

INNOVATIONS IN MATERIALS RESEARCH

Newsletter of The Ohio State University Institute for Materials Research

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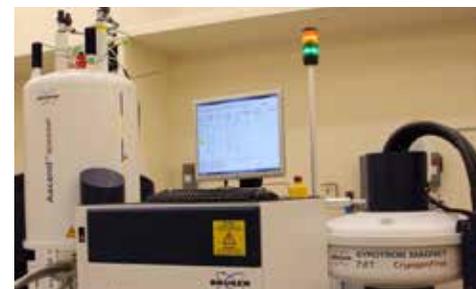
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OHIO STATE'S NEWEST MATERIALS LAB:

CCIC-NMR Facility

The Chemical and Biomolecular Engineering and Chemistry (CBEC) building on Ohio State's Columbus campus is now home to the newest materials research facility, the Campus Chemical Instrument Center (CCIC) Nuclear Magnetic Resonance (NMR) facility, one of only a few facilities to offer Dynamic Nuclear Polarization (DNP) capabilities in the United States.

While the CCIC facility has existed on Ohio State's Columbus campus since 1981, the opening of CBEC combined with capital investments from several sources (including the Technology-Enabling and Emergent Materials Ohio Research Scholar Program award won by IMR in 2008) allowed the NMR team to expand its capabilities, acquire new instrumentation and move some existing equipment to its new location. This large re-investment resulted in a new NMR facility housing five high resolution Bruker NMR spectrometers (600 to 850 MHz) with a range of capabilities including high-sensitivity cryoprobes for biomolecular studies, high-throughput sample changers for metabolomics, solid-state and DNP probes for biomolecules and materials, micro-imaging and diffusion. Three additional high-field instruments are available in the CCIC-NMR location in the Riffe Building on south campus.



> The CCIC-NMR facility's new 600MHz dynamic nuclear polarization (DNP) instrument

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FACULTY SPOTLIGHT:

Rafael Brüscheweiler, Chemistry and Biochemistry



Rafael Brüscheweiler joined The Ohio State University as a Professor of Chemistry and Biochemistry in August 2013. He is the Executive NMR

Director of the CCIC-NMR (Campus Chemical Instrumentation Center - Nuclear Magnetic Resonance) center and an Ohio Research Scholar hired through the Technology-Enabling and Emergent Materials (TEEM) Ohio Research Scholars Program award by the Ohio Third Frontier. He holds a joint appointment in the department of Biological Chemistry and Pharmacology at the College of Medicine. Before coming to OSU, he was the George

Matthew Edgar Professor of Chemistry and Biochemistry at Florida State University and the Associate Director of Biophysics at the National High Magnetic Field Laboratory in Tallahassee. Dr. Brüscheweiler received his Bachelor's and Master's degrees in Physics from ETH, Zürich, Switzerland, and his Ph.D. in Chemistry from the Laboratorium für Physikalische Chemie at ETH under the supervision of Prof. Richard R. Ernst.

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THE OHIO STATE
UNIVERSITY

INSTITUTE FOR
MATERIALS RESEARCH

DIRECTOR'S NOTE:

Dear Colleagues,

It is a great pleasure to welcome you to the Fall 2015 edition of the IMR's Innovations in Materials Research newsletter. So much has happened in our IMR community since our Spring issue. In May, the 2015 edition of our OSU Materials Week conference focused on topics related to the IMR-coordinated Materials & Manufacturing for Sustainability (M&MS) Discovery Theme program with a superlative set of external and internal speakers and more than 100 excellent student posters (pages 10-11). A few weeks later, we also hosted the first workshop between Ohio State and the Indian Institute of Technology, Bombay (IIT-Bombay), which will lead to global joint research projects, and during that same week we welcomed the 2015 Electronic Materials Conference and Device Research Conference (EMC/DRC) to Ohio State for the very first time! I am happy to report that all of these key events were tremendously successful and I cannot thank enough all who were involved with making those events happen.

The last few months also saw the arrival of the first newly hired M&MS Discovery Themes faculty members on campus – Prof. Farhang Pourbogat (Integrated Systems Engineering and Mechanical and Aerospace Engineering) and Prof. Ned Hill (Glenn College of Public Policy and Architecture). They are a fantastic addition to our community and are featured inside this issue (page 6). Ned and Farhang will help spearhead the M&MS thrust on advanced structural materials and manufacturing, which is a key area for growth of the OSU materials community.

I am also proud to report that our Ohio Research Scholars Program (ORSP) to create a cluster of excellence on Technology-Enabling and Emergent Materials (TEEM) is

now complete! With the fifth of five Research Scholars, Professor Rafael Bruschweiler, firmly in place at Ohio State and prominently featured in this issue, and the opening of the new Campus Chemical Instrumentation Center - Nuclear Magnetic Resonance (CCIC-NMR) facility under his direction, the TEEM cluster of excellence that includes faculty from OSU, University of Akron and the University of Dayton, is primed to fulfill its goal and impact the State's materials community as a whole. The opening of the new "virtualLearning" digital lecture theatre at the Center for Electron Microscopy and Analysis (CEMAS), led by Dave McComb, will be able to provide a world-unique "virtual-in-the-lab" education and training experience for electron microscopy to students from academia, industry and government labs. Details of this amazing, paradigm-shifting educational capability are also inside this issue (page 12).

As you can see, the IMR community continues to grow its impact and scope of innovation. I hope you enjoy reading about our highlights in this issue.



With warm regards,

Steven A. Ringel, Ph.D.

Neal A. Smith Chair Professor
Executive Director,
Institute for Materials Research
The Ohio State University

New IMR Members



Ayman Fayed is an Associate Professor of Electrical and Computer Engineering and founder and director of the Power Management Research Lab (PMRL). His current research interests include on-chip power grids for dynamic energy distribution in highly-integrated systems, high-frequency switching regulators with on-chip and on-package passives for SoCs, low-noise power supply modulators for RF transmitters, energy-harvesting platforms for power-restricted & remotely-deployed systems, and power conversion in emerging technologies. Dr. Fayed received his Ph.D. in Electrical and Computer Engineering from The Ohio State University and was on the Technical Staff at Texas Instruments and an Associate Professor of Electrical and Computer Engineering at Iowa State University.



Daniel Gallego Perez is Assistant Professor of Surgery with a joint appointment in Biomedical Engineering. His research focuses on biomaterials, micro/nanotechnology, and regenerative/repairative medicine, the micro- and nanoscale engineering of living cell microenvironments, and the use of micro- and nanoscale technologies for understanding and controlling cell behavior. Dr. Gallego Perez received his Ph.D. in Biomedical Engineering at The Ohio State University and was a Postdoctoral Resaercher with OSU's Nanoscale Science and Engineering Center for Affordable Nanoengineering of Polymeric Biomedical Devices (NSEC-CANPBD) and a Nanotech West Associate Staff Member responsible for photolithography training.



Denis Guttridge is a Professor of Molecular Virology, Immunology and Medical Genetics and director of Research and Management for Cancer Cachexia. Dr. Guttridge's laboratory studies the NF-kB family of transcription factors and the role they play in cell growth and differentiation. The long-term goal is not only to better dissect the function and mechanisms by which NF-kB regulates muscle differentiation and turnover associated with muscle disorders, but also to translate this information into a better understanding of the role of NF-kB in tumor development. He received his Ph.D. from the University of California, Irvine, and completed a postdoctoral fellowship at University of North Carolina, Chapel Hill prior to joining Ohio State.



Jenifer Locke is an Assistant Professor of Materials Science and Engineering, where she holds the DNV-Roger W. Staehle Designated Professorship. Dr. Locke's primary research interests are in environmental cracking and corrosion of metals and alloys, particularly advancing laboratory environmental cracking testing capabilities, quantifying and understanding metal/alloy and thermo-mechanical processing effects on occluded site electrochemistry in corrosion and environmental cracking of metals, and in inhibition of environmental cracking. She received her Ph.D. in Materials Science and Engineering from the University of Virginia where she was a Postdoctoral Research Associate before working at Alcoa Technical Center as a Senior Scientist and Staff Scientist.



Fang Luo is a Research Assistant Professor in the Electrical and Computer Engineering department. His research interests are in high power density converter/module design and packaging, wide bandgap device power electronics, and EMI and its noise filtering. Dr. Luo earned his Ph.D in Power Electronics at both Huazhong University of Science and Technology and Virginia Polytechnic Institute and State University, and prior to joining Ohio State he was research faculty member and a postdoctoral fellow with the Center for Power Electronics Systems at Virginia Tech.



Antonio Ramirez Londono is a Professor of Materials Science Engineering. Dr. Ramirez' research concentrates on the advanced characterization of materials ranging from structural to functional, particularly the study of metallic materials welded/joined using arc welding processes and solid state processes such as friction stir welding. He received his Ph.D. in Material and Metallurgical Engineering from Universidade de São Paulo and prior to joining Ohio State he was the Deputy Director of the Brazilian Nanotechnology National Laboratory and a Principal Researcher at the Brazilian Synchrotron Light Laboratory's Electron Microscopy Center.

> A researcher loads a sample into the 800 MHz Bruker NMR spectrometer



OHIO STATE'S NEWEST MATERIALS LAB: CCIC-NMR Facility

(continued from page 1)

Historically, much of the research taking place at CCIC NMR focuses on biomolecules in solution; however, the new instrumentation has added a variety of solid-state capabilities where researchers can analyze samples in various solid forms, such as crystals, micro-crystalline powders, and glasses. The new NMR instruments allow Ohio State researchers to characterize a wider range of materials, examine structures of many more nuclei, and conduct their experiments in a fraction of the time previously necessary. "What once took us a week to complete can now be done in just a day or even in a few hours," explained CCIC-NMR Research Scientist Alex Hansen. "Our facility now offers so much NMR capability that the average user will barely touch on the full range of what's capable. We want to elevate the science people conduct, whether it's in solid-state, DNP, metabolomics, or in solution."

samples up to 10 mm. The solution state probe has fluorine capabilities that allow researchers to investigate fluorinated samples and measure fluorine-fluorine or fluorine-hydrogen distances to better understand the fine structure of such materials. One Earth Sciences team is currently using this instrument to analyze the porosity of rock samples to determine how water travels into and out of different geological samples.

The newest instrument is a **600 MHz dynamic nuclear polarization (DNP) solid-state magnet**. One of the major hurdles in solid-state NMR is an inherent lack of sensitivity from static samples. DNP overcomes this by transferring magnetization from electron radicals to the nucleus of interest, enhancing the sensitivity several hundred times. CCIC's state-of-the-art DNP instrument is one of only a handful in the U.S., and the only one available at a shared NMR facility, giving Ohio State researchers a unique opportunity to perform materials research hundreds of times faster than previously possible.

On the biomolecular side, the facility staff have extensive expertise in protein structure and dynamics to offer to researchers interested in examining different proteins to determine their structure, identify active sites of molecules, and target sites for drug binding or protein-protein interactions. Researchers looking at RNA or DNA molecules can perform similar studies to determine how they behave, leading to advances in potential therapeutics. All of the facility's solution instruments are equipped with cryoprobes which increase sensitivity up to five-fold over conventional, room-temperature probes. For more information about the CCIC NMR Facility, visit: <http://www.ccic.ohio-state.edu/NMR>

Available Instruments in CCIC NMR Facility at 092 Chemical and Biomolecular Engineering and Chemistry (CBEC) building, 151 West Woodruff Avenue

Bruker Avance III HD Ascend 600 MHz
Bruker Avance III HD Ascend Wide-Bore 600 MHz with DNP
Bruker Avance III HD Ascend 800 MHz (NIH funded)
Bruker Avance III HD Aeon Wide-Bore 800 MHz
Bruker Avance III HD Ascend 850 MHz

Available Instruments in CCIC NMR Facility at 137 Riffe Building, 496 West 12th Avenue

Bruker Avance III HD Ultrashield 600 MHz
Bruker Avance III HD Ascend 700 MHz
Bruker Avance III HD 800 MHz

Some common nuclei we are able to study are ^1H , ^2H , ^6Li , ^{11}B , ^{13}C , ^{15}N , ^{17}O , ^{23}Na , ^{27}Al , ^{29}Si , and ^{31}P . However, one of our researchers is about to examine Sn NMR, so we're more limited by imagination than anything else.

– Alex Hansen, CCIC-NMR Research Scientist

The CCIC NMR facility's five research staff members – each with their own areas of expertise - are available to train and assist researchers or to provide full service consultation and analysis. These experienced professionals consult and collaborate with researchers in developing their project from sample preparation, e.g. by protein expression or metabolomics, to experimental design, NMR data collection and analysis. They also develop software and web servers for NMR data analysis and database query for CCIC-NMR users. While the facility already has approximately 100 users, the staff are excited to expand its user base and work with an even broader variety of researchers from Ohio State, industry, and other universities to fully explore the capabilities of the newest cadre of NMR instruments. "We foresee applications in polymers, ceramics, and semiconductors," said Tanya Young, Director of Research Support Services, "We're very excited and the sky's the limit on what we can do here."

Two pieces of equipment at the facility will be of particular interest to materials researchers. The **800 MHz NMR instrument** is a solid-state NMR allowing scientists to analyze the properties of molecules in various materials. This mixed-use instrument has a large number of probes such as a biomolecular solid-state probe and a microimaging probe to conduct MRI on small

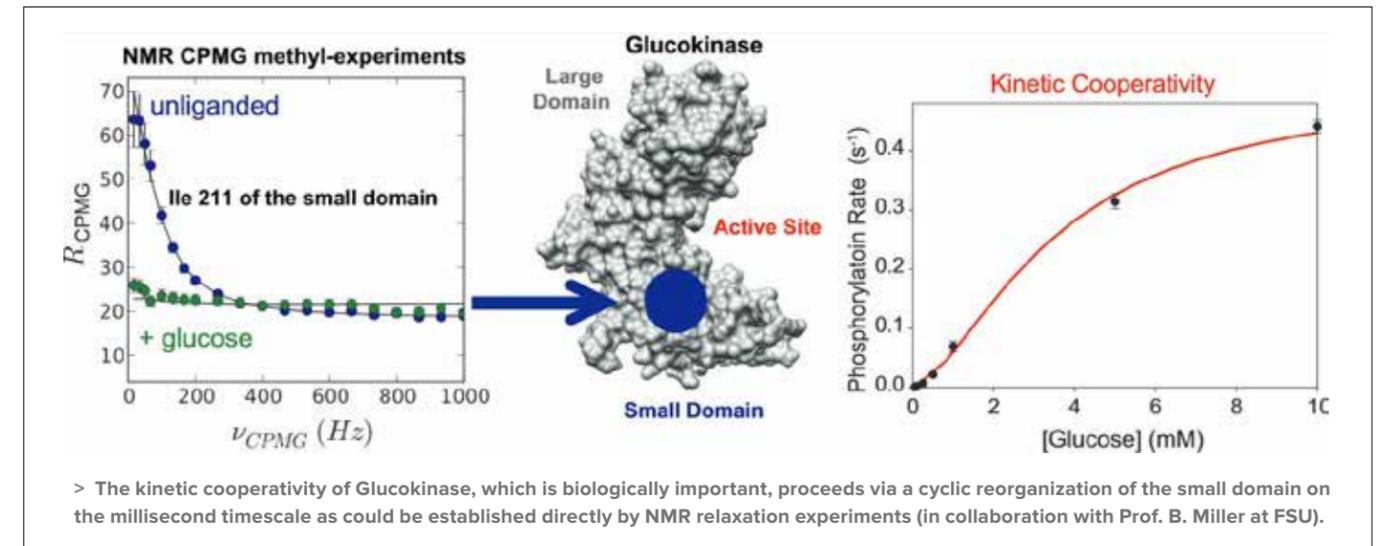
FACULTY SPOTLIGHT:

Rafael Bruschweiler, Chemistry and Biochemistry

(continued from page 1)

He was a postdoc at the Scripps Research Institute in La Jolla, Privatdozent at ETH, and the Carlson Chair of Chemistry & Biochemistry at Clark University. Among Dr. Bruschweiler's honors, he is a fellow of the American Physical Society (APS) and of the American Association for the Advancement of Science (AAAS). In 2006, he was awarded the Günther Laukien Prize for his work on covariance NMR.

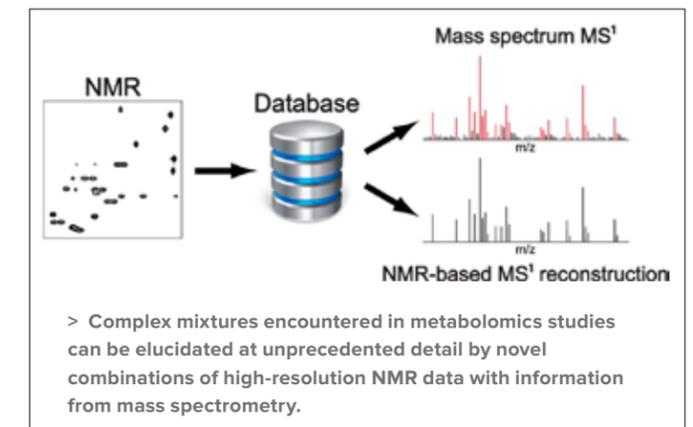
A second area of research is metabolomics, which encompasses the comprehensive characterization of the metabolite content in cells, organisms, and biofluids (Figure 2). Dr. Bruschweiler's lab develops new methods for the more accurate and more efficient analysis of such complex mixtures by the combination of NMR with computation and mass spectrometry without the need for extensive hyphenation by chromatography. These tools,



Since joining Ohio State, much of his efforts have gone to leading the CCIC-NMR team in the upgrade and expansion of the NMR center, which now houses nine Bruker state-of-the-art high-field NMR instruments distributed over two sites on north campus (CBEC building) and south campus (Riffe building). The instrument center, which was inaugurated at a symposium on October 3rd, supports research in a wide range of areas from structural biology and materials science to metabolomics, placing Ohio State at the leading edge of NMR science in the country.

Dr. Bruschweiler's own lab conducts research in physical chemistry, biochemistry, and analytical chemistry with application to biomedicine. Not surprisingly, the major research tools of his lab is nuclear magnetic resonance (NMR) spectroscopy together with high-performance computation. One of the central research themes in his lab is the characterization and understanding of protein dynamics by combining experimental studies of protein motions on a wide range of timescales from picoseconds to milliseconds with advanced computational methods, in particular molecular dynamics (MD) simulations that make heavy use of the Ohio Supercomputer Center. Questions of interest include the kinetic cooperativity behavior of the enzyme glucokinase (Figure 1), which is the primary glucose sensor in the human body, the role of dynamics in arginine kinase, and the allosteric regulation of ion transport in the sodium-calcium exchanger (NCX).

which are made publicly available via the COLMAR suite of web servers at <http://spin.ccic.ohio-state.edu/>, are being applied and sharpened through collaborations with numerous biomedical research groups who have specific questions and hypotheses that can be addressed with them.



Dr. Bruschweiler's research is supported by OSU, the state of Ohio, and through federal grants from the National Science Foundation and the National Institutes of Health. For more information, please visit his lab's web site at <https://research.cbcc.osu.edu/bruschweiler.1/>

M&MS Welcomes First Faculty Hires, Brundtland Sustainability Visit

The Materials and Manufacturing for Sustainability (M&MS) Discovery Theme focus area is an IMR-coordinated, university-wide program that was one of six proposals selected for funding in August 2014 through The Ohio State University's Discovery Themes Initiative. OSU's Discovery Themes Initiative is a comprehensive plan to target faculty hiring and stimulate interdisciplinary activity to address the grand challenges facing our society in the 21st century, namely, Energy and the Environment; Food Production and Security; and Health and Wellness. The Discovery Themes Initiative's goal is to accelerate OSU's rise from excellence to eminence by leveraging Ohio State's special strengths to address the technological, social, and environmental stresses that define today's global world.

The specific goal for the M&MS focus area is to enable Ohio State to become pre-eminent in the field of advanced materials for sustainability by building on existing interdisciplinary strengths in materials, world-class facilities and nationally-recognized centers of excellence, and by exploiting both industrial consortia and recent strategic investments that will enable an academically-driven discovery-to-deployment paradigm. Faculty will be hired in three general technology clusters with almost all being joint appointments between multiple departments: energy harvesting, storage and systems; high performance materials and structures; and materials for sustainable information processing, supported by hiring in business, policy and global awareness. The M&MS plan directly leverages the capacity and capabilities of IMR to ultimately establish an innovation ecosystem within which research can be converted into deployable products enabling a path toward global sustainability. Examples could include affordable solar photovoltaics, biocomposite structures, buildings from sustainable materials, energy-efficient power systems, non-degrading components, ultra-light vehicles and improved urban mining.

M&MS FACULTY HIRES

Through the careful and strategic recruitment and selection activities of the Materials and Manufacturing for Sustainability program's core team and stakeholders in several OSU departments and colleges, two new faculty joined The Ohio State University During at the start of fall semester 2015:



Ned Hill

Dr. Edward "Ned" Hill will hold a joint appointment with OSU's John Glenn College of Public Affairs and the College of Engineering, where he will teach economic policy, public policy and public finance. A distinguished economist and former Dean of the Maxine Goodman Levin College of Urban Affairs at Cleveland State University, Dr. Hill's contributions to the M&MS program fall in the areas of sustainable policy and economic development of high performance materials and structures. Dr. Hill will perform research and manufacturing policy guidance and engagement for the Center for Design and

Manufacturing Excellence and the Ohio Manufacturing Institute, research on factors that affect the competitive position of Ohio's manufacturing sector, workforce policy, and business strategy, and state and local economic development strategy and urban public policy.



Farhang Pourboghrat

Dr. Pourboghrat joins Ohio State as a Professor with joint appointments in the Integrated Systems Engineering and Mechanical and Aerospace Engineering departments, where he will enhance the M+MS program by working with the Center for Design and Manufacturing Excellence and the Lightweight Innovations for Tomorrow (LIFT) consortium in the area of sustainable materials forming and manufacturing. An expert in design and manufacturing with a focus on polymeric thermo-forming of novel composite materials, he has been very active in the field of computational crystal plasticity with applications to multiscale modeling. His work at Michigan State University and Alcoa has significant application to the light weighting of structures, particularly automotive, and his work in the fiber based polymeric sandwich materials and graphene nano-platelet composites are both innovative in concept and application.

GRO HARLEM BRUNDTLAND JOINS OHIO STATE'S SUSTAINABILITY DISCUSSIONS SEPTEMBER 28

Dr. Gro Harlem Brundtland, former Prime Minister of Norway and Chair of the United Nations World Commission on Environment and Development, recently visited Ohio State's Columbus campus for a powerful day of discussions and lectures addressing the challenges of global sustainability and dramatic climate change.

The morning began with a roundtable program on Responding to Global Challenges of Sustainability and Resilience: The Nexus of Science, Technology, and Society. Moderated by Elena Irwin, Professor of Agricultural, Environmental and Development Economics and faculty lead of the Sustainable and Resilient Economy Discovery Theme, the panel included Dr. Brundtland and Ohio State faculty involved in the leadership of OSU's Discovery Themes Initiatives. Dr. Brundtland explained that she had traveled directly from New York where she attended the United Nations Summit to adopt a new sustainable development agenda and a new global agreement on climate change. She repeated for the Ohio State audience the exact speech she had given to the United Nations just the day before. Each panelist then discussed sustainability issues from their academic area's perspective, then answered questions from the audience of Ohio State faculty, staff and students. Casey Hoy, Kellogg Endowed Chair in Agricultural Ecosystem Management and faculty lead of the Initiative for Food and AgriCultural Transformation (InFACT) Discovery Theme, spoke about the agricultural, biological and cultural impacts and goals of sustainability, such as supporting

small farmers in the developing world, who are responsible for over 80% of those regions' food sources. Cinnamon Carlarne, Professor of Law and member of the Faculty Advisory Board for the Energy and Environment theme, focused on international environmental law and its impact on sustainability, and the relationship of economic growth and industrial development with climate change. Steve Ringel, IMR Executive Director, Neal A. Smith Chair Professor of Electrical Engineering and faculty lead of the Materials and Manufacturing for Sustainability (M&MS) Discovery Theme, gave an engineering viewpoint on the need to have sustainable processes in technology and manufacturing.

Later that day, Dr. Brundtland delivered the Provost's Discovery Themes Lecture, *Global Sustainability and the 21st Century*. This lecture, attended by several hundred audience members, was followed by a more casual discussion with retired WOSU talk show host Fred Anderhle. During this event Dr. Brundtland reviewed



her work over the last few decades to bring attention to climate change, and how climate change has now elevated as a global concern, guiding policy and pushing leaders to sign agreements to make policy changes. She gave examples of the successful public-private partnerships in Norway, such as the popularity of Tesla's electric vehicles in the country, largely due to the Norwegian government's commitment to establishing incentives such as high carbon and gas taxes and the elimination of pay tolls for electric vehicles. She outlined goals to address climate change and the need for public funds targeted to supporting those goals. Dr. Brundtland also emphasized her belief that inequalities – both economic inequities and inequities in consumption - must be overcome for sustainability efforts to work. She feels that 2015 will be a crucial year for sustainability efforts, testing our abilities to impact climate change.

> IMR Executive Director Steve Ringel, Gro Harlem Brundtland, Casey Hoy, Elena Irwin, and Cinnamon Carlarne were panelists at the Roundtable Program on September 28.

In Summer of 2015 the OSSIP Executive Advisor Board approved a system of \$2,000 matching (1:1) grants to Ohio industry for the use of Nanotech West facilities. These grants can be used to "jump start" projects that can result in new high-tech products. Two companies have already successfully applied and received grants, and the program requires only a one-page proposal outlining the proposed work and its projected outcomes to apply.

The OSSIP budget also contains \$400k in capital investments for Nanotech West. The first investment was in a materials-flexible tube furnace for the cleanroom. The second investment, which is starting at the time of this writing, is a flexible optical test setup. The latter is intended especially for external quantum efficiency (EQE) testing of IR devices but will also be used for EQE of photovoltaic devices, dark current measurements of detectors, and other optical and electro-optical measurements. This capability will be available to users in the late Winter or Spring of 2016.

OSSIP Elevates Sensor and Semiconductor R&D in Ohio

The Ohio Sensor and Semiconductor Innovation Platform (OSSIP) Program is a \$2.54 million, three-year program awarded in June 2013 by the Ohio Third Frontier Program through the Ohio Development Services Agency (ODSA). Its primary goal is to help Ohio companies create jobs through the development of new "high tech" products. It is currently funding two full engineering positions located at the Nanotech West Lab, and OSSIP activities involve the entire NTW staff.

The initial two "clients" of the program have been L-3/Cincinnati Electronics (Mason, OH) and Srco Inc. (Columbus, OH). The partnership with L-3/CE is focused on the development of high-definition infrared (IR) focal plane arrays, including development of new epitaxial materials using the Aixtron metalorganic chemical vapor deposition (MOCVD) tool located at NTW. The partnership with Srco is focused on electro-optic modulators and sensors based on lithium niobate and other niobate-based materials. In fact, the partnership between OSSIP and Srco, in only its first 14 months, resulted in a new electro-optic product for Srco (see photo).



> As a result of its work with OSSIP, SRICO introduced a Periodically Poled Lithium Niobate (PPLN) waveguide for fiber-based frequency combs and spectroscopy. The product integrates a PPLN waveguide with input and output fibers, a thermoelectric cooler for temperature stabilization, and a robust metal package. The waveguide is designed to accept a super-continuum light source in the 2000 nm wavelength region and outputs a frequency-doubled signal centered at 1064 nm.

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 |



Spin-orbit Coupling and Magnetism in Correlated Transition Metal Oxides Workshop

CEM co-sponsored a workshop titled Spin-orbit Coupling and Magnetism in Correlated Transition Metal Oxides, held May 3-7, 2015 at The Ohio State University. The workshop invited scientists with diverse expertise studying the interplay of spin-orbit coupling and correlations in transition metal oxides, which leads to novel metallic, magnetic and topological states. The topics included recent advances in materials, measurements, phenomena, theory and computation. Pedagogical tutorials, discussion sessions, and poster sessions were included in addition to the invited talks. A total of 75 individuals attended the workshop, with 29 speakers from the U.S., Canada, China, France, Germany, India, Japan, and Switzerland.

Kawakami Hosts Mini-Workshop: Spin Pumping in Magnetic Heterostructures

Prof. Roland Kawakami (IRG-2) hosted a mini-workshop this summer on Spin Pumping in Magnetic Heterostructures. It featured talks by leading experts including Paul Crowell and Michael Flatté, in addition to talks from OSU professors Ezekiel Johnston-Halperin, Fengyuan Yang, and Chris Hammel. Topics included subtle but important questions within the field: When are spin pumping signals real, and how are they distinguished from spurious signals?

CEM Kicks Off 2015 Science Sunday Lecture Series, Hosts Dr. Jeff Childress (HGST)

Science Sundays, a free lecture series open to the public, provides a wide range of current and emerging topics and issues in science that touch our everyday lives. Speakers are experts in their fields from on campus and around the world with experience in making their topics interesting and accessible for audiences of all ages, with or without a science background.



CEM kicked off this year's program by hosting Dr. Jeff Childress, Research Director at HGST (a Western Digital company in San Jose, California). His talk, "Science and technology of data storage," was widely attended at the Ohio Union and well-received. Childress articulated the needs and mechanics of data storage throughout our information age with hands-on hard drives, meaningful analogies and visual aids, history, humor, and science. The Science Sundays schedule is available at <http://artsandsciences.osu.edu/research/science-sundays>

| HONORS AND AWARDS |

Goldberger Receives Camille Dreyfus Teacher-Scholar Award

Prof. Josh Goldberger (IRG-2) joins an elite group of 13 of the country's top young chemical sciences researchers named 2015 Camille Dreyfus Teacher-Scholars. Selection is based on a body of significant scholarship established during the first five years of their research careers and a demonstrated commitment to education.

Trivedi Receives Awarded 2015 Simons Fellowship in Theoretical Physics

Prof. Nandini Trivedi (IRG-1) was awarded a prestigious Simons

Fellowship for the 2015-2016 school year. The Simons Foundation funds faculty for up to one semester of research leave in order to increase creativity and provide intellectual stimulation. Prof. Trivedi will spend the coming school year conducting research from India.

Assoc. Director Winter Honored in "Forty Under 40"

CEM Associate Director, Prof. Jessica Winter, was named to Columbus Business First annual Forty Under 40 list. Out of more than 350 nominations, Prof. Winter was recognized as an up-and-coming professional and community leader for the city of Columbus. Read more at Columbus Business First.

| EDUCATION AND OUTREACH |

CEM and New Mexico Highlands Awarded PREM Funding from NSF

In June, CEM and New Mexico Highlands University (NMHU) were awarded a Partnership for Research and Education in Materials (PREM) grant from the NSF. Prof. Ezekiel Johnston-Halperin (IRG-2) is the co-PI. The objective of the PREM program 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.

As part of the PREM, two new materials science courses will be designed at NMHU in collaboration with OSU. Multiple exchanges will take place during the course of the program, with CEM participants delivering guest lectures and seminars at NMHU, as well as multiple visits by NMHU students and faculty to conduct research or participate in the CEM Research Experience for Undergrads (REU) program. NSF facilities will be used directly and to provide expert advice to NMHU from NSF staff. Additionally, there will be a PREM Annual retreat alternating between Las Vegas, NM and Columbus, OH.

Success and Volunteering at Science Day 2015



The CEM's Science Day- a yearly culmination of the Scientific Thinkers program- was held in May at Innis Elementary School in Columbus. This year, the science-themed field day boasted 49 undergraduate and graduate STEM volunteers, including 13 CEM students and 1 CEM faculty (Kawakami). Science Day is a school-wide event where teachers and students devote one day to learning science by rotating through approximately 15 exciting hands-on lessons or "laboratories." Favorite labs this year included water rockets, geodesic domes, a chemistry show, homemade silly putty, hands-on bugs, and many more.

Welcome New Bridge Students



> Bridge students and program mentors.

This autumn, the CEM and OSU Department of Physics welcome two new students to the M.S.-to-Ph.D. Bridge Program: Bruce Barrios and Martha Nunez Ornelas. The OSU-BP is structured as a two-year transitional M.S. program for students with B.S. or B.A. degrees that show strong promise for research. Three students from the first cohort are now in the physics Ph.D. program at OSU, and two students from the second cohort are on track for acceptance in the OSU Physics Ph.D. program. Currently, three Bridge Fellows work with CEM faculty: Emilio Codecido (Myers),

> CEM Graduate student Maxx Arguilla (Chemistry) interacting with students at Innis Elementary

2015 OSU Materials Week Celebrates Materials Innovations

Since 2008, the IMR has hosted Materials Week, an annual conference that brings together hundreds of researchers from OSU, other universities, national and government labs, and private industry. This event includes plenary sessions, technical talks, and poster sessions covering the full spectrum of materials-allied research.

2015 OSU Materials Week welcomed over 300 attendees, featured 114 student posters, and had significant non-local participation from academia and industry with representatives from 31 universities, government labs and industry collaborators. The conference has been a very successful event for enabling collaborations, sharing innovative research, and celebrating Ohio State's materials community.

IMR KEYNOTE ADDRESS

Sunlight-Driven Hydrogen Formation by Membrane-Supported Photoelectrochemical Water Splitting



Nathan S. Lewis, *California Institute of Technology*
George L. Argyros Professor of Chemistry; Principal Investigator, Beckman Institute Molecular Materials Resource Center;
 Scientific Director, Joint Center for Artificial Photosynthesis (U.S. Department of Energy's Energy Innovation Hub)

2015 OSU Materials Week had a special focus on sustainability, with a total of 41 scientific presentations in eight sessions:

- Two Crosscutting Sessions on **Materials and Sustainability: An Industry Perspective**
- Six Focus Sessions
 - **Sustainable Energy Harvesting and Storage**
 - **The Role of Materials in a Sustainable and Resilient Economy**
 - **Energy Efficient Systems**
 - **Materials for Sustainable Design**
 - **2D Emergent Materials**
 - **Design and Manufacturing**



STUDENT POSTER AWARDS

This year, OSU students presented over 100 research posters during Materials Week's two poster sessions. Each student's work was evaluated by volunteer judges, and the ten best posters were selected and recognized during an awards ceremony.

- **Jessica Alexander**, Materials Science and Engineering, "Variable Angle Spectroscopy and Electron Energy-Loss Spectroscopy of Organic Photovoltaic Materials," Advisor: David McComb, Materials Science and Engineering
- **Katja Binkley**, Chemical and Biomolecular Engineering, "Electrocatalytically-Assisted Oxidative Dehydrogenation of Lower Alkanes in a Solid Electrolyte Reactor," Advisor: Umit Ozkan, Chemical and Biomolecular Engineering
- **Samartha Channagiri**, Materials Science and Engineering, "Low Loss Electron Energy Loss Spectroscopy Investigations of the Aging Mechanism in LiFePO₄ Battery Cathodes Resulting from Prolonged Electrochemical Cycling," Advisor: David McComb, Materials Science and Engineering
- **Eric Coleman**, Chemistry and Biochemistry, "The Complex Inhibiting Role of Surface Oxide in the Oxygen Reduction Reaction," Advisor: Anne Co, Chemistry and Biochemistry
- **Julia Deitz**, Materials Science and Engineering, "Site-Specific TEM Specimen Preparation of Samples with Sub-Surface Features," Advisors: Tyler Grassman, and David McComb, Materials Science and Engineering
- **Chen Ge**, Material Science and Engineering, "Self-Assembled Nanostructures on Ceramic Oxide and Metal," Advisors: Sheikh Akbar and Suliman Dregia, Materials Science and Engineering
- **Jacob Jensen**, Materials Science and Engineering, "STEM-HAADF and Super-X™ XEDS Tomography of Complex Nano-scale Precipitates in High Entropy Alloys," Advisor: Hamish Fraser, Materials Science and Engineering
- **Stephanie Lauback**, Physics, "Magnetically-Actuated Escherichia coli System for Micro Lithography," Advisor: Ratnasingham Sooryakumar, Physics
- **Brelon May**, Materials Science and Engineering, "Three-Dimensional Lattice Matching for Epitaxially Embedded Nanoparticles," Advisor: Roberto Myers, Materials Science and Engineering
- **Derek Miller**, Materials Science and Engineering, "STEM-Cathodoluminescence Studies of Oxide Nano-heterostructure Interfaces," Advisor: Sheikh Akbar and Patricia Morris, Materials Science and Engineering



IMR Member News



Bharat Bhushan, Ohio Eminent Scholar and Howard D. Wingbiger Professor of Mechanical and Aerospace Engineering, was selected for the 2015 BITS Distinguished Alumnus Award by his alma mater, Birla Institute of Technology & Science, Pilani, India in recognition of his significant contributions to the engineering profession and to society.



Anne Co, Assistant Professor of Chemistry and Biochemistry, has been awarded a Faculty Early Career Development (CAREER) grant from the National Science Foundation for her work on "Control of Surface Reactivity for Catalyzing Hydrocarbon Formation From CO₂" by the NSF Division of Chemistry. The \$651,729 award will expand her lab's research on advanced electrocatalytic materials for chemical conversion and energy storage.



Liang-Shih (L-S) Fan, Distinguished University Professor and C. John Easton Professor in the William G. Lowrie Department of Chemical and Biomolecular Engineering, has been named the American Institute of Chemical Engineers (AIChE) Institute Lecturer for 2015. Fan will present AIChE's 67th Institute Lecture on November 22, 2015 at the organization's annual meeting. The Lectureship is awarded to a distinguished AIChE member who has made significant contributions to the chemical engineering sciences in his or her field of specialization. Fan is being cited for his ground-breaking inventions of next-generation clean carbonaceous chemical looping energy conversion processes for carbon dioxide emission control and chemicals production; for his invention of the electrical capacitance volume tomography (ECVT) technology used commercially worldwide for multiphase flow imaging; and for major research, education, and service contributions to particle science and technology.



Joshua Goldberger, Assistant Professor of Chemistry and Biochemistry, was awarded a 2015 Camille Dreyfus Teacher-Scholar Award, one of only 13 awarded nationally. The program supports the research and teaching careers of talented young faculty in the chemical sciences who have attained an independent body of scholarship within the first five years of their research and have demonstrated a strong commitment to education. Goldberger's will receive a \$75,000 unrestricted research grant to further support his research on the design of new materials that synergistically unite and organize inorganic and organic components for applications in energy conversion and medicine.



Yiyang Wu, Professor of Chemistry and Biochemistry, was included in Midwest Energy News' inaugural "40 Under 40" list, which highlights emerging leaders throughout the Midwest and their work to accelerate America's transition to a clean energy economy. Midwest Energy News is a nonprofit news site reporting changes taking place as the Midwest shifts from fossil fuels to a clean energy system.





> The new digital theater at CEMAS

Semiconductor Epitaxy and Analysis Laboratory (SEAL)

SEAL Adds MBE Chamber for Two-Dimensional Material Exploration



> The new 2D materials MBE chamber is guided down Neil Ave toward the SEAL facility.

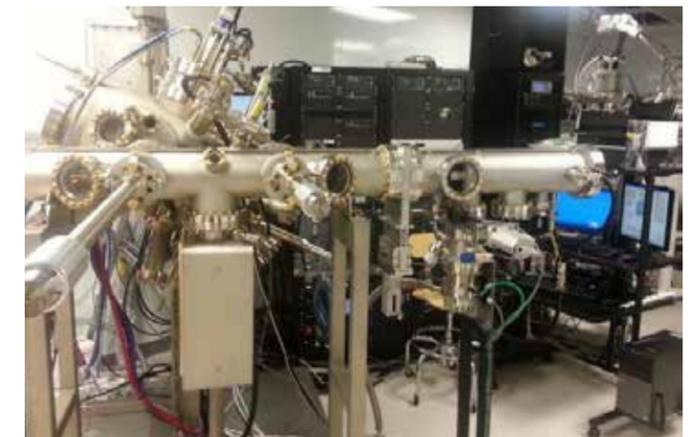
A new molecular beam epitaxy (MBE) chamber is a recent addition to SEAL's epitaxy facility. Acquired through a National Science Foundation grant awarded to Siddharth Rajan, Associate Professor of Electrical and Computer Engineering, the Veeco Gen 930 MBE chamber enhances SEAL's cadre of instrumentation by offering

two-dimensional semiconductor material exploration. While the main focus will be toward 2D growth of MoWSe₂ based materials, discussions are underway to also investigate GaSe and GaTe along with other accompanying materials. Additionally, Roberto Myers, Associate Professor of Materials Science and Engineering,

is developing an optical Raman setup for this system to provide real time in-situ analysis of the 2D materials growth.

The chamber is currently on site and students and staff working toward completing the full facility installation. Evaporation equipment is on order and material research is scheduled to begin as early as mid-November.

For questions or inquiries concerning this equipment, contact SEAL lab manager, Mark Brenner (brenner.34@osu.edu).



> MBE chamber installed in the SEAL facility.

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.

cemas.osu.edu

Center for Electron Microscopy and Analysis (CEMAS)

CEMAS Adds "Virtual Learning" Digital Lecture Theater

Construction is wrapping up on a brand new digital lecture theater at the Center for Electron Microscopy and Analysis (CEMAS), OSU's state-of-the-art facility housing over \$29 million of advanced microscopy instrumentation. This virtual learning environment will revolutionize electron microscopy teaching and further advance our leadership in materials characterization.

CEMAS's instruments offer critical insights to researchers in diverse fields such as medicine, advanced manufacturing, environmental science, energy harvesting/storage, and healthcare, making it essential to expose students and researchers to their capabilities. The new digital theater will create a unique "virtual learning environment" – a critical technology as instrument sensitivity will always limit the number of learners in the instrument room to 3-4 people.

The new learning environment will allow local and non-local participants to interact with state-of-the-art electron microscopes in a fully integrated manner that will result in a paradigm shift in the teaching of electron microscopy. The classroom provides unprecedented opportunities for outreach of STEM research and education to high schools, museums, conference, HBCUs and smaller teaching colleges.

Video wall technology is used to provide multiple display screens and projectors allowing simultaneous display of microscope controls, microscope outputs and lecture slides. This enables students and lecturers to interact with and operate electron microscopes from within the digital theater in a live, seamless manner – as if one were sitting in front of the instrument. The seating plan is designed such that control of the microscope can be transferred to members of the audience using wired and wireless connectivity.

The control of the microscopes can be shared with students and lecturers at geographically distant locations. This is achieved via direct connection to the OARnet flagship program, a 100Gb/s network designed to extend into the education, healthcare, public broadcasting and government communities. More than 1,850 miles of fiber create the network backbone. The network creates the platform for delivered shared services and connects to the Internet2 high-speed network throughout the United States. There are currently high quality audio and visual streaming with three remote sites. Funding for the digital theater was kindly provided by the College of Engineering, Materials Science and Engineering, Institute for Materials Research, and CEMAS. This investment secures the position of CEMAS as the premier center for electron microscopy learning and research in the United States of America.

NanoSystems Laboratory (NSL)



> Corinne Rubright, NSL Program Assistant

The NanoSystems Laboratory (NSL) recently welcomed a new staff member, Ms. Corinne Rubright, who joins us as a new Program Assistant. Originally from Akron, Ohio, Corinne moved to Columbus in 2011 and received her undergraduate degree in Strategic Communication from The Ohio State University. After one year in IT sales, she returned to the university after a positive experience working as a student assistant in the Psychology Department. When not at work, you will find

Corinne loudly cheering on the Buckeyes, going to gallery hops in the Short North, and frequenting Columbus' great concert venues. Please contact Corinne if you are interested in becoming an NSL user, need BuckID access to one of NSL's labs, to schedule trainings, or if you need to purchase PPMS accessories, cantilevers, and other lab supplies. She can also answer all of your NSL billing questions and assist users with the online reservation system. Corinne 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 rubright.4@osu.edu

ensl.osu.edu



> Team IMR Veni Velo Vici Crossing the Peletonia finish line

nanotech.osu.edu

Nanotech West Laboratory

Team IMR – Veni Velo Vici - Finishes Peletonia Charity Ride

Institute for Materials Research members at the Nanotech West (NTW) Lab formed a peloton for Pelotonia 2015 and raised over \$15,000 for Cancer Research at The James Cancer Hospital and Solove Research Center. “Team IMR” – Veni Velo Vici was comprised of 7 IMR members and 6 friends and family. Riders from IMR/NTW were Derek Hansford and Aimee Price and “virtual riders” John Carlin, Robert Davis, Derek Ditmer, David Hollingshead, and Mary McCleery. Other members of the team were George Conti, Mark Corroto, Melinda Corroto, Kristen Huener Henney, John Price, and Kevin McCleery. The riders all pedaled 100 miles on their bicycles on August 8 from downtown Columbus to Kenyon College, finishing triumphantly together. Team IMR needs more riders, virtual riders, and volunteers for 2016. If you are interested in helping Team IMR break its goal of \$16,000 in 2016 contact Peloton Captain and IMR Member of the Technical Staff Aimee Price at price.798@osu.edu.

Nanotech West Lab and NanoSystems Lab Complete 2015 Annual Laboratory Safety Retraining

In the Summer of 2015 Nanotech West Lab and the IMR-Affiliated NanoSystems Lab completed the safety retraining of over 150 Columbus-area users and staff. Users who had previously had a full-hour session were required to take only a half-hour session refresher/update, while users outside of the Columbus area are being retrained as they visit if they were not able to attend a session.

On a related topic, Nanotech West Director Bob Davis became Chair of the OSU University Laboratory Safety Committee, a ~20 person committee organized by the OSU Office of Environmental Health and Safety. The committee is examining laboratory safety practices across all of OSU and its first task was to create a “safety culture survey” to be distributed online to a sampling of OSU lab workers in Fall 2015.

Spotlight: Nanotech West Lab Document System

The IMR Nanotech West Lab (NTW) Document System was begun in 2007 to formalize documentation of the entire lab. The system has an ISO-9001 “flavor” to it although NTW does not intend at this time to pursue certification. There are 6 classes of documents in the system: A- (Admin); C- (Chemical); E- (Engineering), O- (opspec), Q- (Quality), and S- (Safety) documents. Each hyphen is followed by a three-digit number. The goals of the system are manifold - to collect and store knowledge; to better train and inform users and staff in the proper operation of equipment and chemical handling; and to show student users what to expect when they graduate and start jobs, especially those in the private industry sector. All documents pertinent to users were made available online (before, they were emailed and/or handed printed copies) in 2014. When appropriate, Nanotech West has also shared its documents - particularly safety documents - with other labs on campus to be modified to suit their particular needs.

2015 OSU Materials Research Seed Grant Program

After a thorough internal and external review process, 9 awards have been made to fund innovative and exciting materials research on campus through the 2015 OSU Materials Research Seed Grant Program. These awards total \$420,000 in internal research funding to 15 OSU researchers in 5 departments. The program was able to fund 47% of the proposals submitted this year; 9 out of a total 19. Congratulations to the nine research teams whose projects were selected this year for seed grant funding.

The OSU Materials Research Seed Grant Program provides internal research funding opportunities through two distinct Funding Tiers designed to achieve the greatest impact for seeding and advancing excellence in materials research of varying scopes. The OSU Materials Research Seed Grant Program is jointly funded and managed by the Center for Emergent Materials (CEM), the Center for Exploration of Novel Complex Materials (ENCOMM), and the Institute for Materials Research (IMR).

2015 MULTIDISCIPLINARY TEAM BUILDING GRANTS

Multidisciplinary Team Building Grants form multidisciplinary materials research teams that can compete effectively for federal block-funding opportunities. Three Multidisciplinary Team Building Grants were awarded this year:

DNA Devices for Probing Nanoscale Physics of Fluids

PI: Carlos Castro, Mechanical and Aerospace Engineering; Co-Investigators: Michael Poirier, Physics; Shaurya Prakash, Mechanical and Aerospace Engineering; Soheil Soghrati, Mechanical and Aerospace Engineering

Studies of Dopant Dynamics Using Microscopy at Atomic Length and Femtosecond Time Scales

PI: Jay Gupta, Physics; Co-Investigator: Enam Chowdhury, Physics

Skymions in Low-Dimensional Chiral Magnets

PI: Mohit Randeria, Physics; Co-Investigators: Roland Kawakami, Physics

2015 EXPLORATORY MATERIALS RESEARCH GRANTS

Exploratory Materials Research Grants enable nascent materials research to emerge to the point of being competitive for external funding. Six Exploratory Materials Research Grants were awarded this year:

Investigating Crystallization Mechanisms of Microporous Materials Using Ion Mobility-Mass Spectrometry

PI: Nicholas Brunelli, Chemical and Biomolecular Engineering

First-Principles Study of Dislocation Core Structures and Properties in Multi-Principal-Element Alloys

PI: Maryam Ghazisaeidi, Materials Science and Engineering

Direct Imaging of Atomic Scale Electromagnetic Fields in Functional Materials

PI: Jinwoo Hwang, Materials Science and Engineering

Developing Electrodes for Hydrogen Production Based on Robust Biological Catalysts

PI: Hannah Shafaat, Chemistry and Biochemistry

Exploration of the Anomalous Hall Effect at Terahertz Frequencies

PI: Rolando Valdés Aguilar, Physics

Development of Epitaxial Film Growth of Group V-VI Topological Insulators by Molecular Beam Epitaxy

PI: Fengyuan Yang, Physics

Interested in our next seed grant funding cycle?

The 2016 OSU Materials Research Seed Grant Program is now accepting letters of intent.

Deadlines

Letters of Intent: December 7, 2015
Full Proposals: March 21, 2016

For full proposal preparation instructions, visit any of the following websites:

cem.osu.edu
imr.osu.edu
encomm.osu.edu



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SAVE THE DATE:

2016 OSU Materials Week

May 10 – 13, 2016

Join us for 2016 OSU Materials Week, the annual showcase of materials-allied research at The Ohio State University and beyond.

2016 OSU Materials Week will be held May 10-13, 2016 at the Blackwell Inn and Conference Center on Ohio State's Columbus campus.

For more information, including confirmed speakers, registration details, and schedules for past Materials Week conferences:

<http://imr.osu.edu/seminarsandevents/materials-week/>

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