor's Chair for Nuclear Materials
Professor – Nuclear Engineering
College of Engineering
University of Tennessee, Knoxville

Center for Materials Processing Partnerships

Oak Ridge National Laboratory (ORNL) is managed by UT-Battelle, LLC, a limited partnership between the University of Tennessee and Battelle Memorial Institute. Within the College of Engineering and especially within the Department of Materials Science and Engineering (MSE), many of the faculty members either have joint appointments between the two institutions or have strong research collaborations with ORNL. ORNL is home to several Department of Energy (DOE) Office of Science national scientific user facilities where UT faculty and their students conduct research, including the Spallation Neutron Source (SNS), the Center for Nanophase Materials Science (CNMS), and the High Flux Isotope Reactor (HFIR). Drs. Peter Tortorelli and E. Andrew Payzant from ORNL both serve on the CMP Advisory Committee.

The TennXC grows crystals that can be licensed to the scientific community. The majority of crystals are 2D semiconductor crystals that have applications in areas of dry lubrication, energy storage, nitrogen monoxide sensors, and flexible electronics. An important aspect driving the interest in these crystals is the fact that they can be reduced down to incredibly thin layers of atoms and used to build nanoelectronic devices.

The Materials Properties Council (MPC) and the Welding Research Council (WRC) are not-for-profit technical organizations that have provided long term, ongoing support to the CMP. MPC and WRC are each composed of technical committees whose members support a variety of research and development activities essential to writing technically based codes and standards concerning design, life assessment, safety, and reliability of pressure equipment. Essential to the respective activities of MPC and WRC is gathering technical data relevant to the performance of welded equipment in adverse environments and advancing welding and joining technology of new materials. The membership fees of MPC and WRC have for many years supported graduate and undergraduate research assistants in the Materials Joining Group (MJG) headed by Dr. Carl Lundin at the University of Tennessee. Over the years, the MJG has provided MPC and WRC with information essential to alloy development and metallurgical failure assessments, especially in regard to the behavior of welds under adverse conditions and for the development of new alloys. Specifically, the goals of the many studies conducted have been to aid the petroleum, chemical, and electric power industries in fabrication of welds and prevention of failures of pressure vessels and piping in high temperature, high-pressure, and hydrogen services.

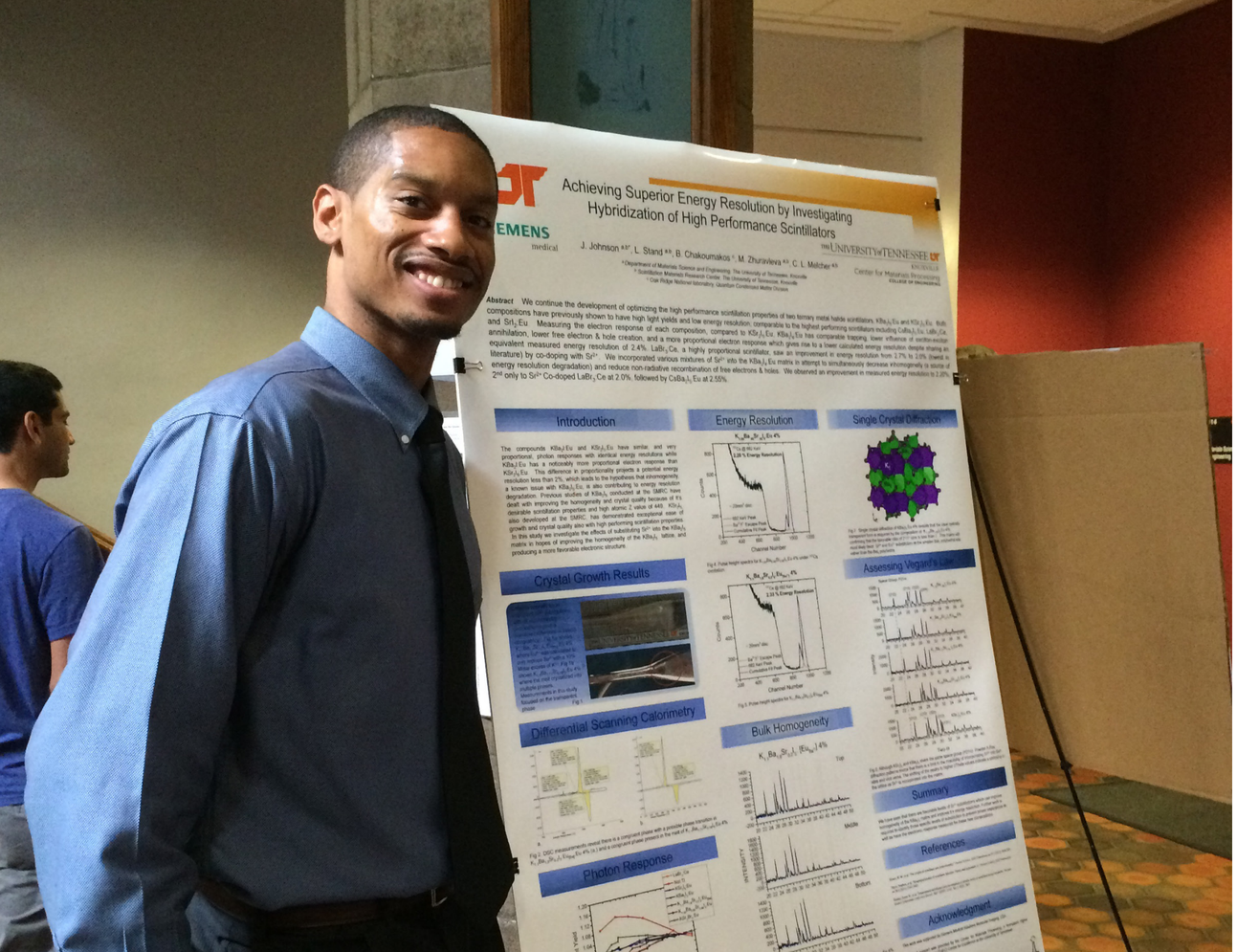
Center for Materials Processing Partnerships

The metallographic procedures developed and studies conducted by the MJG enable better understanding of the factors that govern the mechanical properties, design, and safety of high pressure components used in power and process plants worldwide. Dr. Martin Prager, Executive Director of MPC and WRC, often visits the University of Tennessee, Knoxville campus to discuss the progress of the MJG research with Professor Lundin and the MJG graduate students.

The Scintillation Materials Research Center (SMRC), located in the Tickle College of Engineering, is a unique facility dedicated to the research and development of new and innovative scintillator materials for radiation detection. The SMRC is one of the most active crystal growth groups located in a US university and synthesizes and characterizes a wide variety of scintillators, from high density materials that are well-suited for application in the area of medical imaging to low-density materials well-suited for neutron detection. The SMRC is engaged in a wide range of research activities and boasts many capabilities, including materials purification, handling and processing hygroscopic materials, crystal growth, and a wide range of scintillation and physical characterization techniques. Dr. Chuck Melcher, Director of the SMRC, serves on the CMP Advisory Committee.

The Joint Institute for Advanced Materials (JIAM) holds the distinction of being the only joint institute housed on the UT campus, specifically the new UT Cherokee Farm campus. The construction of the $30 million facility was completed in FY17 and many of the CMP supported graduate students and faculty work in new laboratories at the JIAM. Research activities at the JIAM focus on a variety of materials synthesis techniques and advanced characterization methods often requiring sensitive instrumentation and highly qualified personnel. Dr. Veerle Keppens, the JIAM Director, serves on the CMP Advisory Committee.

The CMP is located within the Tickle College of Engineering (TCE) and endeavors to collaborate with all departments within the TCE that undertake materials research. The mission of the CMP is closely aligned with activities pursued by the TCE Department of Materials Science and Engineering (MSE), and many of the undergraduate and graduate research assistants supported by the CMP are MSE students. Additionally, the CMP partially supports several strategic technical staff members that assist many of the MSE faculty and students in the areas of safety, microscopy, electronics, and machining. This support makes the partnership between the CMP and the MSE Department strong and productive for both parties.



Undergraduate Spotlight

Jesse Johnson, now a graduate student at the University of Florida, recently graduated magna cum laude with a bachelor's degree in Materials Science and Engineering from the University of Tennessee, Knoxville. Mr. Johnson joined the Volunteer family as a transfer student from Iowa State University, originally interested in pursuing a degree in chemical engineering. During his time in high school, he excelled in STEM classes, took all of the offered AP classes, and found he had a natural inclination for chemistry, which led him to be interested in chemical engineering. However, once he arrived at the University of Tennessee and completed the Engineering Fundamentals curriculum, he surprisingly found himself at an existential crossroads. With every intention of continuing a degree in chemical engineering, he ultimately chose to join the Materials Science and Engineering program from nothing more than a gut feeling.

While his performance in the classroom was exemplary, Mr. Johnson credits much of his success to his time spent as an undergraduate research assistant at the Scintillation Materials Research Center (SMRC). His first research experience was a summer experience with the Department of Energy through the Science Undergraduate Learning Internship (SULI) program. His project focused on the crystal growth of up-conversion nanocrystals that are used as biological fluorescent labels. Mr. Johnson's research led to his first two co-authored publications and, ultimately, great talking points when he met Dr. Chuck Melcher, the director of the SMRC, while working a shift at Tomato Head (Dr. Melcher's favorite restaurant). Mr. Johnson went on to conduct research at the SMRC for over three years until he graduated in May 2017. While at the SMRC, Mr. Johnson became drawn to learning techniques in X-ray diffraction, firmly grasping the importance that structural characterization contributed to forming strategies for manipulating the structure-properties-processing-performance paradigm. This led him to also be mentored by Dr. Bryan Chakoumakos at the Spallation Neutron Source (SNS), with whom the SMRC frequently collaborates. By the end of his undergraduate career, Mr. Johnson has co-authored nine publications and won numerous poster competitions at both the local (including several sponsored or co-sponsored by the Center for Materials Processing) and national level. His final thought on his time at the University of Tennessee is that his success is not only his own, but that of all who helped, mentored, taught, and put up with him along the way.

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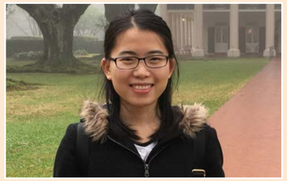
John Bohling is a Ph.D. candidate in the Department of Materials Science and Engineering working with the Materials Joining Group (MJG) under the direction of Dr. Carl Lundin. Prior to receiving his B.S. degree in Materials Science and Engineering from the University of Tennessee in December 2010, Mr. Bohling worked in the MJG for several semesters as an undergraduate research assistant, culminating in an undergraduate thesis with Dr. Lundin entitled "Development of Optimum Welding Procedures for In Situ Weld Replacement for Main-Steam Piping."

Mr. Bohling has been involved in several research areas with the MJG, including microstructural characterization of creep-damaged, submerged-arc weldments in 1.25Cr-0.5Mo steels for steam piping, microstructural characterization and investigation of Type IV creep behavior of 9Cr-1Mo-V-Nb (P91) steels, weldability investigations of high entropy alloys (HEAs) such as AlxCoCrFeNi, and high temperature hydrogen attack of C-0.5Mo steels. For his M.S. degree, his work centered on a 20Cr-32Ni-1Nb heat-resistant austenitic stainless steel casting alloy (ASTM A351 Grade CT15C), which is used for outlet headers and manifolds in hydrogen reforming furnaces. Weldability problems with this alloy have been reported during repair welding of service-exposed material, primarily as the occurrence of cracking in the base metal heat-affected zone (HAZ). Mr. Bohling's research focused on Gleeble hot ductility testing together with microstructural characterization to evaluate the HAZ liquation cracking susceptibility of CT15C materials provided by an industry sponsor (Air Products and Chemicals Inc.). Mr. Bohling successfully defended his M.S. thesis in July 2016; his M.S. committee included Drs. Lundin, Choo (MSE), and McHargue (MSE). His M.S. thesis was entitled "Evaluation of the Potential for Weld-Related Cracking in Cast 20Cr-32Ni-1Nb Heat-Resistant Stainless Steel." Having passed his Ph.D. qualifying exams and completed the necessary coursework, Mr. Bohling will continue working toward his Ph.D. under the guidance of Dr. Lundin.

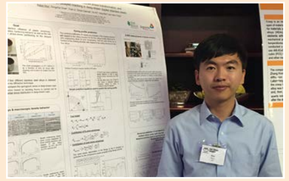
During his time with the MJG, Mr. Bohling has also worked as a teaching assistant in several undergraduate classes taught by Dr. Lundin, including Welding Metallurgy, Materials Processing, and the two-semester MSE senior course sequence, Materials Selection in Design (required for obtaining a minor in MSE) and Materials Selection (the MSE Capstone course). Mr. Bohling's duties have included course organization and planning, proctoring and grading exams and reports, setting up laboratory sessions, and assisting the students with planning of experiments, sample preparation, and microstructure analysis for their group projects. In 2013, he received the MSE Departmental Student Award for Excellence in Service in recognition of his efforts.



Shuying Chen is a fourth year graduate student in the Materials Science and Engineering (MSE) Department at the University of Tennessee, Knoxville (UTK). Prior to joining UTK, Ms. Chen studied the mechanical properties of the refractory high entropy alloy (HEA) AlxNbTiMoV at the University of Science and Technology in Beijing, China, receiving her Master of Science degree in 2014. Ms. Chen's research is mainly focused on the serrated flow mechanism and fatigue behavior in $Al_{0.5}CoCrCuFeNi$ and TaNbHfZrTi HEAs under the direction of Prof. Peter Liaw. The temperature and strain rate effects on the compression, tension, fracture stress, and creep-life experiments are currently being investigated to establish statistical models for serration behaviors in $Al_{0.5}CoCrCuFeNi$ HEAs. Characterization tools, including scanning electron microscopy (SEM) with electron backscatter diffraction (EBSD), transmission electron microscopy (TEM), atom probe topography (APT), and high-energy synchrotron X-ray diffraction and neutron diffraction, are being employed for studying phase transformations and determining the structure of HEAs down to nano-scale, such as nano-particles, slip bands, twinning, and interactions of dislocations. These characterization studies combined with supporting computational modeling could potentially provide in-depth mechanisms for plastic deformation and precursors to fracture of serrations within these application-attractive materials. Ms. Chen has presented her research at an MSE departmental seminar in 2015 and the TMS 144th, 145th, and 146th Annual Meetings.

Funded Graduate Students

Bernadette Cladek is a third year Ph.D. student working with Dr. Claudia Rawn the University of Tennessee, Knoxville (UTK) and is jointly supported by the Center for Materials Processing and a University of Tennessee's Chancellor's Fellowship. Prior to entering UTK, she received a B.F.A. in Crafts from the University of the Arts in 2011 and a B.S. in Ceramic Engineering with a minor in Chemistry from the New York State College of Ceramics at Alfred University in 2015. During Ms. Cladek's time at Alfred University, she participated in undergraduate research projects involving atomistic computer simulation, ceramic powder processing and characterization, and X-ray diffraction and scattering. While at Alfred University, she also participated in a co-op at Kohler Co. Ms. Cladek's research interests include crystallography and diffraction (both X-ray and neutron) techniques, and her graduate research is focused on using in situ neutron diffraction to investigate the decomposition of mixed-gas hydrates. Natural hydrates are a potential source for methane and CO_2 sequestration, and Ms. Cladek is interested in the effects of mixing gases, such as carbon dioxide with methane, on the temperature and pressure conditions of decomposition. Ms. Cladek assembled a hydrate-synthesis lab, which is included in the new Joint Institute for Advanced Materials (JIAM) ceramics processing laboratory. She performed in situ total neutron scattering experiments on synthesized CH_4 and CO_2 hydrates at the Spallation Neutron Source and is producing complimentary classical molecular dynamics simulations of the systems. These structure and thermodynamic studies will provide a more comprehensive understanding of CO_2-CH_4 solid solutions, exchange kinetics, and implications on hydrate structure to better inform the production of CH_4-CO_2 exchange. During the year, Ms. Cladek has presented her research at the Materials Science & Technology (MS&T) Technical Meeting and Exhibition in Salt Lake City, Utah (poster format), and locally at both the Oak Ridge Chapter of ASM (ORCASM) Student Night (poster format) and the 2017 Joint Nanoscience and Neutron Scattering User Meeting (oral format).



Peijun Hou joined Dr. Hahn Choo's research group as a Ph.D. candidate in the Department of Materials Science & Engineering at the University of Tennessee, Knoxville (UTK), in August 2014. Prior to coming to UTK, Mr. Hou received his Bachelor of Engineering in civil engineering in 2009 and his Master of Science in engineering mechanics in 2014 from Dalian University of Technology, China.

At UTK, Mr. Hou's research is focused on modeling the fluid dynamics of the dynamic recrystallization processes in Mg alloys during friction stir welding. Additionally, he is currently working on an industrial project involving the investigation of texture development and phase transformation in stainless steel alloys when manufactured by deep drawing processes. The latter research project has required experimental in-situ synchrotron

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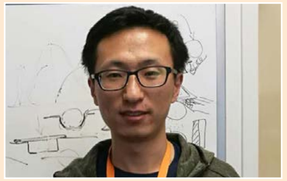
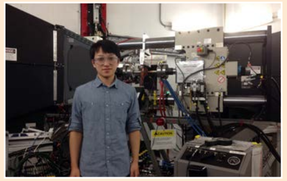
X-ray and neutron diffraction data that were collected at the Advanced Photon Source (Argonne National Laboratory) and the Spallation Neutron Source (Oak Ridge National Laboratory), respectively. Mr. Hou is currently analyzing the experimental data and is planning a manuscript on the interplay between microstructure, texture evolution, transformation kinetics, and load partitioning on delayed cracking in deep-drawn stainless steel alloys.

Chanho Lee is a third-year graduate student in the Department of Materials Science and Engineering at the University of Tennessee, Knoxville (UTK) under the direction of Dr. Peter Liaw. Mr. Lee received his M.Sc. from Sejong University, Korea, in Materials Science and Engineering (MSE) in 2013. During that time, he published four papers for which he was either author or co-author and received one patent. Since joining the UTK MSE Department in 2014, Mr. Lee has been working on the investigation of the microstructural evolution and mechanical properties of refractory high-entropy alloys (HEAs), especially the influences of additional elements (e.g. Bi, Mg, and Sn) in Ti-Fe ultrafine eutectic alloys. He is an expert in the fabrication of metal alloys such as HEAs and bulk metallic glasses using arc-melting suction casting equipment. Mr. Lee is using in-situ neutron diffraction on the VULCAN instrument at Oak Ridge National Laboratory's (ORNL) Spallation Neutron Source (SNS), for an in-depth understanding of the mechanical behaviors demonstrated by his modified refractory HEAs. He is also performing complementary nano-scale microstructure characterization using atom probe tomography (APT) at the Center for Nanophase Materials Science (CNMS) at ORNL. Mr. Lee is currently preparing a publication with the title of "Microstructural Evolution and Mechanical Properties of Single BCC NbTaTiV Refractory High-entropy Alloys after Thermal Treatment for High-Temperature Applications" and has another two papers planned. In 2016, Mr. Lee presented at the CNMS user meeting in 2016 and was recognized with a poster presentation award. Mr. Lee and Dr. Liaw are co-authors on the paper "Design of Light-Weight High-Entropy Alloys" that is published in the open access journal Entropy. Mr. Lee's goal is to combine in-depth studies of fundamental materials science and engineering with the development of new HEAs, ultimately leading to the discovery of advanced materials with superior mechanical properties.



Yongtao Liu is a second-year Ph.D. student in the Materials Science and Engineering Department at the University of Tennessee, Knoxville (UTK) working with Dr. Bin Hu. Mr. Liu received his Bachelor of Science from Nankai University's (Tianjin, China) College of Chemistry in 2014. Prior to coming to UTK, Mr. Liu was a master's degree candidate in the Institute of Polymer Science at Nankai University. He has published two articles, "A simple small molecule as an acceptor for fullerene-free organic solar cells with efficiency near 8%" and "A-D-A-type small molecular acceptor with one hexyl-substituted thiophene as π bridge for fullerene-free organic solar cells" in Journal of Materials Chemistry A and Science China Materials, respectively. His current research focuses on the synthesis and characterization of hybrid organic-inorganic perovskites with efforts to modulate their optoelectronic properties.

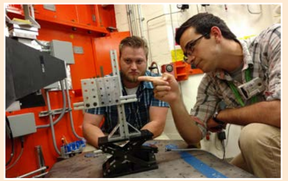


Tingkun Liu is a third-year graduate student in the department of Materials Science and Engineering (MSE) at the University of Tennessee, Knoxville. Mr. Liu previously received his M.S. from Beijing Institute of Technology in 2013. After working two years as an assistant researcher in Shanghai Synchrotron Radiation Facility, Shanghai Institute of Applied Physics, Mr. Liu joined Prof. Yanfei Gao's group. While working with Dr. Gao, Mr. Liu has focused on experimental and computational studies of the mechanical behavior of high entropy alloys (HEAs) and bulk metallic glasses (BMGs). In his simulation studies, finite element crystal plasticity analysis has been conducted to understand the evolution of lattice strain under uniaxial loading of single-phase and dual-phase HEAs using the commercial software package ABAQUS.

Mr. Liu has recently published two papers in the journals Materials and Design and AIP Advances. In his publications, Mr. Liu has reported on the work hardening evolution and twinning activity of the CoCrFeNiMn HEA using ex-situ neutron diffraction and electron backscatter diffraction (EBSD) characterization techniques. He has also studied elastically or plastically induced structural heterogeneities in Zr-based BMGs by nanoindentation pop-in tests. Mr. Liu participated in the third annual "Modern Methods in Rietveld Refinement for Structural Analysis" school that was held from June 18-23, 2017, at Oak Ridge National Laboratory in close partnership with the Shull-Wollan Center Joint Institute for Neutron Sciences (University of Tennessee and ORNL) and Bruker-AXS. He was selected for one of the competitive spots and attended the 2017 National School on Neutron & X-ray Scattering from August 5-19, 2017, which was held at Oak Ridge National Lab (ORNL) and Argonne National Lab (ANL). Both activities enhanced his understanding of the fundamentals and applications of neutron & X-ray scattering techniques.

In the future, Mr. Liu will continue to work on the deformation behaviors of HEAs and BMGs. Specifically, he will conduct in-situ tensile neutron diffraction experiments to compare the deformation texture and twinning activities of HEAs with different carbon concentrations. Mr. Liu also plans on continuing research into the irradiation effects on the deformation behavior of BMGs.

Funded Graduate Students



Robert Minneci is a second year Ph.D. candidate in the department of Materials Science and Engineering (MSE) at the University of Tennessee, Knoxville (UTK) working with Dr. Claudia Rawn. The bulk of Mr. Minneci's financial support is through NASA in its role as an Industrial Advisory Board member of the Manufacturing and Materials Joining Innovation Center (Ma²JIC). Within Ma²JIC, NASA helps to support research determining residual stresses that occur in additively manufactured builds with the goal of decreasing part failure during the building process. Prior to becoming a graduate student, Mr. Minneci earned his bachelor's degree in MSE at UTK with honors distinction in May 2016.

During his time as an undergraduate, he was a Higher Education Research Experience (HERE) intern at Oak Ridge National Laboratory (ORNL) in the polymers research division at the Manufacturing Demonstration Facility (MDF). Mr. Minneci worked with large- and small-scale thermoplastic printers and small-scale thermoset printers in order to perform composite fabrication and design. During his undergraduate career, Mr. Minneci was an undergraduate research assistant for Dr. Rawn and Mr. John Salasin through the CMP's synthesis laboratory, where he performed anionic clay research. Included in this research was wet chemistry synthesis, post processing at high temperatures and pressures, and characterization of the final product using X-ray powder diffraction. Mr. Minneci has served as a teaching assistant (TA) for the Tennessee's Governor's School for the Sciences and Engineering in both 2015 and 2017. He has also assisted with both the Tennessee's Science Olympiad and Materials Camp held at UT. Mr. Minneci is mentoring an undergraduate student, Mr. Jared Floyd, through a Veterans Research Supplement, funded through the National Science Foundation. Mr. Floyd assisted in data collection and sample preparation for a neutron experiment and will continue to

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assist Mr. Minneci with sample preparation, metallography, characterization, and future neutron studies.

Mr. Minneci's research interests lie broadly in additive manufacturing research and development and diffraction based research and characterization using both X-ray and neutron scattering techniques. His current research project involves working closely with staff from the Marshall Space Flight Center (MSFC) in Huntsville, Alabama, on the development of an additively manufactured copper-based alloy that is used by NASA for high temperature applications. He has conducted experiments (with more planned for the future,) at the Neutron Residual Stress Facility (NRSF2) beamline at ORNL's High Flux Isotope Reactor (HFIR). These experiments focus on determining the residual stresses of alloy builds that have experienced large temperature gradients during fabrication and shape and thermal mismatch between other alloys that make up the build. He is particularly interested in the residual stresses formed during the direct deposition of the copper alloy onto the Inconel alloy cladding.

Brianna Musicó is a second year graduate student in the Materials Science and Engineering (MSE) Department at the University of Tennessee, Knoxville (UTK). Ms. Musicó received her B.S. degree in Materials Science and Engineering from the University of Tennessee in August of 2016. Her previous undergraduate and graduate experience as a research assistant was in the Radiochemistry Center for Excellence studying the fabrication of uranium-based semiconductors as part of an effort for the Defense Threat Reduction Agency (DTRA) to design direct-conversion neutron detectors for applications aiming to counter weapons of mass destruction (WMD) applications. Her specific study was with the uranium trioxide system and investigation of electrical and material properties as a function of processing condition. These activities included ceramic powder processing and characterization, X-ray diffraction, grain size determination, and electrical resistivity measurements. During this time, Ms. Musicó mentored 5 interdisciplinary undergraduate students who worked as research assistants (some supported by the CMP), educating them on safe methods for ceramic radioactive material processing, handling, and characterization. She was a recipient of an MSE Travel Support in Spring 2017 that allowed her to attend and present a poster titled "Fabrication of UO_3 Pellets" at the 12th Pacific Rim Conference on Ceramic and Glass Technology in May of 2017.

Her current work is under the direction of Dr. Veerle Keppens and focuses on crystal growth and elastic moduli determination through resonant ultrasound spectroscopy (RUS).

During the 2016-2017 academic year, Ms. Musicó served as a graduate teaching assistant for the sophomore level introductory course in Materials Science. In the 2017-2018 academic year, she will be a graduate teaching assistant for the junior-level Principles of Materials Laboratory. As someone who enjoys outreach, organization involvement, and making others aware of what materials science has to offer, Ms. Musicó has served as a mentor for high school students during the annual Summer Materials Camp and a teaching assistant for the 2016 and 2017 Governor's School for The Sciences and Engineering, where she taught the ceramic processing laboratory. She is a member of the Society of Women Engineers and helped found the UTK Engineering Mentors Program. Ms. Musicó is also delighted to be serving as the 2017-2018 Vice President for the UTK chapter of the Materials Research Society.

Cody Pack is a Ph.D. candidate in the Department of Materials Science and Engineering at the University of Tennessee, Knoxville (UTK) working under the direction of Dr. Brett Compton. Mr. Pack received his B.S. in Chemistry from Lincoln Memorial University (LMU) in Harrogate, TN, where he performed research in polymer formulation. Prior to starting his graduate studies, he spent a year at Oak Ridge National Laboratory (ORNL) investigating the use and applications of strategic and critical materials in the National Stockpile. In the fall of 2014, Mr. Pack received his Master of Science degree in Materials Science and Engineering with his thesis titled "Protective Coating of Titanium Diboride Reinforcement Particulates for Improvement of Titanium Metal Matrix Composite Armor Systems."

Mr. Pack's current research lies in the area of direct ink write (DIW) 3D printing. His primary focus is on developing ceramic and metal powder-based feedstocks and on the printing and characterization of ceramic-metal composites with novel compositional architectures that impart unique properties. In DIW, a viscoelastic feedstock is deposited by extrusion through a small nozzle to build structural or functional components with complex geometry or compositional architecture. DIW is compatible with a broad range of feedstock materials, provided certain rheological requirements are met. DIW directly deposits material only where desired and is ideally suited for printing multi-material composites and novel hybrid architectures in which properties can be tailored in unique ways. Mr. Pack's specific research aims to produce and study new composite biomedical implant materials and advanced carbide composites for wear applications.

In the past year, Mr. Pack was the recipient of two travel grant awards from the National Science Foundation (NSF). The first award allowed him to present his research at the joint POWDERMET/AMPM 2017 conference in Las Vegas, NV, where he received a poster of merit award. The second award allowed him to present at the Solid Freeform Fabrication (SFF) Symposium in Austin, TX. Mr. Pack has also served as a graduate teaching assistant for a senior-level course on biomaterials and the junior-level Principles of Materials Laboratory. During recent summers, Mr. Pack has assisted with the Materials Teachers Camp, hosted by the Oak Ridge Chapter of ASM, and served as a mentor for local high school students attending the annual Materials Camp.

Funded Graduate Students

Stephen Puplampu is enrolled in the Ph.D. program in the Civil and Environmental Engineering (CEE) Department at the University of Tennessee, Knoxville (UTK). He is a graduate research assistant (GRA) working with Professor Dayakar Penumadu. Mr. Puplampu received his B.Sc. in Physics from the Kwame Nkrumah University of Science and Technology (KNUST) in Kumasi, Ghana, in 2008 and started his graduate studies at UTK in the spring of 2012.

His main areas of interest include using neutron diffraction for investigating mechanical properties of structural alloys and the effects of thermal stresses on these alloys. He is also interested in novel neutron detection techniques. With in situ neutron diffraction measurements, he seeks to better understand the post-yield anisotropic lattice plane response to mechanical loading. He is also collaborating with other scientists on the development of two-dimensional neutron detectors for diffraction measurements. The majority of his experiments were carried out at the High Flux Isotope Reactor (HFIR) at Oak Ridge National Laboratory (ORNL) using the Neutron Residual Stress Mapping Facility (NRSF2) instrument with Instrument Scientist Dr. Jeffery Bunn. Similar experiments were conducted at the E3 instrument at the Helmholtz Zentrum Berlin (HZB) in Berlin, Germany. Mr. Puplampu has experience with other techniques such as time-of-flight (TOF) diffraction (experiments conducted on the VULCAN engineering materials diffractometer at the Spallation Neutron Source (SNS) at ORNL) and three-dimensional imaging with X-ray and neutron tomography. Dr. Penumadu's and Mr. Puplampu's collaboration with Professor Larry Taylor and his group from the UTK Department of Earth and Planetary Sciences on the study of the internal texture of diamondiferous eclogites provides an example of the use of non-destructive 3D imaging techniques. Another example is the investigation of stress-induced damage in an aluminum alloy of structural interest. During the fall

Funded Graduate Students

of 2014, Mr. Puplampu worked as a teaching assistant for the graduate class Finite Element Applications for Engineering under the direction of Dr. Timothy Truster.

John Robert Salasin is beginning his fourth year as a graduate student in the department of Materials Science and Engineering (MSE), and he has been partially supported by the CMP since August 2014. He received his bachelor's degree in Physics with a nano-manufacturing concentration from Shippensburg University. Mr. Salasin also completed a certification in nano-manufacturing and fabrication from the Penn State University in 2012.

Mr. Salasin became acquainted with the MSE department during the summer of 2013 while participating in a Research Experience for Undergraduates (REU) site funded by the National Science Foundation (NSF) and hosted by the MSE department. The REU site was directed towards projects fitting within the areas related to the synthesis and characterization of advanced functional materials, and Mr. Salasin's research focused on synthesizing layered double hydroxides for magnetic applications. The next summer, Mr. Salasin participated in the Higher Education Research Experience (HERE) at Oak Ridge National Laboratory (ORNL) where he learned how to collect and analyze low temperature single crystal neutron and X-ray data for determining structural details of thermoelectric materials derived from natural analogs. Data were collected on instruments at the Spallation Neutron Source (SNS) and the High Flux Isotope Reactor (HFIR).

Mr. Salasin's broad research interests include energy materials, with a focus on synthesis of novel thermoelectrics, battery materials, and anion-exchange media. He has actively served as a mentor for some of the Research and Instructional Strategies in Engineering Retention (RISER) program's Undergraduate Research Assistants (URAs) and MSE undergraduate students who perform research supported by the CMP. His mentoring spans supervising them in the laboratory and helping them prepare posters to present their research. Together with the undergraduate students, Mr. Salasin is exploring synthesizing doped calcium aluminate nanocages via sol-gel and hydrothermal processes in an attempt to increase electrical conductivity through induced cage disorder. During the past year, Mr. Salasin presented his research at the Materials Science & Technology (MS&T) Technical Meeting and Exhibition in Salt Lake City, Utah, and locally at the Oak Ridge Chapter of ASM (ORCASM) Student Night, where he was recognized as one of the top three graduate student posters and at an MSE Departmental Seminar. Mr. Salasin is also the first author on the manuscript "Structure Property Relationships and Cationic Doping in $[Ca_{24}Al_{28}O_{64}]4+$ Framework: A Review" published in a special issue of Crystals focusing on the crystallography of functional materials.

In addition to his research and mentoring responsibilities, Mr. Salasin designed and implemented a high pressure/temperature synthesis laboratory in the Joint Institute for Advance Materials (JIAM). He has also worked to procure, install, and train students on equipment for the physical CMP processing laboratory, which includes new characterization equipment to analyze and process starting reactants before densification and to measure density after processing. His research demands that he use high-density samples for physical property measurements, so he is actively using a uniaxial high pressure/high temperature press for consolidation of samples. During FY17, Mr. Salasin was partially funded by one of the College of Engineering's ESPN Fellowships. In the fall of 2016, he also served as one of the teaching assistants for the senior/graduate level course offered on characterizing materials using X-ray powder diffraction. In the spring of 2017, he was the teaching assistant for one of the senior design projects that involved working with students to characterize SiC components in mechanical seals.

Brandon Shaver is a Ph.D. candidate in the Engineering Science program in the Department of Mechanical, Aerospace and Biomedical Engineering. Mr. Shaver completed his B.S. in Materials Science and Engineering in 2013 and an M.S. in Materials Science and Engineering in 2015, both from the University of Tennessee.

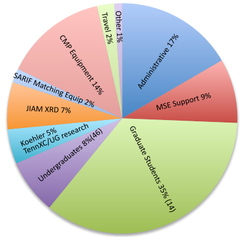
His Ph.D. research is focused on developing the role of microstructure and non-stoichiometry on the electrical properties of uranium dioxide (UO_2). This research formerly involved a study on UO_2 thin films created using wet chemical (sol-gel) solution deposition methods. Surface-doped single crystals with deposited metal contacts have also been investigated. This research is motivated by the pursuit of possible solid-state direct-conversion neutron detector technologies made of uranium oxides as a response to the helium-3 shortage. Such detectors would rely on the increased electron-hole pair production induced by the energy deposition of uranium's neutron-induced daughter products.

In the last year, Mr. Shaver presented his work at the American Vacuum Society's (AVS) 63rd International Symposium and Exhibition in Nashville, TN, and received a National Science Foundation travel award to attend the 12th Pacific Rim Conference on Ceramic and Glass Technology (PacRim12) in Waikoloa, HI. Mr. Shaver contributed a blog post describing his experience at PacRim12 that was featured on the American Ceramic Society's (ACerS) website. His photograph was also included in the August ACerS Bulletin.

Jeremy Tisdale is a fourth-year Ph.D. student in the Materials Science and Engineering Department at the University of Tennessee, Knoxville (UTK). Mr. Tisdale previously received his Bachelor of Science and Master of Science from the Materials Science and Engineering (MSE) Department at the University of Tennessee in May of 2013 and 2016, respectively. His master's research focused on magneto-optical behaviors at ferromagnetic/organic semiconductor interfaces. In June 2017, Mr. Tisdale published his first first-author publication in Organic Electronics titled "Magneto-optical behaviors at a 2-D ferromagnetic/organic semiconductor interface for singlet fission" based on his work during his master's research. Recently, he has changed his focus of research to single crystal methylammonium lead halide perovskites for applications in radiation detection, which is funded through the Department of Nuclear Detection Office under the Department of Homeland Security. Mr. Tisdale's role in the project is the synthesis and characterization of the single crystal material with a focus on the following: optimization of growth conditions for desired optical, electronic and mechanical properties; surface modification to tune the properties of the material; and application studies such as photodetection for a deeper understanding of the material properties.

Ben Wolf worked under the direction of Drs. Philip Rack and Jason Fowkles in the Materials Science and Engineering department at the University of Tennessee, Knoxville (UTK) studying the dewetting properties of metallic thin films. Self-assembled nanoparticles can be used as building blocks for a variety of applications such as tunable optics, nano-plasmonics, fuel cells, magnetics, catalysis, nano-photonics, transparent conductors, chemical and biological sensors, surface enhanced Raman spectroscopy, and quantum dots. Related to self-assembled nanoparticles, Mr. Wolf's research focused mostly on thin film dewetting on solid substrates via nucleation and growth of holes or spinodal dewetting. Prior to enrolling at UTK, Mr. Wolf attended the University of Virginia in Charlottesville, Virginia, where he received a B.S. in Nano-Medicine from the School of Engineering and Applied Sciences. During his undergraduate studies, Mr. Wolf fostered his interests in technology entrepreneurship.

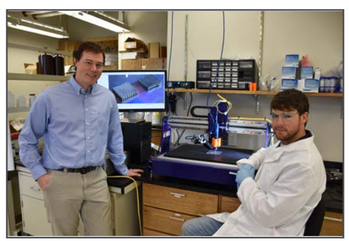
Program Overview and Accomplishments



FY17 Expenditures

The heart of the **Center for Materials Processing (CMP)** is composed of the graduate and undergraduate students along with their research funded by the CMP. Within this Annual Report, important elements include short professional biographies of the graduate students, fully or partially funded by the CMP, along with an undergraduate highlight (Jesse Johnson). Student Assistantships are supported by both State Appropriation funds and Industrial Memberships. When the FY17 expenditures are divided up in the categories of Administration, MSE Support (staff), Graduate Students (stipends, tuition, health insurance), Undergraduates (hourly wages), Koehler (supporting coordination of the undergraduate activities and the TennXC), JIAM X-ray Diffraction Facility, Scholarly Activity and Research Incentive Fund (SARIF) Equipment Matching, Equipment (for CMP students and Industrial Members to use), Travel (supporting graduate and undergraduate students to present at professional meetings), and Other (supporting and participating in the Oak Ridge Chapter of ASM's Industry Night), it shows the bulk of the CMP expenditures support students (43%)!

CMP graduate and undergraduate students are conducting research in the areas of ceramics, metal alloys, polymers, high entropy alloys (HEAs), composites and hybrid organic/inorganic materials. Forms of materials include bulk (polycrystalline), single crystals, and thin films. Studies of metallurgical materials include high temperature hydrogen attack of C-0.5Mo steels (**Mr. John Bohling, Dr. Carl Lundin**, and the **Materials Joining Group** (MJG) members), modeling the fluid dynamics of the dynamic recrystallization processes in Mg alloys during friction stir welding (**Mr. Peijun Hou** and **Dr. Hahn Choo**), using neutron diffraction techniques for investigating mechanical properties and thermal stresses on structural alloys (**Mr. Stephen Puplampu** and **Dr. Dayakar Penumadu**), and additively manufactured Cu based alloys for high temperature applications (**Mr. Robert Minneci** and **Dr. Claudia Rawn**). Several students are focused on ceramic processing and relating processing parameters to the atomic structure, microstructural evolution, and resulting electrical properties (**Ms. Brianna Musico, Mr. John Salasin**, and **Mr. C. Brandon Shaver**). In the area of HEAs, students performed both experimental and computational studies. This includes the utilization of characterization tools, such as scanning electron microscopy (SEM) with electron backscatter diffraction (EBSD), transmission electron microscopy (TEM), atom probe topography (APT), and high-energy synchrotron X-ray diffraction and neutron diffraction, to study phase transformations and determine the structure of HEAs down to the nano-scale. **Ms. Shuyin Chen** and **Dr. Peter Liaw** combine these characterization studies with supporting computational modeling in order to further their understanding of the mechanisms for plastic deformation and precursors to fracture. Another study in this area includes investigating the microstructural evolution and mechanical properties, especially the influences of additional elements, in refractory HEAs (**Mr. Chanho Lee** and **Dr. Peter Liaw**). There is also an effort to perform computational studies of the mechanical behavior of HEAs and bulk metallic glasses (BMGs) using finite element crystal plasticity analysis to understand the evolution of lattice strain under uniaxial loading of single-phase and dual-phase HEAs (**Mr. Tingkun Liu** and **Dr. Yanfei Gao**). Other studies include the weldability of HEAs (**Mr. John Bohling** and **Dr. Carl Lundin**). Students working with **Dr. Bin Hu** are active in the area of polymer synthesis and processing. While **Mr. Jeremy Tisdale** and **Mr. Yongtao Liu** both synthesize and characterize hybrid organic/inorganic perovskites, **Mr. Jeremy Tisdale** focuses on single crystal methylammonium lead halide perovskites for applications in radiation detection. In the area of composites research, **Mr. R. Cody Pack** and **Dr. Brett Compton** are perfecting the refinement of direct ink write 3D printing for producing new composite materials with applications in the areas of biomedical implants and wear applications. **Ms. Bernadette Cladek** has built the capabilities to synthesize gas hydrates, specifically gas hydrates with CH_4 and/or CO_2, and is combining experimental and computational studies to better understand the interactions between the guest molecules and the ice-like host framework. Gas hydrates are of interest to the energy (specifically gas and oil industry) and environmental communities. In the area of thin films, **Mr. Ben Wolf**, under the guidance of **Drs. Jason Fowkles** and **Philip Rack**, is using the Waviks photon delivery system on the Libra 200 TEM to study novel dewetted nanoparticle materials and arrays. More detailed information can be found in the student biographies.



The CMP awards full or partial travel support to students who have won local poster competitions so that they can attend professional meetings and present their research. This travel support acts as a way of disseminating the outstanding research by University of Tennessee students to a larger community, and the majority of travel funds were used in this manner. In FY17, the CMP financially assisted students in presenting their research at the Materials Science & Technology (MS&T) Technical Meeting and Exhibition in Salt Lake City, Utah, in October 2016 and the TMS Annual Meeting and Exhibition in San Diego, California, in late February 2017. At the latter meeting, two undergraduates that the CMP sponsored to attend were recognized for their outstanding posters. The Functional Materials Division recognized MSE graduating senior **Jesse Johnson** for his poster "Discovery of New Ternary Compounds and Scintillators of the A_4BX_6 Family," and The Structural Materials Division recognized MSE junior **Christina Cox** for her poster "Lifetime Prediction of FeCrAl Alloys through Statistical Modeling and High-Temperature Cycling Testing." Both of these efforts highlight collaborations between students and faculty in the MSE Department and **Oak Ridge National Laboratory**. Christina and Jesse, along with MSE Undergraduates **Nick Combs** and **Quentin Eustace**, were also part of the team that competed in the Materials Bowl. Other CMP travel support for students included **William (Will) Hoskins** as he presented his research on high temperature hydrogen attack in C-0.5 Mo steels at the International Hydrogen Conference in Moran, Wyoming. Two other travel supported activities included **Matthew (Matt) Loyd**, a graduate student working at the **Scintillator Materials Research Center**, attending the Radiation Detection for Nuclear Security Summer School held in Richland, WA, and five undergraduates attending Congressional Visit Days, held April 4-5 in Washington, DC, where the students participated in the training and networking sessions and visits with legislators and staffers.

Another mode of supporting students is through the CMP covering initial membership dues for students to join **Materials Advantage (MA)**. In FY17, nineteen student memberships at $30/student were funded by the CMP; in subsequent years, the students are expected to pay for their own membership dues. The UTK MA chapter gets a rebate of $5/member, and the students become members in the American Ceramic Society, Association for Iron & Steel Technology, ASM International, and TMS. As part of the membership, the students receive rotating print and monthly electronic subscriptions of *American Ceramic Society Bulletin, Iron & Steel Technology, Advanced Materials & Processes, and JOM*.

Program Overview and Accomplishments

Program Overview and Accomplishments

Dr. Rawn and CMP students continued to participate in outreach activities including **Materials Camp** and the **Tennessee Governor's School for Engineering** (see updates later in this volume). These events host high school students, mostly from Tennessee, that are academically gifted and interested in science, technology, engineering, and mathematics (STEM). These experiences help the students to evaluate majoring in a STEM discipline and, more specifically, in materials science and engineering. The eventual goal is to add more materials scientists and engineers as part of the STEM workforce. In FY16, we targeted some of the high performing students from these two activities and partnered with the **Department of Materials Science and Engineering** to offer joint scholarships. Several of the students have accepted the scholarships and arrived as freshmen in fall of 2017.

Annually, the **Office of Research and Engagement** seeks proposals for equipment to be funded through the **Scholarly Activity and Research Incentive Fund (SARIF)**. In FY17, the CMP matched funds for two of the successful proposals. **Dr. Philip Rack (Materials Science and Engineering)** acquired and installed a Waviks photon delivery system on the Libra 200 TEM. The system includes two optical channels that are focused onto the TEM sample for simultaneous electron beam imaging and photon irradiation. The instrument is housed in the **Joint Institute of Advanced Materials (JIAM) Electron Microscopy Facility**. In addition to SARIF and CMP funds, the Department of Materials Science and Engineering provided partial funds for acquiring the instrument. Part of the CMP support included funding for a graduate student, **Mr. Ben Wolf**, to encourage system use in the early stages and to support his thesis research. The second successful proposal was submitted by **Dr. Dayakar Penumadu (Civil and Environmental Engineering)** for a nano indentation system, iMicro, also located in the **JIAM** building. This is a depth sensing indentation instrument that can measure the material hardness (H) and the elastic modulus (E). This year, the CMP used new appropriations along with carry over funds to purchase several new pieces of equipment for CMP supported students and Industrial Members to use. The funds supported the purchase of an automatic sieve, high energy ball mill, particle sizer and counter, and a pycnometer. These instruments are all housed in the JIAM and in the near future will be featured on the CMP website along with information on how to access the equipment. CMP purchased equipment from past FY's, including a thermogravimetric analysis (TGA) system, differential scanning calorimeter (DSC), and a dilatometer, will also be listed on the website and available for access.

In past FY's, the CMP has helped to provide matching funds to acquire several instruments in the **JIAM Diffraction Facility**, part of the University of Tennessee's Core Facilities Program intended to provide access to high-end instrumentation, technical support, and expert consultation to users from across the university as well as external customers for a fee. The new PANalytical X'Pert3 MRD and Empyrean X-ray diffractometers were formerly housed and operational in the **Science and Engineering Research Facility (SERF)**. In late FY17, the instruments were relocated to their permanent home in the JIAM laboratories, specially designed for housing X-ray diffraction instruments. As part of the support for the JIAM Diffraction Facility, CMP funds were used for covering a percentage of **Dr. Maulik Patel's** salary and corresponding benefits; however, Dr. Patel accepted a position at the University of Liverpool in the United Kingdom in early 2017, and **Dr. Michael Koehler** (previously coordinating CMP undergraduate and TennXC activities) replaced him as the Facilities Manager. **Dr. Kurt Sickafus** serves as the JIAM Diffraction Facility's Director and Scientific Leader.

For many years, the **Oak Ridge Chapter of ASM (ORCASM)** sponsored an annual **Industry Night**. When the ORNL staff member responsible for coordinating the activity retired, the event went on a hiatus. In April 2017, **Ms. Beth Matlock**, a Senior Materials Engineer at the Knoxville location of **Technology for Energy Corporation (TEC)** and **CMP Advisory Committee** member, organized and implemented Industry Night 2017. The CMP was proud to be one of the Platinum Sponsors, along with Cummins Engine and FactSage, and to participate in the event by hosting a booth to provide interested local industry representatives with information about CMP Industrial Memberships and to reach out to these representatives to determine what type of equipment could be offered by the CMP that would be of interest to them.


Certificate of Appreciation

The Oak Ridge Chapter of ASM International Recognizes

University of Tennessee
Center for Materials Processing

For their sponsorship of East Tennessee Industry Night

April 18, 2017

2016-2017 Chapter Chair

Industry Night Organizer

JIAM ASM

Two programs supported by CMP funds in their initial stages are now mostly financially autonomous. In FY17, the University of Tennessee, Knoxville (UTK) site of the **Manufacturing and Materials Joining Innovation Center (Ma^2JIC)**, with research interests closely aligned with the CMP, continued to grow in both industrial support and students. **Dr. Claudia Rawn** and **Ms. Karen Boyce** are both partially supported by the **National Science Foundation (NSF)** funds allocated for the administration of the UTK site of Ma^2JIC. Another center that the CMP helped during its initial stages was the **Tennessee Crystal Center (TennXC)**, and the TennXC continued to sell crystals to outside institutions in FY17 (see Partnerships).

Goals/Future Plans

Historically, the CMP graduate student support was offered as matching funds for faculty submitting proposals to various funding agencies that requested matching funds as part of the financial package. In other cases, graduate student support was offered as components of startup packages and/or bridge funding between funded projects. Starting in the fall of 2017, the CMP will begin a competitive graduate student support program and will be soliciting proposals for positions beginning in January 2018. This support is for discrete projects related to materials processing and will focus on outcomes related to the projects. The CMP hopes to expand financial support to a greater number of graduate students by attracting Industrial Memberships.

In FY17 Dr. Michael Koehler moved full time to be the facility manager of the Joint Institute of Advanced Materials (JIAM) Diffraction Facility. He is replaced by Mr. Christopher Wetteland who will coordinate placing undergraduate students in research positions, as well as organizing the student poster competitions and events. Mr. Wetteland has a BS in Geology from Northeastern Illinois University, a MS in Ceramics and Materials Engineering from Rutgers University, and is working on his PhD in Earth and Planetary Sciences at the University of Tennessee, Knoxville (UTK). Prior to joining UTK, he worked at Los Alamos National Laboratory as a Staff Member. For the last four years, Mr. Wetteland has been a lecturer in the MSE Department where he has taught all three undergraduate laboratories and advised senior design projects. He has coordinated the renovation of the undergraduate laboratories including major changes in the curriculum. Mr. Wetteland has identified multiple local industries to partner with senior capstone design projects over the last several years. Due to his contacts/interest in the area of industrial relations, he also has been tasked with building new CMP Industrial Memberships.

Another change in FY18 will be the CMP's move from its long-time home on the fifth floor of East Stadium Hall to Ferris Hall, the current home of the Materials Science and Engineering (MSE) Department. This move will bring the CMP closer to the students and faculty it serves.

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Dissertation and Thesis Titles

Student: Maneel Bharadwaj
Degree: Doctor of Philosophy
Graduation Date: December 2016
Major Professor: Carl Lundin
Committee Members: Carl J. McHargue, Hahn Choo, Steven Zinkle
Title: Study of Graphitization in Carbon Steel Weldments for Remaining Life Assessment
Current Position: John Deere

Student: John Bohling
Degree: Master of Science
Graduation Date: August 2016
Major Professor: Carl Lundin
Committee Members: Carl J. McHargue, Hahn Choo
Title: Evaluation of the Potential for Weld-Related Cracking in Cast 20Cr-32Ni-1Nb Heat-Resistant Stainless Steel
Current Position: Ph.D Student

Student: Jingxuan Ge
Degree: Doctor of Philosophy
Graduation Date: May 2017
Major Professor: Gerd Duscher
Committee Members: Ramki Kalyanaraman, Haixuan Xu, Dibyendu Mukherjee
Title: Excitations of Quasi-Particles in Nanostructured Systems
Current Position:

Student: Adam Lindsey
Degree: Doctor of Philosophy
Graduation Date: August 2016
Major Professor: Mariya Zhuravleva
Committee Members: Charles L. Melcher, Eric D. Lukosi, Maulik K. Patel
Title: Material and Process Engineering for Bulk Single Crystal Growth of High Performance Scintillator Potassium Calcium Iodide
Current Position: Northrup-Grumman Synoptics

Student: Caitlin Taylor
Degree: Doctor of Philosophy
Graduation Date: December 2016
Major Professor: William Webber
Committee Members: Maulik Patel, Yanwen Zhang, Brian Wirth
Title: Helium Diffusion and Accumulation in $Gd_2Ti_2O_7$ and $Gd_2Zr_2O_7$
Current Position: Sandia National Laboratories, New Mexico

Materials Camp 2017

Professor Knucklehead was back at it berating graduates students, not following guidelines for responsible conduct of research, and using dubious (if any) safety practices all in hopes of discovering and perfecting his new super alloy for making him rich and famous. As with anyone

not showing respect to students, colleagues, ethical practices, and safety, Prof. Knucklehead met his demise. The week of June 5-9, 2017, fifteen high school students descended on the University of Tennessee, Knoxville (UTK) campus for one of the ASM Foundation's Materials Camps, partially sponsored by the Oak Ridge Chapter of ASM (ORCASM), to get to the bottom of what happened to Prof. Knucklehead. Included in the fifteen high school students were several from out of town/state and one repeat student. When found by his students, Prof. Knucklehead, knocked out next to his laboratory notebook, had hastily scribbled the message "The eagle sees at 10,000x" and left a quarter nearby. This started the materials related quest for the campers to come up with plausible solutions to whodunnit, how, and why. Every day at the end of camp, a new clue was provided that set the course for the next day's activities. Along the way, the students learned about why different microscopes specialize in imaging features at different length scales. They had a chance to modify hardness by cold rolling different brass samples with different Cu/Zn ratios. They also practiced several characterization techniques to test the mechanical properties (hardness and tensile testing) and X-ray powder diffraction (XRD) and energy-dispersive X-ray spectroscopy (EDS) to determine the compounds and elements, respectively, in different clues. Campers enjoyed smoothies made using solar power, and for those campers interested in biomedical engineering and biomaterials, they visited MABEline, the UTK SynDaver (synthetic cadaver). Mid-week, the campers visited Oak Ridge National Laboratory's (ORNL) Graphite Reactor, High Flux Isotope Reactor (HFIR), and the Spallation Neutron Source (SNS). On the last day of the camp, the campers made group presentations on what they believed happened to Prof. Knucklehead including, who did it and why. Judges Trevor Toll (Analysis, Measurement, Services Corporation (AMS)), Kurt Sickafus (ORCASM/UTK Materials Science and Engineering (MSE)), and Veerle Keppens (UTK MSE/Joint Institute for Advanced Materials (JIAM)) found that each presentation excelled in different areas and invited all three groups to the opening technical meeting of the Oak Ridge Chapter of ASM in September to give their presentation and discuss their experiences during the week.

As always, Materials Camp depended on many volunteers, and the Materials Science and Engineering (MSE) undergraduate (Caitlin Harpell, Sabrina Schwerzler, and Noah Strike) and graduate students (Camera Foster, Alex Hanson, Matt Loyd, Aaron Miller, Robert Minneci, Brianna Musico, and John Salasin) helped to mentor the three groups of campers. Demonstrations/hands-on activities of the JIAM microscopes were provided by Prof. Gerd Duscher, his graduate students, and Dr. John Dunlap. Students and staff helping with demonstrations and data collection included Bernadette Cladek (XRD), Willie Kemp (cold rolling and hardness testing), Zane Palmer (preparation of materials and organizing equipment in the MSE undergraduate laboratories), and Victor Tilstra-Smith (tensile testing). Dr. John Simpson discussed super hydrophobic materials with the campers, and Dr. Kurt Sickafus led the students in an interactive activity on salt. Claudia Rawn and Chris Wetteland were the organizers of Materials Camp 2017 and were assisted by Ashley Cole, an administrative assistant in MSE.

Governor's School for Engineering 2017

For the fifth year in a row, Materials Science and Engineering (MSE) participated in the Tennessee's Governor's School for Engineering (GSE). Twenty-eight Tennessee high school rising juniors and seniors were selected out of a large pool of applicants based on their outstanding academic achievements and recommendations. In 2015, Dr. George Siopsis, UTK Physics, took over the reigns as Director of the Governor's Schools for Science (GSS) and Engineering (GSE). The four-week schools are held on the University of Tennessee, Knoxville campus. Several prominent changes to the schools included that all GSSE students participate in Science, Technology, Engineering, and Mathematics (STEM) in Society and STEM Skills curriculums. The STEM in Society portion in 2017 was directed at having students apply STEM concepts to the environment. The STEM Skills portion introduced students to programming, 3D modeling and printing, mobile application development, engineering design, technical communications, data processing, image processing, microprocessor control, and robotics. During the afternoon, GSE students exclusively participated in lectures, seminars, and laboratories introducing them to fundamental materials science and engineering concepts. The students were broken into groups of nine or ten and rotated through three different laboratories: cold working of brass and mechanical testing; computer aided design (CAD) and 3D printing; and solid state synthesis of ceramics ($MgAl_2O_4$) followed by density measurements, scanning electron microscopy and X-ray diffraction. The laboratory experiences were designed to introduce students to metals, polymers, ceramics, biomaterials, and mechanical properties. The curriculum endeavored to expose students to the classic structure-properties-processing–characterization tetrahedron in a similar manner as taught to MSE undergraduates. This year, Claudia Rawn and Chris Wetteland organized and participated in the events with the help of teaching assistants (TAs) for the various laboratories, including graduate students Willie Kemp and Aaron Miller from the Mechanical, Aerospace, and Biomedical (MABE) Department and Robert Minneci and Brianna Musico from the MSE Department.

In addition to their laboratory experiences over the course of the month, the students were able to attend introductory lectures by faculty and students from various Tickle College of Engineering (TCE) departments and workshops led by the TAs on using Excel, preparing lab reports, and general communication skills. Undergraduate students supported by the Center for Materials Processing (CMP) presented research posters to expose the GSE students to the breadth of research conducted at UT and to prepare them for their final poster projects. The GSE students toured several of the large facilities at Oak Ridge National Laboratory (ORNL), including the High Flux Isotope Reactor (HFIR) and the Manufacturing Demonstration Facility (MDF). The month concluded with teams of students preparing posters on their various favorite laboratory experiences and presenting them to the students, faculty, and staff of the MSE Department. The same posters were presented at the GSSE closing ceremony for the public (parents and siblings!) to view and ask questions.

From left: Robert Sellmer, Jordan Sutton, Will Hoskins, Jedidiah Long, Austin Thomas, Jesse Johnson, Daniel Kittsmiller, Bowie Benson, Nicholas Combs, Sid Barry, Samantha Medina, Corey Combs, Jose March-Rico, Joshua Seylar, James Brackett, Dylan Dozier, Paxton Jones, Alec Affolter, Austin Staub, Jared Smith, Daniel San Roman, Joshua Tharpe

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