INNOVATIONS IN MATERIALS RESEARCH

Newsletter of The Ohio State University Institute for Materials Research

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Inside this issue :

THE OHIO STATE UNIVERSITY

INSTITUTE FOR MATERIALS RESEARCH

SEED FUNDING LEADS TO ONGOING COLLABORATIVE RESEARCH:

Lisa Hall and Vishnu Baba Sundaresan Use Simulation and 3D Printing to Explore Polymers

The development of novel and emergent materials is accelerated through collaborations across various disciplines in science and engineering. This is especially true for an ongoing, interdisciplinary project researching structural polymers with unique engineering applications, where two researchers first collaborated through an Exploratory Materials Research Grant (EMRG) funded through the OSU Materials Research Seed Grant Program.

Continued on page 4

FACULTY SPOTLIGHT:

Farhang Pourboghrat, Integrated Systems Engineering and Mechanical and Aerospace Enginering

Farhang Pourboghrat joined The Ohio State University in August 2015 as a Professor with joint appointments in the Integrated Systems Engineering (ISE) and the Mechanical and Aerospace Engineering (MAE) departments. Hired through the Materials and Manufacturing for Sustainability Discovery Theme focus area, he also works closely with the Center for Design and Manufacturing Excellence (CDME) in the area of sustainable materials forming and manufacturing. Prof. Pourboghrat received his BS and MS degrees from the University of Iowa, and a PhD in Mechanical Engineering from the University of Minnesota. From 1990 to 1998, Farhang worked as a staff scientist at the Alcoa Technical Center, where he was primarily involved with the development of constitutive models for aluminum alloys. In 1998, he joined the Mechanical Engineering Department at Michigan State University as an Assistant Professor, and was promoted to the rank of Professor in 2009. Throughout his tenure at MSU, Pourboghrat developed strong collaborations with faculty from other departments and colleges, including collaborations with Chemical Engineering and Materials Science faculty on the multiscale modeling of nanocomposites, and with engineers and scientists at the DOE's National Superconducting Cyclotron Laboratory (NSCL) on the modeling of the tube hydroforming of niobium to fabricate particle accelerator cavities.

Continued on page 5

DIRECTOR'S NOTE:

Dear Colleagues,

When I looked over the contents of this issue of the Innovations in Materials Research newsletter, I was struck by three things. First, the breadth of activities, the quality and impact of the efforts described, and the new names and faces all reveal the sustainability and regenerative capacity of our deep and wide materials community at Ohio State across departments and colleges – a true testament to interdisciplinary excellence. The second thing I noticed was the continuation of explosive growth of our programs and centers - whether it be within the Materials and Manufacturing for Sustainability Discovery Theme with the arrival of our Assistant Vice President for M&MS, new faculty, new labs and global collaboration with multiple entities in India; or the impressive progress made every day within the Center for Emergent Materials, our NSF MRSEC; or the outstanding example being set by the staff at Nanotech West for sustainable practices while they continue to maintain a nanofabrication capability for our community of the highest order. The third thing I noticed, with great pride I must add, were the successful outcomes of our seed programs, represented in this issue by the joint program between Lisa Hall and Vishnu Sundaresan – notable not only for the role of an Exploratory Materials Research Grant (EMRG) in enabling a full-fledged, externally funded effort, but also because this is a true multi-college collaboration between the department of Mechanical and Aerospace Engineering and the department of Chemistry and Biochemistry. With IMR about to celebrate its 10th birthday later in 2016, it is fair to say that IMR is accomplishing its mission every day to nurture, grow and sustain a materials research community of excellence, impact and magnitude. None of this happens without the tremendous quality of our students, researchers, staff and faculty, and their willingness to collaborate, which has become a defining feature for materials researchers at Ohio State. As a result, we are most fortunate to enjoy the synergies that are so obvious across the breadth of IMR.

Inside you will read about innovative, leading research, a bevy of awards being made to our faculty, introductions to new faculty and leaders, and new equipment in our labs. And before closing, I would like to remind everyone of the 2016 OSU Materials Week conference to be held May 10-13 (see imr.osu.edu for details). We are very fortunate to welcome Prof. John Goodenough as our guest of honor to kick off the event with the 2016 IMR Keynote Address. His renowned contributions in the chemical sciences toward energy applications are truly appropriate for this year's technical program, which builds on topics defined within our M&MS Discovery Theme program.

With warm regards,

Steven A. Ringel, Ph.D.
Neal A. Smith Chair Professor

Executive Director,
Institute for Materials Research
The Ohio State University

Nanotech West Achieves Green Buckeye Certification Through Sustainable Practices

Nanotech West Laboratory recently became the first user facility to achieve Green Buckeye Certification through a process initiated by Aimee Price, Senior Research Associate. Price is a member of the University Energy Committee, a group with representation from throughout campus that reviews and provides recommendations for best practices of campus facility management related to energy. It is through this committee that she first learned of the Green Buckeye Certification efforts on campus, modeled after similar national programs. The intent of the Green Buckeye Certification (GBC) program is to inform and encourage implementation of best practices to improve the sustainability performance of campus offices and laboratories.

As part of the Green Buckeye Certification process, Price and Nanotech West Lab Manager Paul Steffen used the initial application checklist as a tool to evaluate the energy and sustainability of Nanotech West's facilities and activities. They were able to quickly identify a few areas of improvement where quick changes could be implemented, such as providing recycling bins in the lab's sink areas so empty bottles of acids that were previously thrown in the trash could be recycled (see side box for more examples). After implementing some improvements and completing the detailed questionnaire, Price and Steffen met with Green Buckeye Certification representatives and toured the labs with them before being awarded the certification. The certification process helped lab staff consider their daily practices and energy impacts. "Our staff now think about minimizing the use of items and wasting fewer materials," explained Price. The next challenge is to extend that sustainable thinking to the lab's many users, encouraging them to make some changes to their practices in the lab, such as using less solvents, which would reduce waste and expenses.

This certification process was not Price's first sustainability effort with Ohio State. Price's family farm is a key player in the Zero Waste initiative at Ohio Stadium to achieve zero waste by 2025 by diverting 90% of waste away from landfills. After each home game, Price Farms Organics collects compostable materials from the stadium's kitchens, food vendors, and suites composts it on their Delaware farm, and about two years later returns the "Stadium Scarlet" compost to campus for use in the planters around Ohio Stadium.

Nanotech West is the only user facility certified at this time and currently is one of only nine Green Buckeye Certified Laboratories on campus - the other being six College of Public Health labs in Cunz Hall, the Lerch Lab in the Biomedical Research Tower, and the Sadee Lab in Graves Hall. With over 3,000 laboratories at The Ohio State University, there is a great opportunity for progress to be made in increasing sustainability efforts in campus research environments.

"This is a beginning," says Price. "It's an ongoing process, and we have identified areas of opportunity and we'll continue to work our way through that list of opportunities." Price said Nanotech West staff continue to work with the Green Buckeye team to identify ways to adapt the current lab questionnaire, making it more universal to better evaluate a broader range of labs and their equipment and uses.

For more information on the Green Buckeye Certification process for campus offices and laboratories, visit: http://footprint.osu.edu/gbc.html

Some simple yet impactful changes Nanotech West Labs made as part of the Green Buckeye Certification process:

- Reduced number of freezers from two to one
- Added recycling containers to labs
- Requested electronic versions of catalogs and journals
- Asking vendors if they accept returned empty packaging
- Communicating with users through meetings, signs, and stickers about the importance of sustainability in the lab and using less solvents and other materials
- Returning some packing materials to local shipping companies for re-use

SEED FUNDING LEADS TO ONGOING COLLABORATIVE RESEARCH

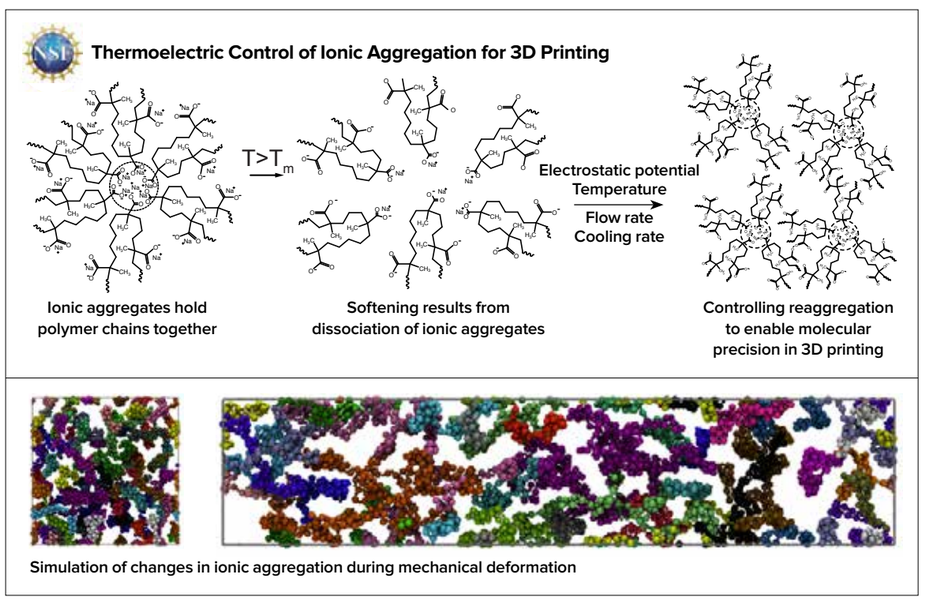
Lisa Hall and Vishnu Baba Sundaresan Use Simulation and 3D Printing to Explore Polymers

(continued from page 1)

Vishnu Baba Sundaresan, Assistant Professor of Mechanical and Aerospace Engineering, had envisioned an additive manufacturing technique to 3D print structural composites with piezoelectric particles embedded in the matrix. Meanwhile, Lisa Hall, Assistant Professor of Chemical and Biomolecular Engineering, had quantified the aggregation of ionic groups in various ionomer systems via coarse grained molecular dynamics simulations. In ionomer materials, there are several experimentally adjustable parameters such as polymer architecture, fraction of ionic groups, and nanoparticle content that all strongly affect the material properties, and it is expensive to attempt to optimize materials by experimentally synthesizing many systems across this parameter space. MD simulations can show the physics behind observed trends in structure and properties and give insight and guidance to experimental investigations. The experimental and modeling results together improve our ability to rationally design new materials. Through the 2013 EMRG grant, the Hall group was able to support graduate student Prasant Vijayaraghavan, who simulated segmented ammonium ionenes at a coarse-grained level. In prior experimental work, changing the fraction of softer polypropylene segments (relative to polyethylene segments) was seen to impact the self-healing ability of the materials. A paper was published in *Macromolecular Chemistry and Physics* early this year showing that the fraction of polypropylene impacts both the degree of ionic aggregation and the local microphase segregation of the two uncharged polymers, with nonobvious effects on the dynamics that may explain the experimental observations (DOI:10.1002/macp.201500466). Vijayaraghavan obtained a Master's degree in the Hall group, then joined the Sundaresan group for his Ph.D. studies.

The seed award from EMRG program provided continuity to this project and allowed Hall and Sundaresan to generate the preliminary data needed to clearly demonstrate the advantage of this multidisciplinary collaboration. The two collaborators then submitted a proposal to National Science Foundation's Manufacturing Machines and Equipment (MME) Program and were awarded a three year grant to investigate the development of an additive manufacturing technique that uses thermoelectric fields for 3D printing of smart structural composites **(Figure 1)**. The researchers are currently investigating the aggregation of ionic groups in a thermoplastic ionomer and simultaneous poling of nanostructured or microstructured piezoelectric particulates in 3D printing using a new extruder nozzle.

For more information on this and related research, visit http://hallgroup.engineering.osu.edu/ and http://integratedsystemslab.org/

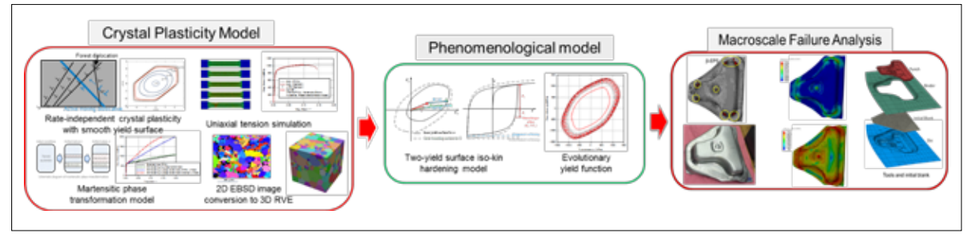


> **Figure 1: The MD results reveal how ionic aggregate morphology changes during strain, and this is dependent on ionomer architecture and directly connected to material properties.**

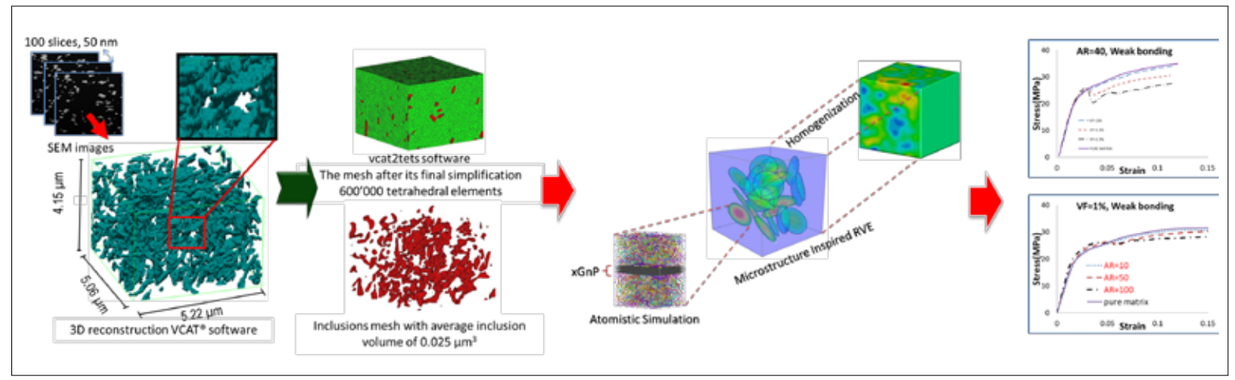
FACULTY SPOTLIGHT:

Farhang Pourboghrat, Integrated Systems Engineering and Mechanical and Aerospace Enginering

(continued from page 1)



> **Figure 1: Multiscale modeling of lightweight third generation advanced high strength steel (3GAHSS).**



> **Figure 2: Multiscale modeling of xGnP reinforced thermoplastic nanocomposites.**

At Ohio State, Pourboghrat's research continues to be focused on the multiscale characterization of engineered materials, with a strong emphasis on the development and application of microstructure-sensitive material models such as crystal plasticity and advanced phenomenological yield functions. He is currently participating in a multi-institution, DOE-funded project on Integrated Computational Materials Engineering Approach to Development of Lightweight 3GAHSS Vehicle Assembly (ICME 3GAHSS). **Figure 1** shows an example of the application of crystal plasticity (CP) model for the simulation of stamping of 3GAHSS sheet, in which the CPFEM accounts for the transformation of retained austenite to martensite phase resulting in increased strengths at large strains. In this example, a two-dimensional (2D) EBSD image of the 3GAHSS steel was used to generate a statistically equivalent three-dimensional (3D) representative volume element (RVE) for the material. The RVE was then meshed and deformed with CPFEM to generate stress-strain data under complex loading. These data were in turn used to numerically generate macroscale phenomenological yield functions with anisotropic evolution under large plastic deformation. Finally, the generated yield function was used to perform finite element simulation of the stamping of an automotive panel and failure analysis.

Another project the Pourboghrat group is currently involved in is related to the multiscale modeling of mechanical and electrical properties of exfoliated graphene nanoplatelet (xGnP) reinforced thermoplastic composites. **Figure 2** shows the various stages involved in developing a multiscale model for nanocomposites. A 3D RVE for the nanocomposite was produced from multiple slices of the actual material obtained with FIB/SEM technique. The generated RVE consisted of the polymer matrix and various sized xGnP nanoplatelets distributed throughout the matrix. The bond strength between the reinforcement and the matrix was estimated with molecular dynamic (MD) simulations. A damage model based on MD results was then incorporated into the RVE for subsequent finite element simulation of the mechanical and electrical properties of the nanocomposite. Figure 2 shows the sensitivity of the mechanical property of the nanocomposite to the volume fraction and aspect ratios of nanoplatelets reinforcement.

For more information about Prof. Pourboghrat's research, you may email him at pourboghrat.2@osu.edu.

Jay Sayre Joins IMR and M&MS in New Leadership Role

We are pleased to announce the appointment of Dr. Jay Sayre to the newly created positions of Assistant Vice President for Materials and Manufacturing Sustainability and Director of Innovation, Institute for Materials Research, effective February 15, 2016.

Dr. Sayre joins us from Battelle Memorial Institute, the world's largest independent research and development organization, where he was Director of Advanced Materials and Director of Internal Research and Development (IR&D) for Energy, Health and Environment. As the Director of Advanced Materials, he was responsible for the management of Battelle's entire materials workforce in all disciplines related to advanced materials. He also established the Office of the Director of IR&D for Energy, Health and Environment at Battelle, providing technical counsel and thought leadership on technical assessments, intellectual property strategies and strategic relationships with universities.

The newly created position of Assistant Vice President for Materials and Manufacturing Sustainability and Director of Innovation, Institute for Materials Research will provide vision, leadership and strategy for the overall development, coordination and advancement of the Materials and Manufacturing for Sustainability (M&MS) Discovery Theme program in collaboration with M&MS faculty leader and Institute for Materials Research (IMR) Executive Director, Prof. Steven A. Ringel, and in conjunction with Discovery Themes leadership. In this leadership role, Dr. Sayre will be actively engaged in M&MS program direction and implementation, faculty cohort development, and the development and implementation of internal and external engagement strategies for a vibrant innovation ecosystem between M&MS faculty, external partners, and across the University.

"I am truly thrilled to have Jay Sayre on board," says Prof. Ringel. "His proven experience in creating and leading major programs translating basic research in functional and composite materials, with applications in energy and sustainability, into real products by working closely industry, will have immediate impact on advancing the innovation culture we are working to instill with the M&MS program. This includes the pivotal leadership role he will play to enhance the mission and growing success of the Center for Design and Manufacturing Excellence, a key College of Engineering center that is now also formally affiliated with the M&MS program and IMR."

Dr. Sayre holds a Ph.D. in Materials Engineering Science from Virginia Tech, as well as a Master of Science in Polymer Engineering from the University of Tennessee. His interdisciplinary research interests are in translating science and technology into products within the fields of applied mechanics and materials engineering. Specifically, his focus is on fuel cells, polymer composites, failure analysis, dynamic mechanical analysis, multifunctional materials, and energy absorbing materials. His work on polymer composites is focused on multifunctional composites (energy generation and survivability), electrochemical composites (fuel cells and electroactive polymer actuators), and survivability (advanced threat armor composites). His work to date has resulted in numerous invention reports, patents, and patent applications. He was recognized for his achievements by receiving the Inventor of the Year Award, which is the highest recognition of technical achievement given at Battelle.

Learn more:

Materials and Manufacturing for Sustainability Discovery Theme focus area at http://discovery.osu.edu/focus-areas/materials-manufacturing/

Institute for Materials Research http://imr.osu.edu/

DISCOVERY THEMES INITIATIVE:

Materials and Manufacturing for Sustainability

Many exciting developments are taking place with the Materials and Manufacturing for Sustainability (M&MS) Discovery Theme focus area. Leadership roles are being filled, the Materials Innovation Greenhouse is coming to fruition, a dozen faculty searches are underway and domestic and international collaborations are being built. Below are several updates on this progress, with much more to come in the near future.

M&MS SPRING UPDATE EVENT INTRODUCES NEW LEADERSHIP

On February 24th, the M&MS program hosted a Spring Update event - an opportunity for the OSU materials community to hear about the exciting advances being made and to introduce the newest leaders of the program. M&MS Faculty Lead and IMR Executive Director Steve Ringel introduced Dr. Jay Sayre, who joined Ohio State in February as the new Assistant Vice President for Materials and Manufacturing Sustainability and Director of Innovation with IMR (see article, page X). Ringel also introduced John Bair, Director of the Center for Design and Manufacturing Excellence (CDME) and discussed how CDME and M&MS are working together to achieve joint goals of manufacturing innovation and successful commercialization. Glenn Daehn, Fontana Professor of Materials Science and Engineering, has been named Deputy Faculty Director of M&MS and in this role will be another key connection between Ohio State materials faculty and students and the manufacturing industry. Partnerships with materials researchers in India, updates on the hiring of 30 new faculty, development of a new energy storage hub, and the creation of a Materials Innovation Greenhouse were also mentioned before the crowd joined an informal reception where there was opportunity for questions and discussion.

M&MS RECRUITMENT AT MRS FALL MEETING

One of the highlights of M&MS is the planned hiring of up to thirty tenure-track faculty in various materials research disciplines at Ohio State. The message that "Ohio State is hiring in materials" was widely shared at the Materials Research Society (MRS) Fall Meeting in early December in Boston. Layla Manganaro, IMR Program Manager, staffed a booth in the career fair section of the conference's exhibit hall and spoke with individuals about the many faculty openings available and the exciting commitment the university has made to further strengthen our materials community. Interested applicants were provided flyers and online job postings for all of the current vacancies, and information about additional upcoming recruitment plans. The Fall Meeting had over 6,000 attendees, making it one of the largest materials-focused professional conferences.

INDIA TRIP

During the first week of March 2016, M&MS Faculty Lead Steve Ringel and College of Engineering Dean David Williams visited India to meet with university and government officials, private industry, and alumni in Mumbai and New Delhi. The trip began with a day-long visit with faculty and leaders from the Indian Institute of Technology-Bombay (IIT-B), with whom Ohio State signed a memorandum of understanding in January 2015 to establish joint research projects and programs in materials science fields. Participants from both universities discussed current projects and additional ways they would like to collaborate. Resulting visiting professor programs and seed grant funding opportunities to support these global research partnerships will be announced later this year.

Dr. Ringel was able to meet with Doug Fowler, Economic Officer of the U.S. Embassy; U.S. Consulate General Thomas Vajda and his staff; officials at the U.S. Agency for International Development and the US-India Educational Foundation; and representatives from several Indian companies during his stay, continuing the momentum built during previous visits to solidify partnerships with Indian collaborators and develop M&MS's global programs.

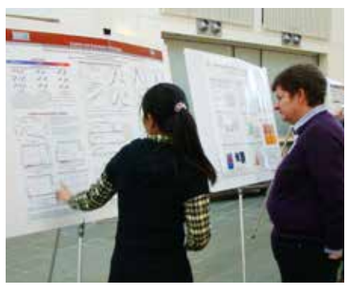
This trip also included a half-day interactive seminar on "Emerging Trends in Solar Technologies" organized by the Federation of Indian Chambers of Commerce and Industry (FICCI) and Ohio State's Global Gateway Office in New Delhi on March 4. Participants discussed the important role that technology innovation and energy storage technologies have to play in the renewable energy space and its significance in achieving a low-carbon future. The OSU-FICCI seminar highlighted latest global R&D advancements in solar technologies and market-ready applications, the role of energy storage, its current market penetration and the prospect of it becoming cost-effective in future. Participants included Ohio State faculty and representatives from Indian industry, government and academia. Dean Williams and Dr. Ringel were both featured speakers and gave presentations which included overviews of Ohio State's photovoltaics research and collaborations with renewable energy industry partners. The deliberations focused on the nature of support required to propel market development of emerging solar technologies and applications.

Center for Emergent Materials Update

The following update was provided by the Center for Emergent Materials (CEM), a National Science Foundation Materials Research Science and Engineering Center (MRSEC) at The Ohio State University. The MRSEC program funds teams of researchers from several different disciplines who work collaboratively on materials research in order to address fundamental problems in science and engineering. By working in teams, called Interdisciplinary Research Groups (IRG), the researchers at CEM tackle scientific problems that are too large and complex for a scientist working alone to solve. For more information about CEM, visit their website: http://cem.osu.edu/.

| EVENTS |

External Advisory Board Visits Center for Emergent Materials: An NSF MRSEC



CEM kicked off 2016 by hosting an external advisory board meeting January 6-7, 2016. Ten scientific leaders from industry, academia, and government labs visited Ohio State to provide valuable feedback and guidance on MRSEC progress and future directions. The meeting was a successful and helpful exercise in preparation for the NSF site visit occurring in May.

The Ohio State University Hosts The Conferences for Undergraduate Women in Physics

CEM enthusiastically participated in The Conferences for Undergraduate Women in Physics (CUWiP), which are coordinated by the American Physical Society (APS) and hosted regionally by colleges and universities across the United States. The Ohio State University was honored to host CUWiP from Jan 15-17, 2016. The goal of this conference is to encourage undergraduate women to identify as physicists. The program strives to achieve this goal through networking events, workshops, and speaker presentations.

The organizational efforts for this conference were spearheaded by CEM post-doc Dr. Jyoti Katoch. In addition to center-wide participation by faculty, staff, and students, CEM Education and Outreach Coordinator, Michelle McCombs, presented on "Strategies for a competitive REU Application."

| HONORS AND AWARDS |

CEM Associate Director Jessica Winter named Design News' Rising Engineering Star

Dr. Jessica Winter, Associate Director of CEM, was recently named Design News' annual Rising Engineering Star at the Golden Mousetrap Awards in Anaheim, California.

Winter was nominated by Matt Schutte, Director of Communications & Engineering Healthcare solutions at Ohio State's College of Engineering. When asked about his decision to nominate Winter, he was quoted as saying she:

"epitomizes the growing trend of engineers applying their skills to solve healthcare challenges. As a cancer survivor herself, she approaches her research with urgency and empathy, and with a focus on translation — on taking knowledge from the bench to the bedside. Jessica is much more than a professor, she is an entrepreneur, a mentor to dozens of students, an enthusiastic Ohio State engineering ambassador, and a productively impatient researcher who knows she can make a difference."

CEM REU Alumna Amanda Belding and Team Head to SpaceX

CEM REU alumna Amanda Belding, traveled to Texas to present with her team at SpaceX. Their Capstone project submitted ideas for Hyperloop travel in competition with more than 300 other university submissions, and was among the finalists.

CEM Director P. Chris Hammel elected to Physics Section of the American Association for the Advancement of Science

CEM congratulates Director P. Chris Hammel on his election to the Executive Committee of the Physics Section of the American Association for the Advancement of Science. His term on the Physics Electorate Nominating Committee began February, 2016.

CEM at Columbus City Schools' Innis Elementary for Annual "Science Day"

CEM's Science Day, a yearly culmination of the Scientific Thinkers program, migrated from Spring to Autumn semester

CEM mobilized a total of 45 volunteers including undergraduates, graduate students, faculty, and staff, to go to Innis Elementary school in Columbus, Ohio for Science Day. About 450 students benefited from the program, with demos such as Energy Bike, Crystalline Snowflakes, Chemistry Show, Helicopters and Autorotation, How Does My Computer Work, and many others.

The program is run by CEM professor Nandini Trivedi, Michelle McCombs and Erin Rinehart, with onsite coordination by Innis Elementary teacher Theresa Barber.

| EDUCATION AND OUTREACH |

CEM Visits PREM partners at New Mexico Highlands University

CEM and New Mexico Highlands University (NMHU) were awarded a Partnership for Research and Education in Materials (PREM) grant, whose objective is to broaden participation and enhance diversity in materials research and education by stimulating the development of long-term, multi-investigator research and education partnerships between minority-serving colleges/universities and NSF materials-related centers and facilities.

Director P. Chris Hammel and Prof. Ezekiel Johnston-Halperin both visited NMHU in recent months to kick-off the partnership. They presented research, met with faculty and students, and laid future plans for collaboration. Associate Director Jessica Winter and several students will visit again this spring to participate in NMHU's

Winter 2016 IMR Facility Grants Awards

Six new research projects were awarded by the IMR in January 2016, for a total investment of $12,000 in nascent materials research. The six projects support eleven faculty researchers from five different departments within the College of Engineering, College of Arts and Sciences, and College of Medicine.

For more information about the IMR Facility Grants and the many other funding opportunities offered through the Institute for Materials Research, visit imr.osu.edu/research/programs/

Analytical TEM for Physiological vs. Pathological Iron Core

Gunjan Agarwal, Biomedical Engineering; Co-Investigators: David McComb, Materials Science and Engineering; Dana McTigue, Neuroscience

This project aims to use analytical electron microscopy techniques to evaluate the mineral composition of ferritin iron core in mammalian tissue(s) under pathological versus physiological conditions.

LIPSS and SIPSS: Novel Surface Patterning Processes for Materials

Sheikh Akbar, Materials Science and Engineering; Co-Investigator: Enam Chowdhury, Physics

The proposed work involves an interdisciplinary study of two novel techniques (LIPSS and SIPSS) that can lead to the spontaneous formation of surface patterns. These two processes take place in very different time scales (femtoseconds for LIPSS, hours for SIPSS), however, can result in very similar features. The main objective of the proposed work is to fill gaps in the current mechanistic understanding of LIPSS formation by performing careful materials characterization. The role of stress in the LIPSS formation will also be examined by strain mapping and annealing experiments to test our hypothesis that LIPSS is a type of laser-activated SIPSS.

A Micro/Nanofabricated Platform for Enhanced Gene Delivery: Applications in Cell-based Therapies

Daniel Gallego Perez, Surgery; Co-Investigator: Savita Khanna, Surgery

The proposed research focuses on the development and fabrication of silicon-based platforms for non-viral transduction of genes into cells in a controlled and benign manner. Such genes will be delivered with the intent to induce directed cell reprogramming of fibroblasts into excitatory neurons that could potentially be used in regenerative medicine applications. These platforms will be tested within the context of stroke research, where gene-transduced cells will be stereotactically-implanted into the brains of stroked mice. Brain tissue repair and/or remodeling in response to cell delivery will be characterized via immunofluorescence microscopy.

Development of Photonic Crystals for the Investigation of Magneto-Optical Properties in 2D Materials

Ezekiel Johnston-Halperin, Physics

This project will focus on the development of successful fabrication strategies for the creating of photonic crystal structures in SiOx and SiNx substrates. These photonic structures will be coupled to various 2D materials by exfoliation and transfer, enabling both higher fidelity measurement of their optical properties and the inclusion of active optical functionality (such as gain and chirality selection) in the integrated photonic structures.

Quantification of the Effect of Active Beta Phase Grain Boundary Coverage on Fatigue in Simulated Marine Environments

Jenifer S. Locke, Materials Science and Engineering

Al-Mg alloys, identified as 5xxx alloys, are used in naval applications and susceptible to a process called sensitization, which leads to greatly reduced resistance to intergranular corrosion and corrosion fatigue. Sensitization is a process by which unsuitable combinations of time and temperature cause precipitation of a detrimental beta (β) phase on grain boundaries of Al-Mg alloys. Preliminary work is being conducted which establishes that time spent at elevated temperatures accelerates corrosion fatigue crack growth, but the link between crack growth and sensitization needs to be verified. This work proposed here aims to conduct scanning electron microscopy on intergranular surfaces to quantify the percent grain boundary area occupied by β phase and correlate it with the measured resistance to corrosion fatigue.

Sample Fabrication for BEEM Studies of Contacts to 2D Materials

Jonathan Pelz, Physics; Co-Investigator: Roland Kawakami, Physics

The research team will use the NanoSystems Laboratory (NSL) facilities to fabricate Au/MoS2/graphene samples for nm-resolution studies of Au/MoS2 Schottky contacts using Ballistic Electron Emission Microscopy (BEEM). Large local variations in contact properties can significantly alter performance of devices made from 2D semiconductors such as MoS2, produced by factors such as local variations in 2D film thickness, local defects or disorder in the 2D film, or defects in the device substrate. BEEM should allow direct measurement of such local variations, which has not been possible in prior studies. These proof-of-principle measurements will be critical for future proposals to the NSF to study contact effects in 2D material device structures.

New IMR Members

Hanna Cho is an Assistant Professor of Mechanical and Aerospace Engineering and director of the new Micro/Nano Multiphysical Dynamics Lab. Her research interests are in the field of nano- and bio-science and nonlinear dynamics, including developing nonlinear NEMS/MEMS using multi-functional materials to utilize intrinsically nonlinear characteristics such as broadband resonance, frequency tunability, and nonlinear instability; advancing state-of-art AFM techniques through understanding and enhancing the AFM cantilever dynamics to achieve better material characterization; and developing energy systems based on multi-functional ferroelectric material. Before joining Ohio State, Dr. Cho was a Postdoctoral Researcher at the University of Illinois at Urbana-Champaign, where she also received her Ph.D. in Mechanical Science and Engineering.

Ryan Harne is an Assistant Professor of Mechanical and Aerospace Engineering and directs the new Laboratory of Sound and Vibration Research. His research interests include integrating analytical and experimental investigations in mechanics, dynamics, vibrations, acoustics, and waves to elucidate and harness the rich characteristics of nonlinear systems that span disciplines such as engineering, physics, and biology. His research strategically leverages instabilities, bifurcations, and multifield behaviors (e.g., electro-/magneto-elasticity of smart materials) to create structural/material systems that are adaptive, versatile, and robust and applies these principles in the contexts of vibration/noise damping, isolation, and control; energy harvesting and guided energy transfer; structural/material properties change and shape morphing; sensing methodologies and sensor development. Prior to joining Ohio State, Dr. Harne was a Research Fellow in the Department of Mechanical Engineering at the University of Michigan and received his M.S. and Ph.D. degrees in Mechanical Engineering from Virginia Tech.

Katelyn Swindle-Reilly is a Visiting Assistant Professor in the Biomedical Engineering department. Her research focuses on polymeric biomaterials, primarily for ophthalmic and wound care applications, and she works with a variety of natural and synthetic polymers, in the form of films, hydrogels, and electrospun fibers. Before joining Ohio State, Dr. Swindle-Reilly was an Adjunct Assistant Professor at University of Texas at San Antonio and a Senior Scientist at Rochal Industries, where she developed innovative wound care products including polymeric skin protectants, antimicrobial formulations, and a soft tissue regenerative matrix, and designed manufacturing processes and preclinical studies for FDA clearance of these products. Dr. Swindle-Reilly received her M.S. and Ph.D. degrees in Chemical Engineering at Washington University in St. Louis, and her dissertation research resulted in the development and successful in vivo testing of an injectable, in vivo-gelling biomimetic vitreous substitute. She completed postdoctoral training in Biomedical Engineering at Saint Louis University where she developed 3-D biopolymer and electrospun scaffolds for peripheral nerve regeneration.

Materials Facilities Updates

In each issue of our newsletter, IMR provides relevant updates from our core materials research facilities - the NanoSystems Laboratory (NSL), Nanotech West Laboratory, the Center for Electron Microscopy and Analysis (CEMAS), and our newest addition, the Semiconductor Epitaxy and Analysis Laboratory (SEAL). More information on these facilities and over a dozen other open user materials research facilities on OSU's Columbus campus, visit our website at: imr.osu.edu/research/facilities.

nanotech.osu.edu

Nanotech West Laboratory

NTW Staff Move from Room 218 in Science Village Building

Nanotech West (NTW) Lab staff are moving from their upstairs office location to the downstairs office suite. Not only does this consolidate the staff into one location (for the first time), it also frees up space for the establishment of the Materials Innovation Greenhouse (MIG). The MIG is an integral part of the Materials and Manufacturing for Sustainability (M&MS) Discovery Theme focus area and staff are outfitting that space now.

Nanotech West Debuts New Lab Information Display

> The new Nanotech West Lab Information Display, located in the pre-togging area of the cleanroom. Standing beside the display is Nanotech West Administrative Intern Ms. Sydney Parrott, an undergraduate majoring at OSU majoring in Pre-Occupational Therapy

A new, large flat panel display is now located in the pre-togging room of the Nanotech West cleanroom. The display continuously pulls information from the NTW central databases and displays information on who is currently in the lab, what tools they are using, and what tools are down or partially operational and their status. In the future it will also be used to display information on events such as anticipated times for lab tours and laboratory-wide issues such as recent power glitches.

Biohybrid Lab and other Lab Space to Support New Energy Storage Hub

Also as part of the Materials and Manufacturing for Sustainability (M&MS) effort, space at Nanotech West will be used in the near future for activities in Energy and Energy Storage research. These areas include much of the Biohybrid Lab and also Room 117. Lab space will support a broad spectrum of activities ranging from basic materials and electrochemistry research to the testing of complete battery systems, and is planned to support the activities of new faculty hires that are central to the M&MS program.

OSSIP Update: Electro-Optical Test Station Construction

Capital funds from the Ohio Sensor and Semiconductor Innovation Platform (OSSIP) Program are being used to construct a flexible electro-optical (EO) test station (named prober 5, or PRB05, in the Nanotech West tool database) in Room 119 of the Science Village Building. The test station will consist of several light sources, detectors, and supporting electronic equipment that will be available to users to perform a wide variety of EO testing; its first objective will be to establish an infrared (IR) detector testing capability out to 2.5 microns wavelength. It has optical table space sufficient for at least two tests to be set up in parallel. Future capabilities planned for the setup include L-I-V (light-current-voltage) and dark I-V characterization of diodes; multi-junction photovoltaic cell characterization; room- and perhaps 77 Kelvin photoluminescence (PL) for epitaxial semiconductor materials characterization; and possibly time-resolved photoluminescence (TRPL) measurements. It will make its first measurements in April of 2016 and will likely be available to general users shortly thereafter.

OSSIP Offers $4k Matching Grants

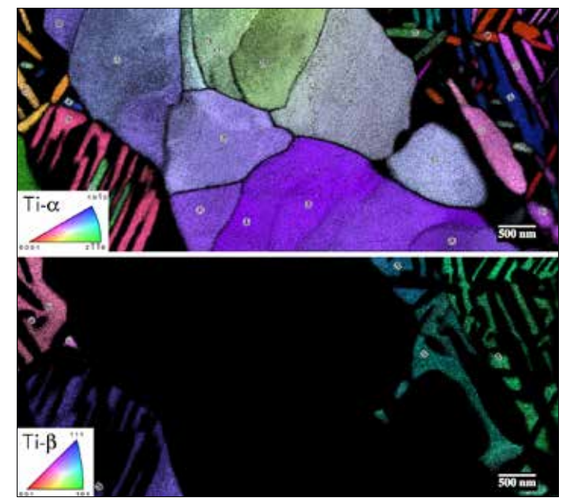
With approval of its Executive Advisory Board, OSSIP now has available 1:1 user fee matching grants of up to $4k for Ohio companies – especially small companies - that plan to use the Nanotech West Lab. To date, four such awards have been made. Only a one-page summary of the proposed work, including a link of the work to high-tech product and job creation in the State of Ohio, is required; if interested contact Dr. Robert J. Davis (davis.2316@osu.edu), Nanotech West Director and Principal Investigator of OSSIP. If awarded, OSSIP matching grants must be expended before 31 December 2016.

cemas.osu.edu

Center for Electron Microscopy and Analysis (CEMAS)

Transmission Kikuchi Diffraction Available to Characterize Nanomaterials

Transmission Kikuchi Diffraction (TKD) is a high-resolution Electron Backscatter Diffraction (EBSD) technique using scanning electron microscopy (SEM) to measure crystallographic properties and achieve a spatial resolution improvement of up to one order of magnitude over traditional EBSD. While CEMAS instruments and staff have been able to perform TKD in the past, CEMAS Research Associate Jon Orsborn recently developed procedures specific to TKD to assist users in the technique to characterize nanomaterials. TKD could particularly help researchers studying nanocrystalline or ultrafine grained materials, as TKD allows them to make precision crystallographic orientation maps and dark-field images in transmission (see **Figure 1** for examples).

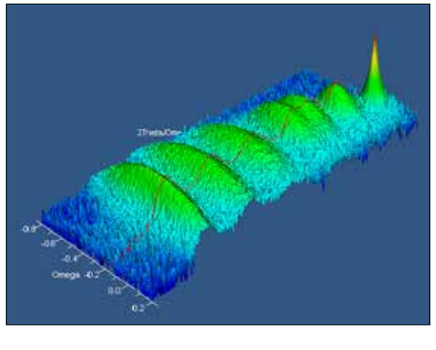


> Figure 1: Transmission Kikuchi Diffraction (TKD) map of alpha+beta processed Ti-17. The top image is an inverse pole figure map of alpha titanium, overlaid with a grayscale of confidence index. The bottom image is of the same region, but shows an inverse pole figure map of beta titanium, overlaid with a grayscale of confidence index. The unique crystallographic orientations are also represented by the lattice unit cell icons. This map was collected with a 10 nm step-size, and shows resolved and indexed precipitates as small as ~50 nm. (Images by Jon Osborne using CEMAS's FEI/Philips XL-30 Field Emission ESEM)

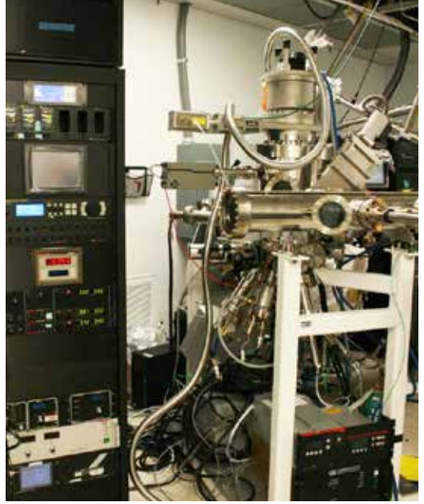
Introduced a few years ago, TKD has quickly been adopted by the scientific community as it fills the spatial resolution gap between EBSD and electron diffraction techniques in a Transmission Electron Microscope (TEM), i.e. from 100 nm down to a few nm. The TKD technique uses a signal (Kikuchi patterns) captured from underneath an electron transparent sample, while the EBSD signal is produced by back scattering diffracted electrons escaping a highly tilted bulk sample. TKD technique's spatial resolution performance makes it a great option for quantitative characterization of nanomaterials or ultrafine grained materials with crystal/particle sizes from 10 to 100 nm. In certain cases, characterization of deformed or heavily deformed structures would also benefit from the smaller interaction volume of the TKD technique.

Reciprocal Space Map (RSM) Offers High-Resolution X-Ray Diffraction

The Rigaku SmartLab X-ray diffraction system (XRD) is a fully automated, modular system for advanced x-ray diffraction measurements on a wide range of materials including thin films, nanomaterials, powders, or liquids. This instrument allows CEMAS users to take advanced x-ray diffraction measurements such as x-ray reflectivity, grazing incidence diffraction, reciprocal space maps, rocking curves, and small angle X-ray scattering (SAXS) and can be particularly applicable to users who will be studying polycrystalline or epitaxial oxide thin films. For example, growers can create an RSM (Reciprocal Space Map), a high-resolution XRD scan which allows researchers to characterize the quality of the epitaxial layers grown on a substrate (**Figure 2**). For users evaluating the quality of nitride thin films, RSM provides quantitative information about the lattice constant variation, alloy composition, misfit strain and strain relaxation, lattice tilting, and mosaicity related to the dislocations in a nondestructive manner.



> Figure 2: An (004) triple-axis HRXRD scan of a 6-step InAs(x)P(1-x) metamorphic grade on an InP substrate with a 65% As terminal composition. When combined with an additional (224) scan, composition and strain/relaxation of each of the layers can be calculated. (Image by Henk Colijn and John Carlin using CEMAS' Rigaku SmartLab XRD)



> SEAL's new Riber M7 MBE chamber.

seal.osu.edu

Semiconductor Epitaxy and Analysis Laboratory (SEAL)

Another molecular beam epitaxy (MBE chamber) is about to be open for business within SEAL - a prototype Riber M7 MBE will be ready for growth later this Spring. This system is currently equipped with an oxygen plasma source as well as high purity gallium, iron and a rod fed platinum e-beam source. Initial research is geared toward exploration of advanced wide bandgap Ga2O3 semiconductors as well as Fe / Pt - magnetic epilayers with integrated Pt spin detectors for thermal spintronics. Additionally, this chamber is connected in vacuum via a magnetic transfer system to another MBE chamber which grows plasma assisted nitrogen based semiconductors allowing integration of these materials without exposure to atmospheric conditions. Contact SEAL Lab Manager Mark Brenner for further info on this new MBE chamber and its use (brenner.34@osu.edu).

We are also happy to announce that SEAL has launched its new website: https://seal.osu.edu/. Users can now access info, news and scheduling capabilities through one common resource, with a much easier-to-remember URL.

ensl.osu.edu

NanoSystems Laboratory (NSL)

The NanoSystems Laboratory (NSL) is pleased to announce the newest addition to its staff, Ms. Christine Prechtel, who will be taking over as the NSL Program Assistant. Christine received her undergraduate degrees in Linguistics and Spanish and graduated Summa Cum Laude with research distinction in Linguistics from The Ohio State University in 2015. Before accepting this position, she worked at the university as an Operations Support Associate at the Office of Graduate and Professional Admissions.

Please contact Christine if you are interested in becoming an NSL user, need BuckID access to one of NSL's labs, need to schedule trainings, or need to purchase PPMS accessories, cantilevers, and other lab supplies. She is also the point of contact for all questions regarding NSL billing, online reservations, website problems, and for reporting any problems that might occur in the labs. Christine is located in the NSL kiosk desk on the second floor bridge way on the south side of the Physics Research Building, and can be reached at prechtel.4@osu.edu or 614-688-1158.

> New NSL Program Assistant Christine Prechtel

IMR Member News

Marcelo Canova, Assistant Professor of Mechanical and Aerospace Engineering, received two professional awards of note recently. Dr. Canova has been awarded the 2016 SAE International Ralph R. Teetor Educational Award for outstanding contributions as a top engineering educator, elected by a board of judges comprised of both academic and industry personnel based on his contributions to research, publications, and leadership in student activities and participation in engineering society activities. Dr. Canova also earned the NSF Faculty Early Career Development (CAREER) Award for his research in model-based control design for electrified vehicles and advanced automotive propulsion technologies. The 5-year award of $500,000 will fund his work to create a new model order reduction framework to improve the accuracy of control algorithms and design processes for advanced energy storage and conversion systems for electrified vehicles.

Katrina Cornish, Ohio Research Scholar in Bioemergent Materials and Professor of Horticulture and Crop Science and Food, Agricultural and Biological Engineering, was awarded the rank of Fellow by the National Academy of Inventors. NAI Fellows are nominated by their peers for outstanding contributions to innovation. Cornish has submitted 26 invention disclosures since joining Ohio State in 2010, spanning a range of fields including transgenic enabling technologies, plant utility patents, process engineering, value-added materials, sustainable fillers and medical products and devices.

Maryam Ghazisaeidi, Assistant Professor of Materials Science and Engineering, was selected by the National Science Foundation to receive the Faculty Early Career Development (CAREER) award, given to support the work of the nation's most promising junior faculty. Dr. Ghazisaidi received a five-year, $499,687 grant for her work to understand novel characteristics of defects in concentrated solid solutions. Dr. Ghazisaeidi will create a computational framework for predictive and quantitative models of the mechanical behavior of metal alloys to accelerate the design of materials with tailored properties. This project will provide a new understanding of the structural defects and plasticity in high entropy alloys, a new class of multicomponent alloys with desirable and nonconventional properties.

Roland Kawakami, Professor of Physics, was nominated to be a Fellow of the American Physical Society. APS Fellows are selected for their exceptional contributions to the physics enterprise, and Kawakami was honored for his pioneering advances in understanding the magnetic properties of graphene, including mechanisms of spin lifetime and spin transport, and the role of adatoms in magnetic moment formation.

Stephen Niezgoda, Assistant Professor of Materials Science and Engineering and Mechanical and Aerospace Engineering, received a Young Faculty Award from the Defense Advanced Research Projects Agency (DARPA). This program provides funding, mentoring and industry and Department of Defense contacts to awardees early in their careers. Niezgoda's project is focused on developing the mathematics to properly quantify materials variability so that product designers and manufacturers can properly account for it through rational assignment of safety factors without the need to build and test multiple prototypes.

Susan Olesik, Dow Professor and department Chair of Chemistry and Biochemistry, was named to The Analytical Scientist's 2015 Power List, naming the top 100 most influential people in the world of analytical science. Olesik and her research group continue to contribute to the advancement of the speed of analysis using separation science and mass spectrometry in the future.

Junmin Wang, Associate Professor of Mechanical and Aerospace Engineering, has been elected to the SAE (Society of Automotive Engineers) Fellow grade of membership, the highest grade of membership recognizing long-term members who have made a significant impact on society's mobility technology through research, innovation and/or creative leadership. This SAE Fellow election recognizes Wang's pioneering and fundamental research in new control methods that allow substantial advances in the performance of engines, exhaust gas aftertreatment systems and vehicle chassis systems for conventional and electrified vehicles.

Jessica Winter, Professor of Chemical and Biomolecular Engineering and Biomedical Engineering, has been induced into The American Institute for Medical and Biological Engineering (AIMBE) College of Fellows for outstanding contributions in biomolecular engineering, particularly the synthesis and development of magnetic quantum dots for cell imaging and separations. The College of Fellows is comprised of the top two percent of medical and biological engineers in the country and its Fellows are recognized for their contributions in teaching, research, and innovation.

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IMR Keynote Address

Rechargeable Batteries for Electric Cars

John Goodenough
Virginia H. Cockrell Centennial Chair in Engineering
University of Texas at Austin

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