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## A Message from the Interim Department Head



Greetings from the MME Department at CSM! As *Professor Ivar Reimanis* you peruse our newsletter,

you'll note the high level of activity from faculty, staff, and students. Furthermore, we have undergone and are still undergoing many positive changes. I continue to serve as interim Department Head while we search for a new Head. Our previous Head, Professor Mike Kaufman, has accepted the position of Dean of CSM's College of Applied Science and Engineering. Fortunately, he is just a building away.

Our undergraduate students continue to make international headlines in materials. They won the annual International Materials Bowl competition at the 2015 TMS conference in Orlando, Florida. If that wasn't enough, they came in third place for the first, annual TMS Bladesmithing Competition.

The MME faculty have received several key distinctions. Professor David Matlock has been named to the 2015 Class of Fellows by TMS. Professor Stephen Liu was awarded a Fulbright Distinguished Chair in Oil and Gas. Professor John Speer is the recipient of the J. Willard Gibbs Phase Equilibria Award. Professor Geoff Brennecka currently serves on the governing bodies of two international societies: The American Ceramic Society and the Ultrasonics, Ferroelectrics, and Frequency Control Society of IEEE. I encourage you to go to the MME website and check out the many other honors and awards bestowed on our faculty. Our undergraduate and graduate students have also been recipients of several awards from numerous organizations, including NSF, ASM, IEEE, SME, AWS, AVS, MS&T, and the CoorsTek Fellowship. Two students, Lee Rothleutner and Ginny Judge, serve as Student Board Members.

The Department is currently searching to fill two faculty positions. One is for the American Bureau of Shipping (ABS) endowed chair. The other is for an assistant professor level position. After serving 25 years on the Mines faculty, Professor Brajendra Mishra has announced his retirement this August; he will still remain technically active as the Kenneth G. Merriam Professor of Mechanical Engineering at Worcester Polytechnic Institute. Change is inevitable, but we'll use this change to keep getting stronger, especially in our core areas.

Have a great summer! Remember: if you are in Golden, please stop by to see us.

# Mines Professors Discover New Type of Fuel Cell That Could More Efficiently Power Your House

Contributed by Ryan  
O'Hayre

A team of two metallurgical and materials engineering professors and three mechanical engineering professors at Colorado School of

Mines has been awarded \$1 million through Advanced Research Projects Agency-Energy's Reliable Electricity Based on Electrochemical Systems Program to develop high-efficiency, medium-temperature fuel cells that can produce electricity from natural gases.

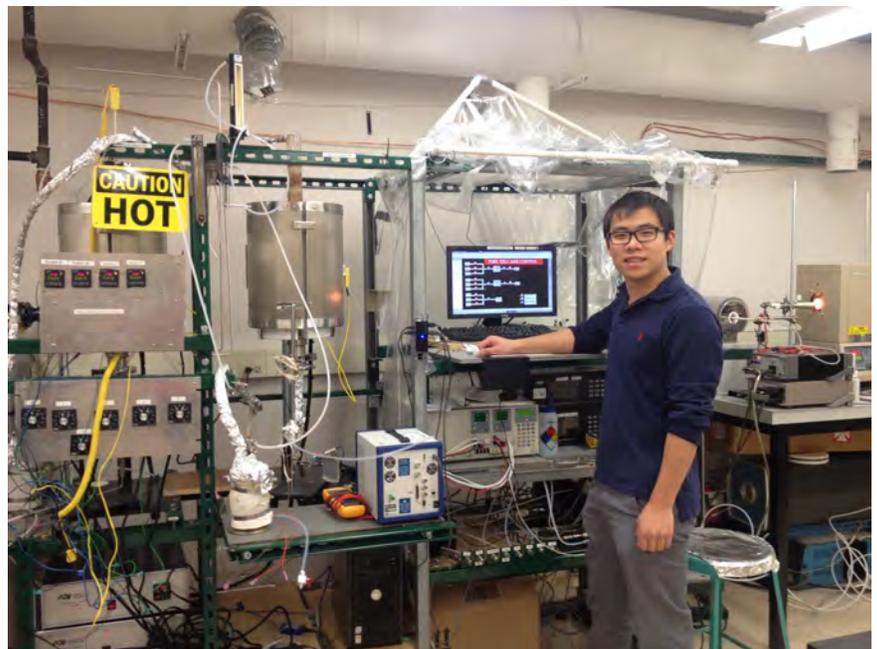
"Imagine you could replace the water heater in your home with a similarly-sized fuel cell unit that could also produce the electricity for your home," metallurgical and materials professor Ryan O'Hayre said. "You wouldn't need the electric grid anymore. This would be great for remote cabins, but also for people that want to "get off the grid."

O'Hayre, and Drs. Neal Sullivan, Robert Braun, Jianhua Tong and Sandrine Ricote, are working to address three opportunities for this new fuel cell technology: lowering the cost and temperature, and designing a fuel cell that can operate on a variety of fuels.

"I am hoping for the day when I can buy a natural-gas powered fuel cell for my home that could provide both my electricity and hot-water with an overall combined efficiency of more than 80 percent," O'Hayre said. "I am optimistic that this could happen before my baby daughter goes to college."

In the next two years, the team will demonstrate feasibility in a single-cell fuel cell device and then scale it to a larger size with multiple fuel cells connected together to produce a larger amount of power.

Sullivan will test durability and performance of the fuel cell stack, while Braun will build models to guide the optimal design of the system and estimate the cost and performance on a commercial scale. O'Hayre and Tong will develop new materials and synthesis processes to fabricate the "heart" of the fuel cell device.



Above: Chuancheng Duan, the doctoral student working on the fuel cell efficiency project, in his lab .

# CSM Material Advantage Club Update

## Mines student chapter remains active and outstanding

Contributors: Ryan Peck, CSMMAC President; Jerry Bourne and Kip Findley

The Colorado School of Mines Material Advantage Chapter (CSMMAC) has had another busy and productive semester of activities! We greatly appreciate the support of the CSM alumni and those who have given talks or tours to the chapter! We couldn't do it without you. A few of our recent highlights are presented here.

### CSMMAC Out and About!

#### TMS 2015

Twelve undergraduate members of our chapter attended this year's TMS'15 in Orlando Colorado where we participated in several of the student competitions. The Mines Material Bowl team of Blake Whitely, Andrea Bollinger, Connor Campbell, and Emily Mitchell trounced the com-



Above: CSMMAC Meets with Rep. Ken Buck (CO-R) in Washington D.C.. Left to Right: Rep. Buck, junior Michelle Hoffmann, senior Emily Mitchell, senior Tyrel Jacobsen

petition, most notably the fight-song-stealing Georgia Tech in the finals, to bring home the fifth win in the nine year history of the event. Mines metallurgists further went on to place third of 25 schools in the inaugural TMS Bladesmithing competition for our submission of a Nepalese-style Kukri. Many students enjoyed working hard at the forge and grinding shop of two local artisans to help us produce the knife. Our success was even published by the Colorado School of Mines Newsroom promoting the chapter, the department, and the school.

#### Congressional Visit Days

Three members traveled to Washington D.C. in April as part of Material Advantage's Program to meet congressmen and senators to discuss the importance of supporting STEM education and career fields. Tyrel Jacobsen, Emily Mitchell, and Michelle Hoffmann met with Rep. Ed Perlmutter (CO-4), Rep. Ken Buck (CO-7), Sen. Cory Gardner (CO-R), and Rep. Pete Visclosky (IN-D) who graciously took the time to hear what students from Mines had to say about materials science and engineering, and other STEM fields. Mark Burtschi, CSM alumnus and the Senior Director Federal and State Government Relations at ArcelorMittal, helped the group organize several of the visits.



Above: CSMMAC's 3<sup>rd</sup> Place Kukri submission to the TMS'15 Bladesmithing Competition.

Top: CSMMAC and all Mines Students at TMS'15. Celebrate and congratulate the TMS'15 Material Bowl Champions with a popular social media campaign.

(Continued on page 4)

# CSM Material Advantage Club Update, continued

(Continued from page 3)

## Community Outreach

### Westminster High School Materials Science Class Tour

A group of about 50 high school students from a Denver area high school were able to travel to Mines and get an in-depth tour of the department to learn about STEM education and careers, specifically as they apply to metallurgy and material science. Students were guided through many of the labs including the foundry, welding center, mechanical testing, glass manufacturing, sintering lab, and the electron microscopy labs. The tour was very well received by the students who were engaged with various mini-demos and pieces of equipment not available to them at their high school.

### Trefny Institute Tour of Hill Hall

Seventy-five elementary school children, as part of an educational supplement program for K-12 STEM lessons, were given a tour of Hill Hall. The children saw several of the labs and were particularly excited about seeing the foundry. Enthusiasm for the tour has prompted scheduling another tour for next year so that more and more people can not only be inspired by STEM fields or Mines, but with metallurgy and materials science specifically.



CSMMAC Ski Day at Winter Park Ski Resort, Colorado.

## Science Fairs

CSMMAC volunteers travel to many elementary schools in the Denver area to help judge science fairs. The schools appreciate the demonstrations we bring as well as the technical expertise to engage and help kids with their projects. We helped at Parmalee Elementary, Ralston Elementary, and Broomfield Elementary.

## Professional Presentations

As part of our professional development program and ongoing work to expose the members of our chapter to various aspects of metallurgy and the many different branches of industry and academia, CSMMAC hosted many speakers this semester. Dr. Findley and Dr. Reimanis from CSM, Dr. Boldrik from Cinvestav in Mexico, Dr. Luke Jain from Shell, and Rebekah Kovarik and Meredith Heilig (Lockheed Martin and Colorado Metallurgical Services) for the ASM Rocky Mountain Chapter.

A team of CSMMAC (Colorado School of Mines Materials Advantage Chapter) students, led by MME sophomore Josh Pelz, won a \$1,000 prize in the AIST Foundation "Real Steel" Video Challenge for their video entitled "Living in Steel." The AIST (Association for Iron & Steel Technology) Foundation provides scholarships and grants to foster interest in the steel industry among engineering students. The annual video contest challenges students to produce a three-minute video that brands the steel industry as potential career field. Link to the video: "[Living in Steel](#)".

## CSMMAC Gets Social

### Ski Day

With our campus' supremely unique location next to the best skiing in Colorado (possibly the world) our chapter organized a Saturday trip to the mountains for both students and faculty to enjoy the slopes. The event was a huge success and provided another opportunity for the non-professional benefits of being a member of our chapter. Photos from this event have also been highly effective in soliciting interest in both CSMMAC and the MME Department.

### Breakfast Club

On the first Friday of the month from 7:30 to 9:00 A.M. CSMMAC serves breakfast to the students and faculty of the metallurgical and materials engineering department. It's a fun way to socialize and get a good start to the

(Continued on page 5)

# CSM Material Advantage Club Update, continued

(Continued from page 4)

best day of the week. It's also a place that underclassmen can come speak with upperclassmen in an open and relaxed environment to learn more about the department and major.

## Foundry Free Pour

Using the foundry on campus, our members green sand cast Mines "M" symbols out of aluminum. The purpose of these M's is to show an appreciation for the speakers that present at our general meetings, but also they make excellent holiday presents. It gave a chance for CSMMAC members to experience the foundry facility and learn about the process of producing aluminum castings. The after-hours free pour session allowed for nearly a dozen members to enjoy the unique facilities and opportunities of the department.

## RHA Quidditch Tournament

Eight members of our chapter participated in the RHA Quidditch tournament, and made it to the semifinals. Running around with brooms between our legs, CSMMAC won our first match after Kyle Hesel ran an estimated two or three miles to chase down a human snitch for a final score of 80-30. The game, based upon the rules and styles of the famous sport from the Harry Potter series, proved to be not only great exercise, but a great way to bond over one of our favorite books during the end of the semester.



Above: Dr. Mike Boldrik from Cinvestav Presents TBC Research to CSMMAC..  
Middle: CSMMAC Plays in the RHA Quidditch Tournament  
Top: Green sand molds for aluminum castings cooling from CSAMMAC special Foundry Free Pour.

# Department is a Major Player in a New U.S. Government Lightweight Materials Initiative

Contributed by David Matlock

The Colorado School of Mines is a key participant in a new manufacturing institute focused on lightweight materials, initiated in 2014 as one of the initial 5 institutes funded by the US government with the goal to maintain America's manufacturing leadership and accelerate technologies. Development of lightweight materials and technologies are critical to industries for a variety of applications including the development of more fuel-efficient transportation vehicles, production of lighter weight armor for land and sea-based military equipment, etc.

The specific program, referred to as LIFT (Lightweight Innovation for Tomorrow) is operated by the American Lightweight Materials Manufacturing Innovation Institute (ALMMII). ALMMII is one of the initial five manufacturing institutes created as part of President Obama's initiative to establish a National Network for Manufacturing Innovation (NNMI). ALMMII is a non-profit public/private partnership that involves universities, companies, and national laboratories. The institute was funded in response to a competitive proposal led by The University of Michigan, The Ohio State University and the Edison Welding Institute, with support of two primary partner universities, CSM and Worcester Polytechnic Institute. Today LIFT has over 80 partners (see <http://lift.technology/>) and the first group of research projects has been funded. The initial five-year budget is \$148 million, \$70 million of which was provided by the government through the Office of Naval Research (ONR) with the remaining funds from private industry.

The institute will work primarily with aluminum, magnesium, titanium and advanced high-strength steel alloys, and inclusion of CSM in the institute, which has most of its participants aligned along interstate 75 between Michigan and Ohio, was "natural" due to the

strength of the industry-based programs on advanced metals at CSM. Advanced high strength steel research has been a mainstay of the research agenda for the industry-based research programs of the Advanced Steel Processing and Processing Research Center, a program founded at CSM in 1984 (<http://aspprc.mines.edu/>). In addition, non-ferrous research is expanding at CSM in the new Center for Advanced Non-Ferrous Structural Alloys (CANFSA) (<http://canfsa.unt.edu/home>).

LIFT is organized around six primary "pillars," each related to advanced processing technologies: thermomechanical processing, joining, casting, powder

coordinated by Prof. David Matlock as a member of the LIFT Technical Leadership team and head of the thermomechanical processing (TMP) pillar. CSM has significant expertise in TMP and the attached photograph illustrates examples from laboratory hot rolling and simulation experiments on the Gleeble 3500.

LIFT has recently opened its headquarters in downtown Detroit in a newly renovated facility (ribbon cutting was on January 15, 2015) and the attached photo shows Prof. Matlock at the TMP display hosted by CSM at the opening ceremony. Pilot-scale equipment, to supplement research equipment available in

research partner laboratories, is currently being ordered. As LIFT fully develops, it is anticipated that CSM's involvement will expand and significant graduate student oriented research projects will be managed by CSM staff in MME.

## Thermomechanical Processing Research and Education

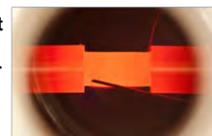
### Laboratory Based TMP Hot Rolling



### Gleeble 3500 – Thermomechanical Processing Simulator



- Simulator used to provide physical models of industrial processes
- Example shown is hot torsion to simulate TMP of multi-pass bar rolling



processing, agile manufacturing, and coatings. Supporting the pillars are several "cross-cut" themes including integrated computational materials engineering, cost modeling, supply chain analysis, etc. Activities of LIFT will build upon the Materials Genome Initiative (MGI) and Advanced Manufacturing Partnership to capitalize on recent breakthroughs in materials modeling, theory, and data mining to significantly hasten discovery and deployment of advanced materials while decreasing their cost.

In addition to participating as a major research partner, CSM is providing leadership, currently



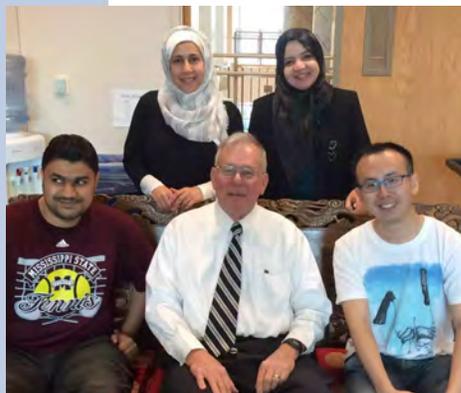
Above: Prof. Matlock monitoring the showcase at the new facility's ribbon cutting event on January 15th. ALMMII is headquartered on Rosa Parks Boulevard in Detroit, Michigan.

# Faculty Update

## Professor Mishra to retire from CSM at the end of the summer



Please congratulate Professor Brajendra Mishra upon his retirement from CSM after 25 years of distinguished service. He has accepted a position as the Kenneth G. Merriam Distinguished Professor of Mechanical Engineering at Worcester Polytechnic Institute. Professor Mishra served Mines in variety of capacities, including Associate Director of the Kroll Institute, Associate Director for the Advanced Coatings and Surface Engineering Laboratory, and Associate Department Head. He is one of the co-founders of the Center for Resource Recovery and Recycling, and is currently a Co-Director. During his tenure at Mines, he has served extensively in professional service activities, including as the president for TMS (2006) and president of AIME (2011). He taught and performed research in the area of corrosion, extractive metallurgy, iron and steel making, and coatings. While at Mines, he supervised 41 PhD and 33 MS students. Professor Mishra will continue to collaborate with colleagues at CSM while he is at Worcester Polytechnic Institute.



## After 43 years at CSM, Professor Olson gives his final lecture

On Tuesday, April 28th, Professor David Olson, University Emeritus Professor of Metallurgical and Materials Engineering, gave his last class on *Alloying Theory, Structure and Phase Stability*. He has been a valuable member of the MME department for many decades, and has taught and advised countless students. Graduate students in the MME department honored him with a reception after the class. For Dr. Olson's complete profile, please see: [metallurgy.mines.edu/Olson](http://metallurgy.mines.edu/Olson)



# New Adventures at the Atomic Scale

## TEM Upgrades in the Electron Microscopy Lab

Contributed by Brian Gorman

In September 2014, CSM and CoorsTek announced a major partnership that included elements of education, research and infrastructure upgrades at CSM. One of the major infrastructure upgrades included \$1.5M from CoorsTek to purchase a new transmission electron microscope (TEM). Specifically, we purchased an FEI Co. Talos 200FX, which is the first instrument of its kind in the US. This new instrument makes a major leap forward in our TEM capabilities on campus. Some of the new capabilities include:

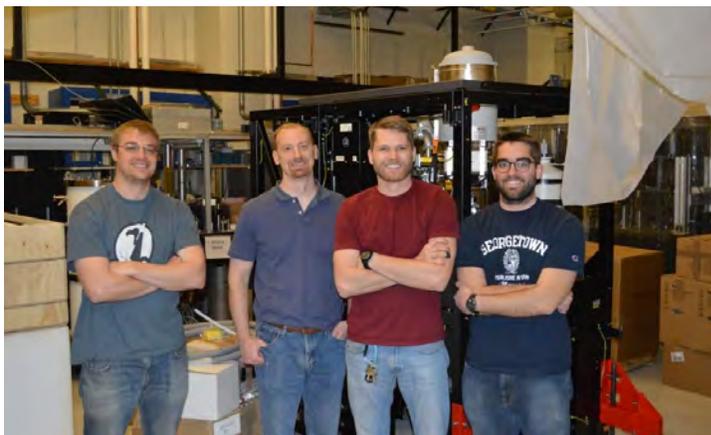
- High brightness field emission electron source
- TEM imaging resolution down to 0.08 nm—check out our cover image from the Journal of the American Ceramic Society (Dec 2014 issue) taken with this microscope, (right).
- Digital image capture at 16 megapixels using direct electron detecting CMOS camera; diffraction users are going to love the dynamic range
- Scanning TEM imaging including detectors for simultaneous Z-contrast, diffraction contrast, and bright field imaging; resolution to 0.1 nm
- Energy dispersive X-ray microanalysis using 4 silicon drift detectors. Count rates to 1 M counts per second are possible, thus making EDS mapping possible in minutes to seconds
- TEM and STEM tomography, allowing for 3-D imaging using any of the above image acquisition techniques
- In-situ gas, liquid, and electrochemical cells allowing us to do corrosion, deposition, and catalytic reactions while watching with near full TEM resolution



(Physics) was generous enough to share some of his lab space in GRL with us for the next 2 years, at least until the new CoorsTek Center is completed. Next time you are on campus, be sure to stop by and take a tour.

Speaking of the CoorsTek facility, there will be a laboratory space in the new CoorsTek building specifically for multi-scale characterization instrumentation. It will include space designed for 2 new TEMs, our atom probe tomography instrument, several SEMs and FIBs, X-ray diffraction and tomography, acoustic microscopy, AFM, optical imaging, and surface analysis instruments. Our hope is this new facility will be a one-stop shop for solving microstructure related issues in virtually any material.

I will be sure to send updates as we get closer to moving in late 2017.



Above: A hardy TEM uncrating and installation crew: graduate student Adam Stokes, Research Professor Dr. David Diercks, graduate student Cody Miller, and graduate student George Burton.

The instrument was delivered in December 2014 and we uncrated it in January 2015, with the help of some well-fed graduate students. Unfortunately, the TEM was too big to fit through the doors of Hill Hall. Jeff Squier

Top: Our new FEI Talos 200FX TEM taking its first look at North Table Mountain.

# Partnering with Fashion Sportswear Company to Create Specialty Performance Materials

## Project “Dancy Pants” enhances energy absorption of padding

Contributed by Terry Lowe

The Colorado School of Mines and Denver’s fashion sportswear company Kadylux, LLC have partnered to produce a hybrid material system that can absorb the energy and forces of impact. The target applications for the new hybrid material are sports helmets and padding for many athletic activities. Kadylux LLC plans to market the new material in its line of dance inspired activewear ([www.kadyluxe.com](http://www.kadyluxe.com)). The overall vision of Kadylux is to make it possible for people of all ages to lead active lifestyles, including high risk sports, with less possibility of injury.

The project started in 2014 with seed funding from Kadylux LLC and the Colorado State Advanced Industries Accelerator program. By adding specially designed metal lattices into polymeric foam padding, the project

shown in the adjacent figure.

Now the research is shifting to establishing cost effective means to fabricate the hybrid materials system. A second phase of the project is about to begin

which will focus exclusively on manufacturing technology for the hybrid material.



Black-White Knee Pad (Perspective)



Above: Dr. Lowe and his research team: Connor Campbell, Casey Davis, Brendan Lyle, Peter Rovira, Mason Woish, Logan Woish, Michaela Rillings, Joel Grzenia, Emma Woodyard, Erik Sease, Kodi Burns, Leah Brown, Katie Duval, Jame Leon, Billy McCarthy, Bill Schvetz, Madeline Woodard.

has demonstrated a means to enhance the energy absorption of impact padding by a factor of four. One of the distinctive features of the hybrid material is the ability to absorb energy in very thin packaging. A rendering of knee pad strip designed to be 2 mm thick is

Professor Lowe oversees the project while MME senior Michaela Rillings leads the day-to-day research.

Michaela is also an Irish step dancer and dance instructor, and looks forward to being able to use the new padding to reduce impact to her feet during dancing. This year Mines football team members and MME juniors Logan Woish and Mason Woish joined the research team, bring the passion for their sport into the overall research team effort. In total, 16 students are working on some facet of the project, including a mechanical engineering senior design team and a metallurgical engineering senior design team, complementing the central effort by Dr.

Lowe core research team. The group photo of the entire “Dancy Pants” Project Team features some member displaying sports for which the technology will eventually provide benefit.

# Faculty Update

## Tenures reached, sabbaticals planned, awards and distinguished publications

**Prof. Corby Anderson**, Harrison Western Professor of Metallurgical and Materials Engineering, was granted tenure by the CSM Board of Trustees in March 2015. Prof. Anderson has been at CSM almost 6 years. He works in the Kroll Institute for Extractive Metallurgy, researching Mineral Processing, Extractive Metallurgy, Recycling and Environmental topics.

"I am very pleased to be here," said Corby.

**Associate Prof. Kip Findley** will go on sabbatical for the fall 2015 semester. Dr. Findley has been at CSM for seven and a half years. His research is in the Advanced Steel Processing and Products Research Center (ASPPRC). He teaches Mechanical Properties of Materials at the undergraduate level and Analysis of Metallurgical Failures and Strengthening Mechanisms at the graduate level.

Dr. Findley will be going to the Delft University of Technology in the Netherlands. The visit will take place between August and December. He will be working with Prof. Maria Santofimia in the Mechanical, Maritime, and Materials Engineering Department. They will be performing research on mechanical behavior of third generation microstructure concepts for advanced high strength sheet steels.

"The sabbatical will be an excellent opportunity to develop an international collaboration with a research group who works in areas complementary to some of our ASPPRC research activities," said Kip. "I also look forward to connecting with some of our current partners and other steel researchers in the region."

**Associate Professor Brian Gorman** will go on sabbatical for the 2015-16 academic year. He has been at CSM 6.5 years. Dr. Gorman teaches ceramic processing, transmission electron microscopy, field session / particulate materials processing, and phase equilibria in ceramics. He is Director of the interdepartmental Materials Science graduate studies program, leads the Atom Probe Lab and is Director of the Electron Microscopy Lab.

Dr. Gorman will be splitting his time between National Renewable Energy Lab (NREL) in Golden, CO and The National Institute of Standards and Technology (NIST) in Boulder, CO and the University of Sydney, New South Wales, Australia.

He will be working with Mowafak Al-Jassim and Teresa Barnes (NREL), Norman Sanford and Ann Chiamonti (NIST), and Simon Ringer and Julie Cairney (U Sydney) His research topics will vary but include atomic scale characterization of solar cell materials (NREL), new hardware

for atom probe tomography (NIST), and new atom probe tomography data analysis techniques (U Sydney) "I hope to write a bunch of papers and ride my bicycle. A lot," said Brian.

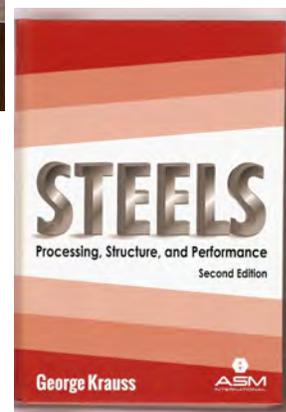
**Professor Ryan O'Hayre** received the CSM Excellence in Research Award for Junior Faculty, at the April 22nd Faculty Forum. *Pictured right.*

**Teaching Associate Professor Gerald Bourne** received the Outstanding Faculty award at the April 22nd Faculty Forum. *Picture below.*

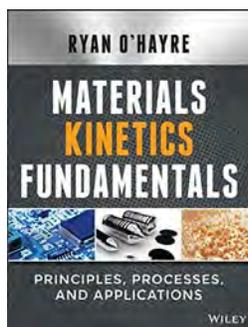


**University Emeritus Professor George Krauss** authored the second edition of his

textbook, *STEELS: Processing, Structure and Performance*, published by ASM International in March 2015. *Pictured right.*



**Professor Ryan O'Hayre** authored a first edition textbook, *Materials Kinetics Fundamentals: Principles, Processes, and Applications*, published by Wiley in January 2015. **Dr. Michael Sanders**, Research Professor in MME, created the illustrations for the book. *Pictured left.*





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**MINES**

## SUPPORT MME

A gift to the Department of Metallurgical and Materials Engineering is an investment in the future.

Gifts can support scholarships, fellowships, professorships, academic programs, faculty research, and other initiatives that are not through state appropriations. Private philanthropy empowers the Department to achieve greater excellence in research and education.

To learn more about supporting the Department, contact the CSM Foundation:

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