THE OHIO STATE UNIVERSITY

INSTITUTE FOR MATERIALS RESEARCH

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FISCAL YEAR 2015 ANNUAL REPORT

Acknowledgments

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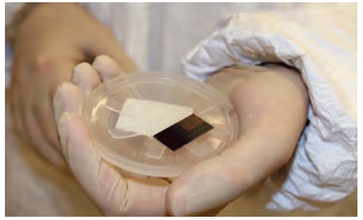
Dear Colleagues:



I am proud to welcome you to read this year's annual report that highlights the many activities and exciting new programs within The Ohio State University Institute for Materials Research – IMR. This has been a banner period for the IMR community both externally and internally. Not only did it see the development and awarding of the Materials and Manufacturing for Sustainability (M&MS) Discovery Theme Initiative (DTI), one of seven DTI programs started at The Ohio State University in the areas of Energy and the Environment, Health and Wellness, and Food Production and Security, but the past year also saw the successful renewal of the Center for Emergent Materials (CEM), Ohio State's NSF-supported Materials and Research Science and Engineering Center (MRSEC), with more than 50% increase in its scope and funding, the creation of a formal partnership for shared research programs with the Indian Institute of Technology-Bombay, the rapid acceleration of activities surrounding the Center for Electron Microscopy and Analysis (CEMAS) as a world-leading center in microscopy, the addition of the Semiconductor Epitaxy and Analysis Laboratory (SEAL) as a formal member of the IMR constellation of core research facilities, and the hiring of the last of five Ohio Research Scholars within our state-funded Technology-Enabling and Emergent Materials (TEEM) program. Additionally, IMR hosted a very successful 2015 OSU Materials Week conference devoted to technologies, science and policy surrounding the development of materials products for clean energy and sustainability, and IMR landed and coordinated the 2015 Electronic Materials Conference and Device Research Conference (EMC/DRC), the first time the renowned EMC/DRC have been held at Ohio State in the 50+ years of its existence, which was kicked off by the 2014 Nobel Prize winner in Physics.

This has been a banner period for the IMR community both externally and internally.

At a more programmatic level, our research activities are thriving. The OSU Materials Research Seed Grant Program awarded ten new grants totaling $460,000 to 25 researchers from ten departments, 23 IMR Facility Grants were awarded to support IMR faculty usage of core facilities, targeted workshops covering topics such as materials for energy and sensor applications and spin-orbit coupling and magnetism were hosted, and certainly not least, the new sponsored projects awarded during FY 2015 to IMR's 222 faculty members exceeded $72 million.

With all that our community has accomplished, you may have missed the major overhaul of the presentation of this year's IMR annual report. We have worked to create a much fresher, simpler, highlight-first approach that we believe will enhance our ability to show off all the great activities and successes of the IMR community. On behalf of the entire IMR staff and faculty, I hope you will enjoy reading about us.

With best regards,

Dr. Steven A. Ringel
Neal A. Smith Endowed Chair Professor

Executive Director
Institute for Materials Research
The Ohio State University

The Institute for Materials Research (IMR) provides vision, coordination and support to advance multi-college excellence and impact in materials-allied research. IMR is the gateway to materials-allied research at The Ohio State University.

Funded by the Office of Research, College of Engineering and the College of Arts and Sciences, the IMR was created in 2006 as the campus-wide, multidisciplinary institute to nurture, grow and support excellence in materials research at OSU, assist the advancement of research team development, and provide strategic planning, resource, infrastructure, and educational activities.

IMR SUPPORTS OHIO STATE'S MATERIALS COMMUNITY THROUGH:

- Strategic leadership
- Intercollege coordination
- Multi-university relations
- Management of major research facilities
- Seed funding and facility access funding
- Promotion of industry partnerships
- Infrastructure support and development
- Development and administration of major research programs and centers
- Scientific educational programs and annual conference
- Faculty recruitment

Fiscal Year 2015 Figures

MEMBERSHIP

222
IMR members

In **7** colleges

From **26** departments

PUBLICATIONS

12.42
publications per IMR member average FY 15[1]

304.52
citations per IMR member average FY 15[2]

EXTERNAL FUNDING

IMR members served as Principal Investigators on sponsored projects

with awarded budgets just over **$397 MILLION,**

of which **$72.45 MILLION** were new projects[3]

Industry R&D Expenditures: Ohio State – 4th nationally

($110.6 MILLION)[4]

Engineering R&D Expenditures: OSU – 5th nationally in materials

($29.365 MILLION)[4]

1. Google Scholar 2. Web of Science 3. Office of Sponsored Projects, The Ohio State University 4. National Science Foundation Figures (NSF Higher Education Research and Development Survey (HERD), Fiscal Year 2013 data, released February 3, 2015 http://ncsesdata.nsf.gov/herd/2013/

Discovery Themes Initiative: Materials and Manufacturing for Sustainability

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. A critical element of M&MS is that stakeholders will engage within a Materials Innovation Greenhouse (MIG) that will serve as an innovation collaboratory connecting science to technology to industry, with a scope that is regional, national and global through the development of expansive partnerships.

The Discovery Themes Initiative focuses on critical societal needs, leveraging Ohio State's special strengths to address the technological, social, and environmental stresses that define today's global world.

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. While hiring the right faculty hiring is certainly central, establishing the MIG with exceptionally skilled "technology integrators" who can enable the innovation collaborations needed between small and large companies, faculty and students in an open innovation ecosystem is essential. Our expectation is to coordinate the MIG development with the existing Center for Design and Manufacturing Excellence (CDME) so that the innovation and deployment components can be accelerated, which is essential for the M&MS to maximize its impact.

FISCAL YEAR 2015 ACTIVITIES AND ACCOMPLISHMENTS

Currently the implementation plans of each Discovery Theme program are being developed, and IMR leadership is working closely with a core team of representatives from throughout the OSU materials community to enact the M&MS mission. The core team meets regularly for strategic and programmatic development, and to move forward an aggressive hiring plan to fill up to thirty new faculty positions, with two positions already filled and an ambitious goal of completing this first hiring wave of twelve faculty positions in the next fiscal year. M&MS has already moved fast on its programmatic development as well. On the global interaction front, collaborations with several companies, universities and government agencies in India have begun, expanding the M&MS scope globally. Internal leadership and administrative positions are being filled to meet the challenge of the M&MS growth plan. To encourage rapid engagement, IMR programmed the 2015 OSU Materials Week conference to reflect the primary technology domains of the M&MS plan in sustainable materials to further synthesize the M&MS agenda into the OSU materials community. We have also opened an Executive in Residence position shared between IMR and the College of Engineering which will focus on rapid engagement with industry partners globally.

M&MS LEADERSHIP TEAM

- **Steven A. Ringel,** Executive Director, Institute for Materials Research and Neal A. Smith Endowed Chair in Electrical Engineering
- **John Bair,** Executive Director, Center for Design and Manufacturing Excellence
- **Glenn Daehn,** Fontana Professor, Materials Science and Engineering
- **Chris Hammel,** Director, Center for Emergent Materials and Professor and Ohio Eminent Scholar, Physics
- **Marty Kress,** Assistant Vice President of Research Business Development
- **Layla Manganaro,** Program Manager, Institute for Materials Research
- **Dave McComb,** Ohio Research Scholar and Professor, Materials Science and Engineering
- **Susan Olesik,** Department Chair and Professor, Chemistry and Biochemistry
- **Giorgio Rizzoni,** Director, Center for Automotive Research and Ford Motor Company Chair, Mechanical and Aerospace Engineering

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 will join The Ohio State University 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 on 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. Farhang Pourboghrat joins Ohio State as a Professor with joint appointments in the Integrated and 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.

International Collaborations – Focus on India

The Institute for Materials Research and OSU's materials community have many vibrant, international collaborations, such as joint research activities in electronic oxide materials and III-V compounds for optoelectronics with the Institute of Optoelectronics Systems and Microtechnology (ISOM) of the Universidad Politécnica de Madrid (UPM), and the Center for Emergent Materials' ongoing partnership with Leibniz Institute for Solid State and Materials Research (IFW Dresden). This year, IMR expanded its international network by forging new connections with materials-allied colleagues in India, resulting in an international medical conference, the signing of an MOU by IIT-Bombay and Ohio State, and a materials science IITB-OSU joint workshop. IMR continues to work with OSU's India Gateway office and others to stimulate research collaborations between OSU's materials community and researchers and industry partners in India, as the umbrella organization for Ohio State materials research. These collaborations with Indian colleagues is also an important focus of the Materials and Manufacturing Sustainability Discovery Theme.

INITIAL IMR-INDIA DISCUSSIONS (FEBRUARY AND APRIL 2014)

In February 2014, IMR Executive Director Steve Ringel spent a week in India, in collaboration with OSU's India Gateway, for a series of meetings with industrial executives and academic leaders across India for the purpose of establishing meaningful linkages between the OSU materials community and Indian companies and universities. Meetings were held with OSU alumni in academia and industry in Chennai, Bangalore and Mumbai, including discussions with Larsen and Toubro, Kiran Energy Solar Power, several divisions of the Tata Group of companies, Indian Institute of Technology-Bombay, Indian Institute of Technology-Madras and the Indian Institute of Science in Bangalore. During his visits, Dr. Ringel gave several presentations on the strengths and breadth of the OSU materials community and discussed areas of mutual research and innovation interests. Based on the success of Dr. Ringel's visit, the IMR in turn hosted a delegation from leading Indian companies in the materials and energy sectors, who visited Ohio State's Columbus campus April 2014. Leaders from these Indian companies toured research facilities and met leaders from the State, Columbus and the University to further discuss opportunities of mutual benefit to all parties.

OHIO STATE AND ITT-BOMBAY SIGN HISTORIC AGREEMENT (JANUARY 2015)

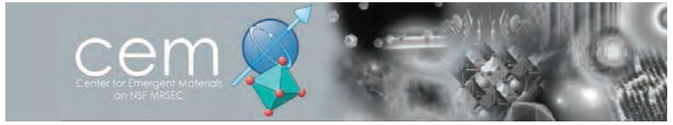
In January 2015, a delegation from The Ohio State University, including OSU President Michael Drake and IMR Executive Director Steve Ringel, traveled to Mumbai, India to formalize a partnership between The Ohio State University and the Indian Institute of Technology – Bombay. Leaders of both institutions – President Drake and IIT-B Director Dr. Devang Khakhar – signed a Memorandum of Understanding formalizing a strategic partnership building on the two universities' complementary strengths and assets, beginning with first wave focus areas of advanced materials and manufacturing, solar energy, semiconductor devices and bioengineering, and a commitment to fold in data analytics over time. Participants from both universities quickly acted on these commitments and began planning joint scientific workshops and exchange programs of their faculty and research scholars.

IITB-OSU COLLABORATIVE WORKSHOP (JUNE 2015)

In June 2015, IMR hosted Materials for Energy and Sensor Applications, the first IITB-OSU joint workshop focusing on advanced materials and manufacturing, solar energy, semiconductor devices and bioengineering. This workshop included tours of IMR's four core research facilities, presentations from 19 IITB and OSU faculty, and networking opportunities. The goal of the workshop was to share information between the two universities' researchers about research activities in fields where there may be obvious synergies, such as photovoltaics. Collaborations have already begun as a result of the two-day meeting, and the group will soon pursue joint activities to fund students, seed research funding, and exchange scholars. Notably, two weeks after this workshop, a joint IITB-OSU team developed and submitted a funding proposal to the U.S. Mission to India's Public Diplomacy Programs to further support ongoing collaborations between the two universities.

Center for Emergent Materials

National Science Foundation Materials Research Science and Engineering Center (NSF MRSEC)



In December 2014, the National Science Foundation (NSF) announced it renewed funding for Ohio State's Center for Emergent Materials (CEM): an NSF Materials Research Science and Engineering Center (MRSEC). 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. The six-year, $17.9 million grant funds Ohio State's adventurous, long-term studies of forward-looking new materials that are on the very edge of the possible.

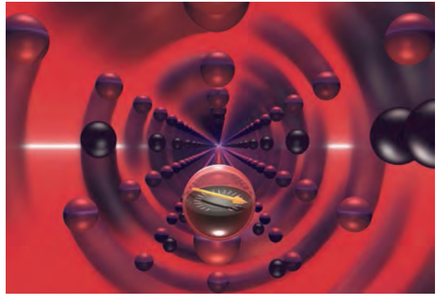
After a rigorous, uber-competitive review process, only 12 MRSECs were funded. These NSF Flagship institutions form a national network of top materials research programs at top research institutions — Princeton, Harvard, MIT, Ohio State — capable of performing complex and ambitious multi-disciplinary sciences.

It would be difficult to overstate the benefits that the Center for Emergent Materials' infrastructure investments have Ohio State and the state of Ohio during its initial six-year funding phase. Eleven Ohio companies have benefited directly from the availability of cutting-edge materials' research tools that the CEM-supported NanoSystems Laboratory provides to university and industrial researchers. Two of the three projects funded by the NSF grant were developed through the integrated OSU Materials Research Seed Grant Program. Seed grants complement IRG research by supporting emerging developments in materials research. The program also identifies and nurtures future leaders, which extends CEM impact beyond IRG membership.

One of CEM's goals is to increase the quantity and quality of scientists and engineers prepared to contribute to and lead research, development and commercialization in materials-related fields. CEM researchers are doing that through focused, coordinated and sustained activities that engage groups extending from elementary school students through faculty ranks. Initiatives include using cognitive research to enhance classroom education, and providing undergraduates with immersive, authentic research experiences.

Diversity enhancement efforts are tightly interwoven with every educational and outreach activity, and the CEM is committed to increasing diversity in science and engineering by eliminating barriers to the success of underrepresented groups.

The NSF grant renewal funds three powerful Interdisciplinary Research Groups led by proven research teams poised to make breakthrough discoveries:



Spin-Orbit Coupling in Correlated Materials: Novel Phases and Phenomena, is co-led by physicist Nandini Trivedi, and chemist Patrick Woodward. The group has a long record of successful collaboration, establishing fundamentals for understanding and prediction in this area. It includes physicists, chemists and materials science engineers from Ohio State, Iowa State and the University of Tennessee. The grand aim is to design a new class of tailored quantum materials with tunable magnetic and electric properties that would impact technology and society.

Control of 2D and 1D Electronic Structure by Surface Functionalization of Group-IV Graphane Analogues, is co-led by chemist Joshua Goldberger and physicist Roland Kawakami. Group members are leading experts in creating and manipulating single-atom sheets. The team includes chemists, electrical and computer engineers, materials science engineers and physicists from Ohio State, UC-Berkeley, and Case Western. The flexibility of these new materials will find broader applications in science and technology including new opportunities in materials by design, platforms for chemical sensing and information processing.

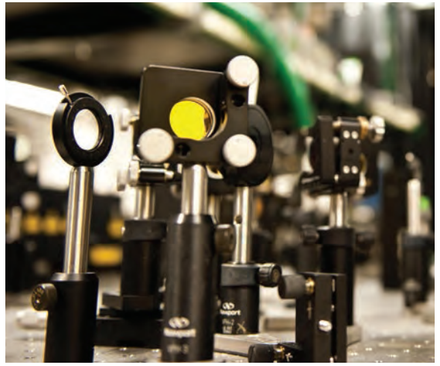
Nonlinear Interactions between Spin Flux and Engineered Magnetic Textures, is co-led by Jos. Heremans, mechanical and aerospace engineering and physics; and physicist Fengyuan Yang. Group members are leaders in the theory of spin dynamics and dynamic spin transport and include physicists, mechanical engineers, materials science engineers and electrical and computer engineers from Ohio State, Iowa and UCLA. This research could enable transformative technologies that move beyond current spintronics concepts and technologies.

"This is not about short-term funding that has clearly-defined achievable goals. Rather, the focus is on adventurous, foundational research that enables far-reaching technologies. Great science is the heart of this funding"

— P. CHRISTOPHER HAMMEL, Ohio Eminent Scholar, physics professor and director of the Center for Emergent Materials, NSF MRSEC

Technology-Enabling and Emergent Materials

Ohio Third Frontier Ohio Research Scholars Program



In 2008 an $18.1 million Ohio Research Scholars award in advanced materials from the Ohio Department of Development was announced, creating a university coalition consisting of The Ohio State University, the University of Akron and the University of Dayton. Five endowed chairs with the title of Ohio Research Scholar were established – three at OSU and one each at the University of Akron and the University of Dayton.

The goal of this program, entitled **Technology-Enabling and Emergent Materials**, is to pioneer revolutionary approaches to accelerate the development of materials for technological impact, by evaluating emergent materials at an early stage through the application of advanced characterization and predictive modeling. By targeting the Scholars positions toward advanced microscopy, including applications toward biomaterials, chemical synthesis from bio-based sources, and scalable processing based on nanostructure-enhanced composite and also bio-based materials, this unique cluster aims to build upon and coordinate strategic strengths existing at the partnered universities in areas of international impact. A prime area of focus is the exploration and development of innovative materials that possess tailored functionalities and are derived from nontraditional (including bio-based) sources, with the state's universities and industries being the prime beneficiaries.

This program pioneers revolutionary approaches to accelerate the development of materials for technological impact.

KATRINA CORNISH, OHIO RESEARCH SCHOLAR IN BIO-BASED EMERGENT MATERIALS

Dr. Cornish is an expert in alternative natural rubber production, properties and products, and on natural rubber biosynthesis in general. Her research focuses on bioemergent materials including exploitation of opportunity feedstocks from agriculture and food processing wastes for value-added products and biofuels. She joined OSU in July 2010, leading a multidisciplinary team in the creation of innovative industrial materials from plant-based sources and associated biological, chemical and physical processes and she trains new scientists and engineers for the emerging global bio-based economy. Dr. Cornish holds joint appointments with the Department of Horticulture and Crop Science and the Department of Food, Agricultural and Biological Engineering. She is based on the Wooster campus of the Ohio Agricultural Research and Development Center (OARDC) – which is the research arm of CFAES and the largest university agricultural bioscience research facility in the United States.

DAVID MCCOMB, OHIO RESEARCH SCHOLAR IN NANOSCALE MATERIALS CHARACTERIZATION

Dr. McComb's research concentrates on the development and application of nanoanalytical electron microscopy techniques for the study of chemistry, structure and bonding at the interfaces of atoms. His work also includes the synthesis of novel, multifunctional three-dimensionally ordered solids. Since joining OSU in October 2011 from Imperial College London, Dr. McComb has established OSU's Center for Electron Microscopy and Analysis (CEMAS), a major materials research facility with the highest concentration of high-end micropes in North America. CEMAS is a hub for business and academia materials characterization and home to $28 million of equipment, including 10 FEI electron microscopes, two X-ray diffractometer systems, facilities for nanoindentation, and an extensive array of sample preparation facilities. instrumentation in North America. McComb also serves as an IMR Associate Director, a key leadership position within the IMR where he contributes to institute's strategic planning and operations.

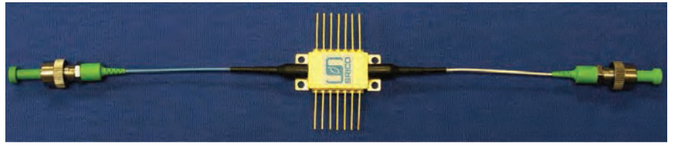
RAFAEL BRÜSCHWEILER, OHIO RESEARCH SCHOLAR IN ORGANIC SYNTHESIS

Dr. Brüschweiler's research is highly cross-disciplinary in the area of biophysical chemistry as well as analytical chemistry, focusing on the understanding of the role of dynamics and thermodynamics of proteins properties for their function and on the analysis of complex biological mixtures in the context of metabolomics. The main research tools are high-field nuclear magnetic resonance (NMR) and high-performance computation, which includes the development of new and improved techniques. Since joining OSU in September 2013 from Florida State University, he has established the NMR Laboratory, a nuclear magnetic resonance imaging center set to open October 2015. The NMR is a state-of-the-art, campus-wide core facility that houses eight high resolution Bruker NMR spectrometers (600 to 850 MHz) with a range capabilities: high-sensitivity cryoprobes for biomolecular studies, high throughput sample changers for metabolomics, solid state probes for biomolecules and materials, micro-imaging and diffusion. Dr. Brüschweiler holds joint appointments in the Department of Chemistry and Biochemistry and the College of Medicine.

NITA SAHAI, OHIO RESEARCH SCHOLAR IN POLYMER SCIENCE, UNIVERSITY OF AKRON

Dr. Nita Sahai joined the University of Akron during Fall 2011 as an Ohio Research Scholar and Professor of Polymer Science within the College of Polymer Science and Polymer Engineering. Dr. Sahai is an expert on biomolecule and cell interactions at mineral surfaces, environmental geochemistry, biomineralization, and biomaterials. Dr. Sahai's research falls within the field of interfacial biogeochemistry, which includes medical mineralogy and biomineralization, bioceramics, and environmental geochemistry. Specific research projects she and her group work on include the self-assembly of phospholipids as model cell membranes at mineral surfaces, cell adhesion to mineral surfaces, protein-mediated biomineralization of calcite, silica and apatite, bone growth on silicate bioceramic prosthetic implants, and biomimetic silica synthesis. Sahai was previously at the University of Wisconsin-Madison, where she was a professor of geochemistry in the Materials Science and Environmental Chemistry and Technology programs. As a University of Wisconsin member of the NASA Astrobiology Program, her research was also involved in understanding biomineral morphologies as potential biosignatures on Mars.

Ohio Sensor and Semiconductor Innovation Platform (OSSIP) Program



The state of Ohio's Innovation Platform Program awarded the Ohio State University Institute for Materials Research (IMR) funding to establish the Ohio Sensor and Semiconductor Innovation Platform (OSSIP) Program in July 2013. The OSSIP program builds on current and past successes in enabling technology advancement and capitalizes on existing best practices, one-of-a kind infrastructure in Ohio, and already-trained staff engineers and technicians to enable new partner companies to advance near term product development in the area of infrared sensors and semiconductor-based devices and materials.

Based in OSU's Nanotech West Lab, the $2.54 million, three-year award partners OSU with Ohio industry to create high-tech jobs in the state, with a specific goal to commercially market new products within the 3 years of the program. OSSIP leadership includes Principal Investigator Dr. Robert J. Davis, IMR Associate Director and Director of Nanotech West Lab, and co-investigators Dr. Steven A. Ringel, IMR Director and Neal Smith Chair Professor of Electrical Engineering, and Dr. John Carlin, Associate Director of Nanotech West Lab.

This award was funded by the Ohio Third Frontier's Innovation Platform Program (IPP), which supports operating and capital equipment needs to benefit an entrepreneurial and commercial purpose. IPP collaborations are formed to further the near-term commercialization of specific or platform technologies with significant, defined market opportunities. A major goal of the Ohio Third Frontier is to build strong commercialization and innovation capabilities and capacities in defined technology areas within the state's colleges and universities and nonprofit research organizations that support the needs of Ohio industry.

FISCAL YEAR 2015 ACTIVITIES AND ACCOMPLISHMENTS

- Hired two full-time engineers to provide technical expertise to support the research and development efforts of Ohio companies tackling their most challenging nanotechnology problems
- Offered matching grants to facilitate the research and development efforts of Ohio companies
- Collaborated with Srico Inc. to develop advanced processing techniques to enable a suite of custom electro-optic modulator (EOM) products for the telecommunications market
- Working with L-3/Cincinnati Electronics to develop process technology for its next generation of infrared (IR) focal plane arrays (FPA) to revolutionize spectral sensitivity without compromising bandwidth for military and civilian surveillance applications
- Partnered with other Ohio companies in micro- and nanofabrication process development, and has independently developed new photolithography, thin film deposition, and etching processes for all Nanotech West Laboratory users

Advanced Structural Materials for Sustainable Transportation and Manufacturing

Advances have been made in four key programs connecting university researchers with manufacturing partners to achieve groundbreaking materials innovations and deploy research to the private sector. ALMMII and LIFT, the Center for Design and Manufacturing Excellence, the Ohio Manufacturing Institute and the project team on an Alcoa Foundation award all work together as part of the overall integrated advanced manufacturing plan developed by Ohio State's College of Engineering.

In 2010, the Ohio Board of Regents named The Ohio State University as a Center of Excellence in Materials, Manufacturing Technologies and Nanotechnology, aligning the university with manufacturing from the perspective of the State of Ohio. To that end, the Ohio Manufacturing Institute (OMI) was organized to service the needs of Ohio manufacturers by connecting these needs with the resources available at OSU, including faculty expertise, student resources, labs, and equipment, to provide technical solutions through teamed research and development projects. One of the earlier IMR-OMI actions was the successful creation of a strategic partnership with Alcoa Foundation in 2011, resulting in research support for innovative research in lightweight vehicle structures by OSU faculty and students. In 2014, The Ohio State University, along with Columbus-based EWI and the University of Michigan, co-founded a consortium of universities, companies and nonprofits to establish a $148 million high-tech manufacturing research institute, the American Lightweight Materials Manufacturing Innovation Institute (ALMMII). That same year, the Center for Design and Manufacturing Excellence (CDME) was formed to increase the overall competitiveness of manufacturing firms globally and establish OSU as the preeminent leader in manufacturing innovation.

CENTER FOR DESIGN AND MANUFACTURING EXCELLENCE
CDME.OSU.EDU

The Center for Design and Manufacturing Excellence's (CDME) primary mission is to facilitate mutually beneficial interactions between the manufacturing industry and The Ohio State University's research and teaching faculty, staff and students to promote innovation and advances in design, commercialization and manufacturing using the most advanced technology by creating a collaborative platform involving leading industry participants worldwide and Ohio State. Created in 2014, CDME is The Ohio State University's center for integrated design, manufacturing and manufacturing-related commercialization, developed with a vision of integrating manufacturing design and development assets from the entire University, across multiple colleges and departments. In doing so, the Center offers global OEM's, small and medium sized businesses and entrepreneurial/startup companies with the unique ability to draw value from the University at large throughout the entire lifecycle of their products from fundamental research to applied manufacturing.

Advanced Structural Materials for Sustainable Transportation and Manufacturing *(continued)*

The second half of FY 2015 marked the true launch of CDME, beginning with a program award by the U.S. Department of Defense's Office of Economic Adjustment of approximately $7.3 million dollars. The program's purpose is to create an environment that both helps the product portfolios of the defense manufacturers so they become more competitive in the global market-place and help small companies and startups grow, creating a robust environment for the human capital that is required for defense manufacturing, keeping the skills and resources in the state to support future defense manufacturing needs.

In another project, the CDME and key industry partners identified multi-material joining as a needed area of research in order to facilitate implementation of lightweight materials and composites and to allow for increased flexibility of manufacturing without the use of spot-welding. Together with partners of Honda Research America, Honda EGA, Böllhoff Fasteners, and Ashland Adhesives, the CDME plans to utilize Böllhoff's proprietary RIVTAC® technology, along with Ashland, to develop a robotic system to implement a dual multi-material joining process comprised of both adhesive and high-speed tack technologies.

LIGHTWEIGHT INNOVATIONS FOR TOMORROW (LIFT) OPERATED BY ALMMII **LIFT.TECHNOLOGY**

In partnership with the University of Michigan and Edison Welding Institute, The Ohio State University proposed and won the competition for the Lightweight and Modern Metals Institute in the National Network of Manufacturing in 2014, a commitment of $70 million from the federal government matched by $78 million in cost-share. The resulting institute, monitored by the Office of Naval Research, is centered in technology and workforce development for advanced lightweight metals components that will reduce the energy use and improve sustainability in land, air and sea vehicles. Lightweight Innovations for Tomorrow (LIFT), operated by the American Lightweight Materials Manufacturing Innovation Institute (ALMMII), has significant activities both in technology development and developing a world-class manufacturing workforce.

The technology development focuses on projects that are in the 'valley of death' of Manufacturing Readiness Levels 4-7 for the metal systems that include high strength steels, aluminum alloys, magnesium alloys and titanium alloys. Projects are organized around pillars such as thermomechanical processing, casting, coatings, agile manufacturing, joining and powder processing. Projects are cooperative between the three core institutions and a network of many other universities, most of which are clustered near the I-75 corridor. As the best metallurgists in the country are associated with this institute, the prospects for important technical developments are great.

The workforce development aspect of LIFT is as important as the technical development. Projects are based on documented industry needs and a holistic group of programs including pipeline building from K-12 and stackable certificates from "K to grey" with multiple educational on and off ramps are being developed by LIFT and in partnership with other thought leaders. Coupled with the technology development, this offers a great opportunity for manufacturing-based economic development.

OSU-ALCOA FOUNDATION PARTNERSHIP IN ADVANCING SUSTAINABILITY RESEARCH

In July 2011, IMR was the recipient of a $400,000 development grant by the Alcoa Foundation in support of innovative design and manufacturing technologies and research in the area of material lightweighting for transportation applications, as part of Alcoa Foundation's $4 million "Advancing Sustainability Research: Innovative Partnerships for Actionable Solutions" initiative that funds 10 global sustainability research projects in Australia, Brazil, Canada, China, Russia and the United States. OSU researchers pursued technologies that will significantly reduce greenhouse gas emissions and the area of high performance multi-material joining for vehicle mass reduction – high velocity conformal interference joining and high velocity impact welding through the vaporizing foil actuator approach. Based on the initial success of this program, the Alcoa Foundation provided an additional $200,000 grant in 2013 to further support innovative design and manufacturing technologies that will enable the creation of lighter, more environmentally friendly vehicle structures.

The results from the Vaporizing Foil Actuator Welding (VFAW) are of particular importance, as this technology offers a unique and important method of joining high strength similar or dissimilar metals without weakening the metal, as is common in fusion welding. Further, techniques have been demonstrated to make this method quite practical. These successful results have enabled several new awards, including a Department of Energy Breakthroughs in Joining Program award of $550,000, a National Science Foundation Major Research Instrumentation award of $450,000, an additional NSF research award of $300,000, and several industrial programs.

OHIO MANUFACTURING INSTITUTE

The mission of the Ohio Manufacturing Institute (OMI) is to make the technical resources of The Ohio State University easily accessible to industry and to facilitate their use for economic development. This is achieved by teaming industry needs with university assets such as faculty expertise, student engagement, and access to university labs and test equipment. As an example, OMI engaged faculty to help a manufacturer improve their resistance flash butt welding process on a new series of lug-to-cable assemblies for automotive battery cables.

Based on the institute's experience in addressing manufacturing needs, OMI received state funds to build an Ohio Advanced Manufacturing Technical Network to support manufacturers with existing resources, including university research centers, community colleges, technical centers, public/private labs and Manufacturing Extension Partnerships. OMI also leads industry engagement efforts for the Department of Higher Education's Ohio Innovation Network, an online interactive tool to make university resources more easily available and to establish research relationships between industry and academia. Finally, a state grant was awarded to OMI for a co-located internship program in advanced and lightweight manufacturing with individual or teams of students supervised by faculty mentors working together to solve pressing industry problems.

Research Enhancement Program

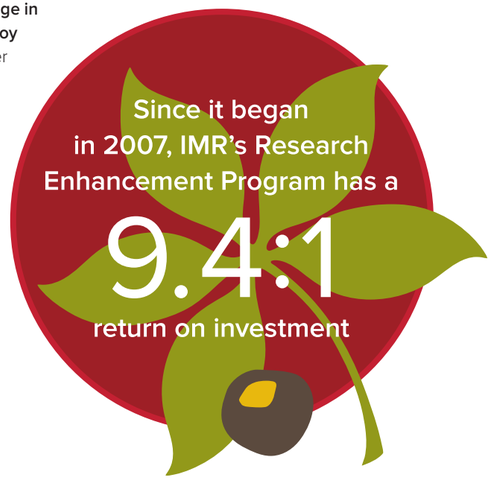
INTERNAL RESEARCH FUNDING

One of IMR's key directives is to enhance materials research activities at The Ohio State University through direct funding support to OSU researchers. IMR's Research Enhancement Program includes several mechanisms to internally support collaborative teams and encourage highly innovative individual research. Funding decisions within each category are based on competitive peer review, often using external reviewers. This year, IMR managed two Facility Grants competitions and co-coordinated the 2014 OSU Materials Research Seed Grant Program. In addition, an IMR Industry Challenge Grant was awarded to Jinsuo Zhang, Associate Professor of Nuclear Engineering, to support his work with an undisclosed industry collaborator.

IMR FACILITY GRANTS

IMR Facility Grants provide $2,000 to assist OSU faculty with facility user access fees and related minor charges associated with conducting innovative materials-allied research. The IMR typically offers two rounds of IMR Facility Grants each fiscal year, with deadlines in the fall and spring. This fiscal year, IMR was able to award 23 new Facility Grants, for a total investment of $46,000.

- **Second Harmonic Generation (SHG) and Confocal Reflectance Microscopy (CRM) for Imaging Collage,** Gunjan Agarwal, Biomedical Engineering
- **Optimizing Schottky Contact for Silicon Carbide Alpha Particle Detectors,** Thomas Blue, Mechanical and Aerospace Engineering; Co-Investigator: Lei Cao, Mechanical and Aerospace Engineering
- **Identifying Nucleation and Growth Intermediates for Zeolite Crystalization,** Nicholas Brunelli, Chemical and Biomolecular Engineering
- **Three Dimensional Imaging of Point Defects in Functional Materials Using Quantitative Scanning Transmission Electron Microscopy,** Jinwoo Hwang, Materials Science and Engineering
- **Investigation of "Microalloying" Effect in Precipitation Strengthening in Lightweight Magnesium Alloy,** Alan Luo, Materials Science and Engineering
- **Improved Wirebond Multichip SiC Power Module for Harsh Environment,** Fang Luo, Electrical and Computer Engineering
- **Site Specific TEM Specimen Preparation of Devices with Sub-Surface Feature,** David McComb, Materials Science and Engineering
- **STEM-Cathodoluminescence Studies of Oxide Nano-heterostructure Interfaces,** Patricia Morris, Materials Science and Engineering
- **Directing Cancer Cell Migration through Non-Contact Induced Electric Fields in Confined Microfluidic Channels,** Jonathan Song, Mechanical and Aerospace Engineering; Co-Investigator: Vish Subramaniam, Mechanical and Aerospace Engineering
- **Construction of Broadband THz Quarter Wave Plate,** Rolando Vales Aguilar, Physics
- **Multiscale Characterization of Degradation Mechanism in LiFePO4 Battery Cathodes with Prolonged Electrochemical Cycling** – Marcello Canova, Mechanical and Aerospace Engineering; Collaborators: Frank Scheltens and Robert Williams, Center for Electron Microscopy and Analysis
- **Intrinsic Radiation Detection Characteristics of Gallium Nitride** – Lei Cao, Mechanical and Aerospace Engineering
- **Nanoparticle Actuators for DNA Nanomachines** – Carlos Castro, Mechanical and Aerospace Engineering; Co-PI: Jessica Winter, Chemical and Biomolecular Engineering
- **Nanoscale Structure and Dynamics of Supercooled Glass Forming Liquids** – Jinwoo Hwang, Materials Science and Engineering
- **Development and Characterization of Novel Ferromagnetic Transition Metal Dichalcogenides Grown through Chemical Vapor Deposition** – Ezekiel Johnston-Halperin, Physics
- **High-Resolution Valence-Loss EELS Mapping of Oxide Nano-heterostructure Interfaces** – Patricia Morris, Materials Science and Engineering
- **Novel Plasma Synthesis of Heteroatom Doped Carbon Nanostructures for Highly Active Oxygen Reduction Reaction Catalysts for PEM Fuel Cells** – Umit Ozkan, Chemical and Biomolecular Engineering; Co-PI: Nicholas Brunelli, Chemical and Biomolecular Engineering
- **Dissimilar Materials Joints Exploration through TKD and Nanoidentation** – Antonio Ramirez, Materials Science and Engineering; Co-I: Boian Alexandrov, Materials Science and Engineering
- **Imaging Skyrmions in Low-Dimensional Chiral Magnets with Image-Corrected Lorentz Microscopy** – Mohit Randeria, Physics; Co-I: Robert Williams, Center for Electron Microscopy and Analysis
- **Quantification of 3-D Extracellular Matrix Fiber Remodeling in a Microphysiological Model of Tumor Stroma Activation** – Jonathan Song, Mechanical and Aerospace Engineering
- **Spin Excitations Coupling with THz Metamaterials** – Rolando Valdes Aguilar, Physics
- **Study on Mechanistic Understanding of the Environmental Damage in a Ni-based Turbine Disk Alloy** – Gopal Viswanathan, Center for Electron Microscopy and Analysis
- **Microstructure and Pitting Corrosion Resistance of Used Nuclear Fuel Welded Stainless Steel 304 Canisters** – Jinsuo Zhang, Mechanical and Aerospace Engineering

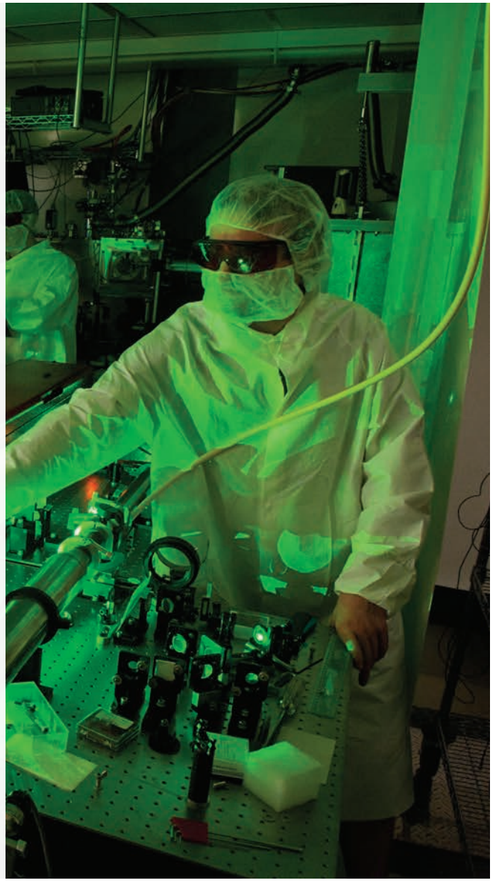


Research Enhancement Program (continued)

2014 OSU MATERIALS RESEARCH SEED GRANT PROGRAM

The OSU Materials Research Seed Grant Program provides internal research funding opportunities through three distinct Funding Tiers designed to achieve the greatest impact for seeding and advancing excellence in materials research of varying scopes: Proto-IRG grants for large teams, Multidisciplinary Team Building grants for smaller teams, and Exploratory Materials Research grants that target higher risk, individual investigator grants with a bias toward junior faculty members. The seed program is jointly funded and managed by IMR along with the Center for Emergent Materials NSF MRSEC and the Center for Exploration of Novel Complex Materials (ENCOMM). Created in 2011, it leverages resources and best practices from the seed programs of the three organizations to achieve the greatest impact for seeding excellence in materials research of varying scopes.

After a thorough internal and external review process, ten awards were made to fund innovative and exciting materials research on campus through the OSU Materials Research Seed Grant Program this fiscal year — three Multidisciplinary Team Building Grants and seven Exploratory Materials Research Grants, the most awarded in the program's four years. These ten awards total $460,000 in research funding to 25 OSU researchers in ten departments from four colleges, as well as two external collaborators.



2014 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 $60,000 each this year:

- **Ultrastructural and Ultrasensitive Characterization of Iron-overload,** PI: Gunjan Agarwal, Biomedical Engineering; Co-Investigators: Dana McTigue, Neuroscience; David McComb, Materials Science and Engineering; Collaborators: Eric Kraut, Hematology; John Moreland, National Institute of Standards and Technology
- **In-situ Solid-State NMR for Battery Studies,** PI: Anne Co, Chemistry; Co-Investigator: Philip Grandinetti, Chemistry
- **Group-III Nitride Nanowires for High-Efficiency Hydrogen Production via Photocatalytic Water Splitting,** PI: Tyler Grassman, Materials Science and Engineering; Co-Investigators: Roberto Myers, Materials Science and Engineering; Patrick Woodward, Chemistry

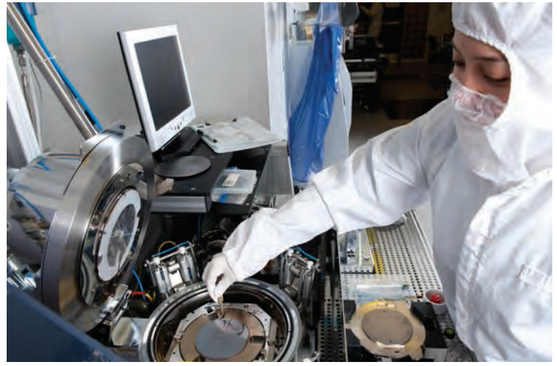
2014 EXPLORATORY MATERIALS RESEARCH GRANTS

Exploratory Materials Research Grants enable nascent materials research to emerge to the point of being competitive for external funding. Seven Exploratory Materials Research Grants were awarded $40,000 each this year:

- **Self-Patterned Oxide Nano-Structures: Laser Material Interaction,** PI: Sheikh Akbar, Materials Science and Engineering; Co-Investigator: Enam Choudhury, Physics
- **Enabling High Efficiency Thin-Film Photovoltaics through Nanometer-Scale Defect Characterization (second year renewal),** PI: Aaron Arehart, Electrical and Computer Engineering; Co-Investigators: Tyler Grassman, Materials Science and Engineering; Jonathan Pelz, Physics; Collaborators: David McComb, Materials Science and Engineering; Sylvain Marsillac, Old Dominion University
- **Electric Field-Induced Effects on Defects in Complex Oxides,** PI: Leonard Brillson, Electrical and Computer Engineering; Co-Investigator: Wolfgang Windl, Materials Science and Engineering
- **Development of a Tactile-Sensing Bio-Complex Material for Engineering of Electronic Skin,** PI: Liang Guo, Electrical and Computer Engineering
- **Nanoscale Materials for Oxygen Sensing with Optically Detected Electron Paramagnetic Resonance,** PI: Michael Poirier, Physics; Co-Investigators: Ramasamy P. Pandian, Physics; Vidya P. Bhallamudi, Physics; Chris Hammel, Physics
- **Advanced Finite Element Approach for the Virtual Design of Functionally Graded Al/Al2O3 Reinforced Composites,** PI: Soheil Soghrati, Mechanical and Aerospace Engineering; Co-Investigators: Marcelo Dapino, Mechanical and Aerospace Engineering
- **Fabrication of Patterned Protein Molecules Using Living Magnetic Microbes,** PI: R. Sooryakumar, Physics; Co-Investigators: Steven Lower, Earth Sciences; Brian Lower, Environment and Natural Resources

Materials research at the cutting edge cannot happen without world-class facilities operating at peak conditions. IMR operates, manages and/or supports a broad collection of shared core facilities, laboratories and facility centers so that Ohio State's materials community can carry out world-class research and also provide world-class educational experience to our students through the use of these facilities. Our support of core facilities comes in a variety of forms, including providing Members of Technical Staff who are responsible for ensuring the effectiveness and efficiency of the labs, occasional support to deal with critical near term needs, and internal research funding used by our researchers to carry out key experiments. The largest core facility, the Nanotech West Laboratory, is fully operated and managed by IMR, with Members of Technical Staff, administrative oversight and lab leadership all provided by IMR. We also currently support one Member of Technical Staff each at the NanoSystems Lab (NSL), the Center for Electron Microscopy and Analysis (CEMAS), and – new this fiscal year – the Semiconductor Epitaxy and Analysis Laboratory (SEAL). The overall coordination of these and other facilities through IMR's domain (see http://imr.osu.edu/research/facilities/) continues to be a driving force for IMR activities.

Nanotech West



Located on West Campus, the Ohio State Nanotech West Laboratory is the largest and most comprehensive micro- and nanofabrication user facility in the state of Ohio. Open to both academic and industrial users, Nanotech West houses a 6,000 square foot class 100 cleanroom with a comprehensive 100mm wafer process flow, a 5,000 square foot Biohybrid Lab, and additional laboratory, administrative, and support space. Home to more than 50 large pieces of user accessible material synthesis, fabrication and metrology equipment, Nanotech West operations are supported by 1.5 administrative and 8 full-time engineering core staff (most with semiconductor industry or manufacturing experience) who provide training, process and project support to Nanotech's diverse user base. Activities at Nanotech span a range of cutting-edge materials research that is rather extraordinary for a single facility — from high-frequency GaN/AlGaN electronics, to solar cells, to microfluidics and biotechnology, to the fabrication of structures for use in the study of basic physics and chemistry. As the primary IMR location on the OSU West Campus, Nanotech West provides substantial impact and continues to be a centerpiece of collaborative research to the OSU materials research community.

AVAILABLE INSTRUMENTATION

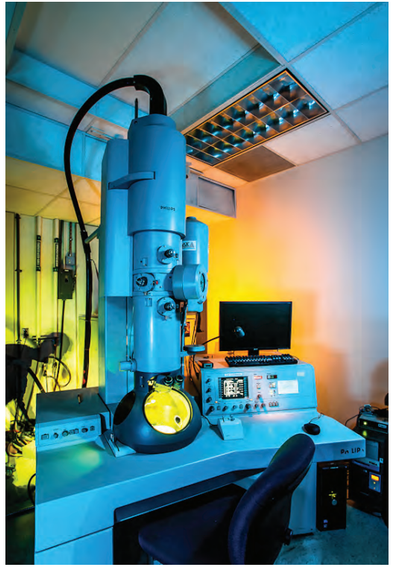
- Electron beam lithography [Vistec/RAITH® EBPG-5000]
- Metalorganic chemical vapor deposition [Aixtron/Swan® 3 x 2"]
- Atomic layer deposition [Picosun® SunALE R-150B]
- Field-emission scanning electron microscopy [Carl Zeiss® Ultra 55 Plus]
- ICP-RIE, inductively coupled plasma reactive ion etching [Plasma-Therm® SLR 770] and several other plasma etch tools
- Wafer bonding [EVG 520HE]
- DC and RF sputtering [AJA Orion]
- Electron beam evaporation [CHA Solution and Denton EV-502A]
- I-V, C-V, L-I-V, carrier lifetime, and solar device testing
- Atomic force microscopy [Bruker Dimension Icon3® with ScanAsyst®]
- Wire bonding [K&S 4123 Wedge Bonder]
- Dicing saw [K&S 7100]
- Spectroscopic Ellipsometry [Woolam Alpha-SE]
- Full-flow 100mm process capability including photolithography, wet/dry etching, deposition, oxidation, metrology

FISCAL YEAR 2015 HIGHLIGHTS

- Supported over 275 users with 78% of user base representing 19 different OSU departments
- Supported multi-year research funding in excess of $30 million, representing 55 OSU Principal Investigators and 96 funded projects
- Hired two engineers to support Ohio industrial collaborators through the Ohio Third Frontier Ohio Sensor and Semiconductor Innovation Platform (OSSIP) Program
- Continuous upgrading of facilities:
  - Installed new 1200°C general use tube furnace (150mm diameter)
  - Upgraded III-V metalorganic chemical vapor deposition system with Si_2H_6 source for high growth rate silicon deposition
  - Upgraded lab management system with addition of tool interlocks

Location: Science Village
1381 Kinnear Road, Columbus, Ohio 43212
Website: http://www.nanotech.osu.edu
Contact: Dr. Robert J. Davis, Director,
(614) 292-7309, davis.2316@osu.edu
Dr. John Carlin, Associate Director
(614) 292-6112, carlin.9@osu.edu

Center for Electron Microscopy and Analysis



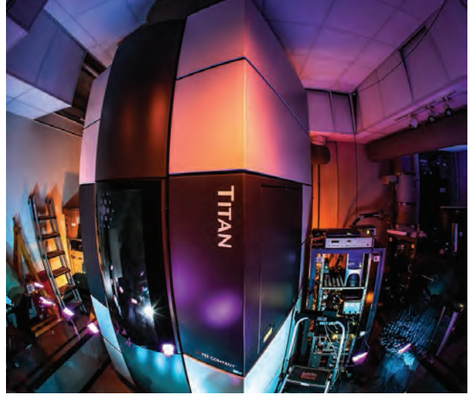
The Center for Electron Microscopy and Analysis (CEMAS), is the newest major materials research facility on Ohio State's Columbus campus. CEMAS boasts one of the largest concentrations of electron and ion beam analytical microscopy instruments in any North American institution, housed in a custom-designed environment located on West Campus.

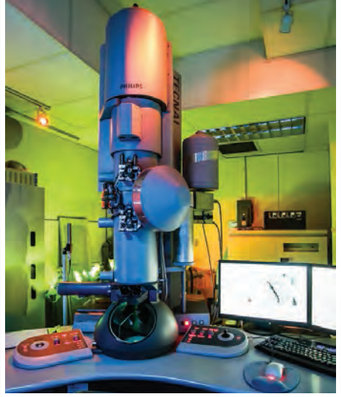
The facility provides a world-class environment for five transmission electron microscopes (TEM), three scanning electron microscopes (SEM) and two dual-beam focused ion beam (FIB) instruments. CEMAS's two aberration corrected scanning transmission electron microscopes (S/TEM) include one instrument optimized for high spatial resolution imaging and analysis with the capability to provide sub-angstrom resolution, and a second instrument designed for investigation of soft materials and biomaterials with the ultimate in chemical analysis capabilities as well as high resolution imaging performance. Sample preparation laboratories for life sciences, physical sciences and engineering are provided with full technical support. The provision of comprehensive computer facilities for data processing and image simulation allows academic and industrial users to carry out their entire microscopy and analysis program at CEMAS.

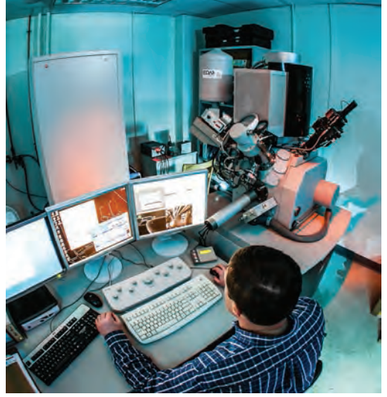
CEMAS has one of the largest concentrations of electron and ion beam analytical microscopes in North America

AVAILABLE INSTRUMENTATION

- FEI Image Corrected Titan 60-300 S/TEM
- FEI Probe Corrected Titan 80-300 S/TEM
- FEI Tecnai F20 S/TEM
- FEI/Philips CM-200T TEM
- FEI/Philips CM-12T TEM
- FEI Helios NanoLab 600 DualBeam (FIB/SEM)
- FEI Nova NanoLab 600 DualBeam (FIB/SEM)
- FEI/Philips Sirion Field Emission SEM
- FEI/Philips XL-30 Field Emission ESEM
- FEI Quanta 200 SEM
- Rigaku MiniFlex 600
- Rigaku SmartLab





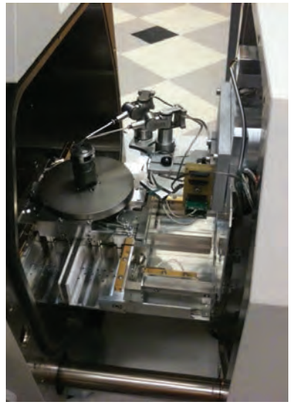


FISCAL YEAR 2015 HIGHLIGHTS

- Supported 220 Ohio State University researchers and 34 users from external academic institutions and industry partners, for a total of 254 users
- Acquired and installed two additional biological sample preparation instruments: FEI Vitrobot™ Mark IV and Reichert UltraCut E Microtome.
  - FEI Vitrobot™ Mark IV is an automated device for vitrification (rapid cooling) of aqueous (colloidal) samples. The critical vitrification parameters, such as temperature, relative humidity, blotting pressure and time, can be precisely controlled. The simple, easy to use touch-screen user interface and programmable vitrification process allow for consistent and high-yield sample output.
  - Launched first remote collaboratory with the Air Force Research Lab at Wright Patterson Air Force Base, allowing AFRL researchers to remotely utilize CEMAS's high-powered microscope technology over the internet to analyze how materials perform on aircraft.
  - Reichert UltraCut E Microtome produces high quality precise cutting ultra-thin and semi-thin sections of resin embedded biological samples for electron microscopy. It features motorized cutting stoke with adjustable speed range of 0.1 to 50 mm/sec, cutting up to 99 nm for ultra-thin sections and up to 990 nm for semi-thin sections.
- Further developed focused ion beam (FIB) preparation of small scale tomographic TEM specimens for STEM and Super EDS tomography.
- Analyzed the distribution of porosity in gel-like materials using Cryo-FIB serial sectioning and MIPAR™ as the 3D reconstruction software
- Implemented a correlative multi-scale approach to characterize the same material at various length scales from computed tomography, at 0.7 micron and 50nm resolution, down to FIB/SEM and finally STEM EDS for compositional analysis

Location: 1305 Kinnear Rd, Suite 100, Columbus, Ohio
Website: http://cemas.osu.edu
Contact: Hendrik (Henk) Colijn, Associate Director (614) 643-3458, colijn.1@osu.edu

NanoSystems Laboratory

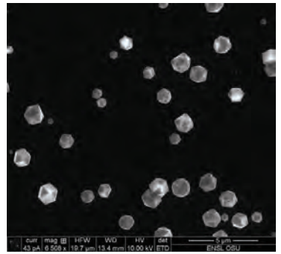


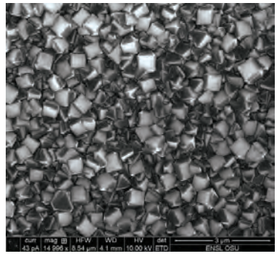
NanoSystems Laboratory (NSL)provides users with access to advanced material characterization and fabrication tools for research and development applications. NSL operates a diverse set of research instrumentation and research capabilities including Focused Ion Beam/Scanning Electron Microscopy, X-ray diffractometry, SQUID magnetometry, Atomic Force/Magnetic Force microscopy, EDS X-ray microanalysis, Langmuir-Blodgett trough monolayer deposition, e-beam lithography, Electron Spin Resonance spectroscopy, Physical Vapor material deposition, ion milling, maskless photo lithography, Low-Temperature/High Magnetic field magnetotransport measurements, diamond CVD growth, material polishing, Kerr microscopy, THz spectroscopy, critical point drying and magneto-optical material studies.

NSL also operates two 1,600 ft^2 clean room facilities. One clean room houses instruments for material deposition and photo lithography, while the other clean room is devoted to processing organic spintronics devices, organic photovoltaics, organic LEDs, and other air and moisture sensitive materials. It is equipped with four interconnected gloveboxes with Ar and N2 atmosphere. Equipment installed in the gloveboxes includes an organic deposition chamber, metal deposition chamber, parylene deposition system, a spin coater, a solar simulator, wiring station and a system for electrical testing.

AVAILABLE INSTRUMENTATION

- Focused Ion Beam/Scanning Electron Microscope (FIB/SEM) – FEI Helios Nanolab 600 Dual Beam sophisticated platform for sample preparation, imaging and analysis. High-performance ion column, Platinum deposition, X-ray EDS microanalysis and custom e-beam lithography.
- 2 SQUID Magnetometers – One Quantum Design MPMS 5 system and one MPMS XL system for magnetic sample characterization. A very sensitive tool for measuring DC sample magnetic moment.
- 2 Atomic Force/Magnetic Force Microscopes (AFM/MFM) – One Bruker Dimension Icon and one Dimension 3000 Scanning Probe Microscope.
- Langmuir-Blodgett Trough (LBT) – NIMA Technology model 612D trough used for studying properties of monolayers of amphiphilic molecules and for depositing molecular monolayers on various substrates.
- X-Ray Diffractometer (XRD) – Bruker D8 Discover high-resolution triple-axis X-ray diffractometer with high performance optics for optimum resolution.
- Low-Temperature Magnetotransport Measurement System (LTMT) – Can be used to measure electrical properties of materials and devices at low temperatures and in magnetic field
- Kurt J. Lesker Lab-18 Thin Film Deposition system installed in a clean room environment with RF and DC sputtering and e-beam deposition capabilities. Optimized for sputter deposition of magnetic metals and/or oxides followed by coating with a precious metal (gold, platinum, etc.) using e-beam deposition. The system is equipped with an ion mill in the load lock for sample cleaning and etching
- 14 T Physical Properties Measurement System (PPMS) with a cryogenic Atomic Force Microscope/Magnetic Force Microscope (AFM/MFM).
- Diamond Chemical Vapor Deposition System (CVD) for synthesizing high quality poly crystalline and single crystal diamond films for research and production.
- Bruker e500 Electron Paramagnetic Resonance (EPR) spectrometer
- Heidelberg Instruments Tabletop Maskless Aligner System µPG501 for photo lithography and contact mask making installed in clean room environment
- Magneto-optical cryostation from Montana Instruments, Inc. for rapid optical and electrical measurements on samples in vacuum in the temperature range of 3 K – 300 K and in magnetic fields as high as 1 T
- Organic clean room with four interconnected gloveboxes with Ar and N2 atmosphere. Equipment installed in the gloveboxes includes an organic deposition chamber, metal deposition chamber, parylene deposition system, a spin coater, a solar simulator, wiring station and a system for electrical testing.
- Other available instruments include a Wire Bonder, a Critical Point Dryer, two Terahertz spectrometers, a Magneto-optical Kerr Microscope, and a new optical microscope.



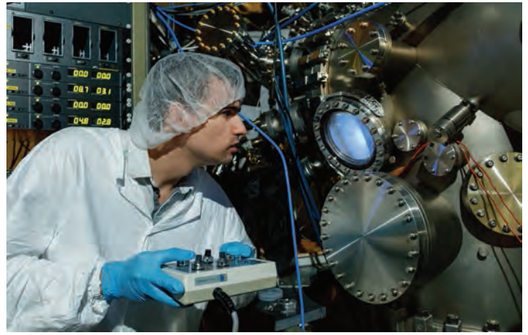


FISCAL YEAR 2015 HIGHLIGHTS

- Commissioned a new optical cryostation by Montana Instruments, Inc. for optical and electrical studies of materials and devices in vacuum at temperatures between 3 K and 300 K and in magnetic fields as high as 1 T.
- Provided research services to the scientific community in the amount of $233,000.
- Supported 55 research groups from OSU, external academic institutions and industry partners with a total of 180 users.
- Laboratory services benefited 107 research projects.

Location: Physics Research Building
First floor and Lower Level,
191 West Woodruff Avenue,
Columbus, Ohio 43210
Website: http://ensl.osu.edu
Contact: Dr. Denis V. Pelekhov, Lab Manager
(614) 292-9125, pelekhov.1@osu.edu

Semiconductor Epitaxy and Analysis Laboratory

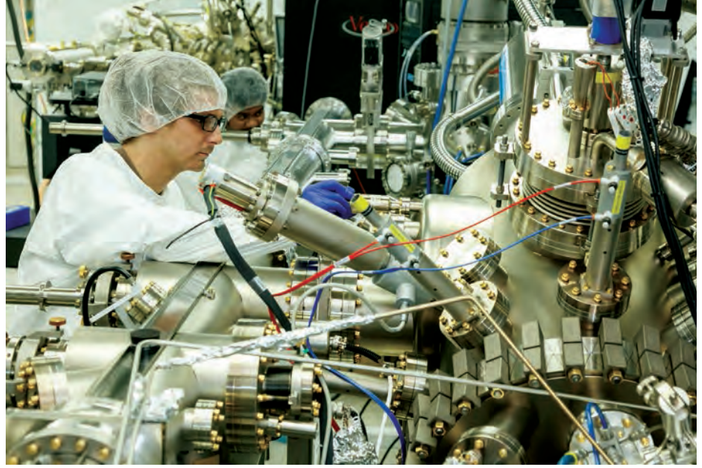


The Semiconductor Epitaxy and Analysis Laboratory (SEAL) is OSU's primary facility for molecular beam epitaxy (MBE) located within the 4,000 square foot Dreese Lab Cleanroom (DLC) on central campus.

SEAL is home to five state-of-the-art MBE chambers each dedicated to different, complementary material systems, to ensure high quality material epitaxy for both basic studies and true device development. Research is focused on MBE-grown III-V materials and devices, including both III-AsP and III-N compounds, III-V/Si integration and a variety of 2-D, 1-D and 0-D nanostructures. SEAL's growth facility contains two MBE vacuum clusters, which allow in-situ transfer between MBE chambers, enabling the integration of unique materials which would be otherwise highly compromised or not possible. Vacuum Cluster I encompasses two MBE chambers and an analytical system allowing III-V/IV integration studies and high resolution x-ray photoelectron spectroscopy (XPS) for in-situ chemical studies of pristine surfaces and interfaces. Vacuum Cluster II enables growth of magnetic epilayers and spin detectors on pristine nitride hetereostructures through two MBE chambers. The lab also includes a wide range of advanced, state-of-the-art materials characterization tools to support advanced epitaxy and forefront advances in electronic materials. SEAL is a fully staffed user facility open to university and industry researchers.

AVAILABLE INSTRUMENTATION

- Vacuum Custer I:
  - MBE1: Highly modified 3 inch Varian GENII solid source III-V MBE chamber for GaAlInAsP family of materials
  - MBE2: Modified 3 inch Varian GENII MBE chamber designed for Si and Ge materials.
  - X-ray photoelectron spectroscopy (XPS) analytic chamber with monochromatized Al Kα x-ray source and a high temperature stage.
- Vacuum Cluster II:
  - MBE3: Veeco 930 solid source plasma-assisted MBE chamber for AlGaInN family materials.
  - MBE4: Riber M7 MBE chamber for Ni, NiO, Pt–magnetic epilayers with integrated Pt spin detectors for thermal spintronics. This chamber also offers plasma-assisted oxide MBE for advanced wide bandgap Ga_2O_3 semiconductors.
- MBE5: Veeco 930 MBE chamber for 2D $MoWSe_2$ based material.
- SEAL Analysis Facility:
  - BEDE D1 High Resolution Triple Axis X-ray Diffraction System with x-ray reflectivity, symmetric and asymmetric reciprocal space mapping, environmental stage and x-ray topography
  - Variable field and temperature Lakeshore Cryotronics Hall Effect system, including QMSA capability; temperature range is 10k-325K and with fields up to 10T
  - Photoluminescence (PL) Spectroscopy: Low temperature capability and 488nm Argon laser



FISCAL YEAR 2015 HIGHLIGHTS

- Purchased an MBE chamber for the purposes of 2D material exploration into the MoWSe2 materials which will operate out of SEAL. Funding for this purchase came from a National Science Foundation award to Prof. Siddharth Rajan. Discussions are underway to also investigate GaSe, GaTe, and other materials within this system, and material research will be ready by mid-November 2015.
- Installation of Vacuum Cluster II has been completed and the integrated materials from MBE3 and MBE4 are expected by the end of 2015.
- A full time technician from Nanotech West, Pete Janney, has joined SEAL on a part-time basis as a technician and mechanical consultant to assist in the complex nature of the current lab upgrades and upkeep. This cross-training of technical staff ensures continued high-level service of critical infrastructure operations, while providing professional development opportunities for employees.
- Completed an overhaul to the liquid nitrogen storage and delivery system for the lab, equating to a 40% reduction in liquid nitrogen usage.

Location: SEAL Molecular Beam Epitaxy (MBE) Lab
Cleanroom: 095 Dreese Laboratories,
2015 Neil Avenue, Columbus, Ohio
SEAL Analysis Lab: 360 Caldwell Laboratory,
2024 Neil Avenue, Columbus, Ohio
Website: http://emdl.ece.ohio-state.edu/seal
Contact: Mark Brenner, Lab Manager
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2015 OSU Materials Week

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 Photoelectro-chemical 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

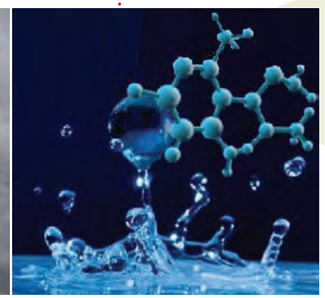
Distinguished Lecture Series

Each year, the Institute for Materials Research Distinguished Lecture Series brings world renowned materials researchers to The Ohio State University campus to share the latest developments in materials-allied fields and discuss their research with OSU students, faculty, and staff. IMR Distinguished Lecturers include the top scientists in their fields, and this year we were honored to host two prominent lecturers.

FALL 2014

THE AUTOMOTIVE INDUSTRY, VEHICLE ELECTRIFICATION, AND INDUSTRIAL RESEARCH

Mark W. Verbrugge, Chemical and Materials Systems Laboratory, General Motors Research and Development
October 14, 2014



SPRING 2015

IONIC LIQUIDS FOR POST-COMBUSTION CO_2 CAPTURE

Joan F. Brennecke, Keating-Crawford Professor of Chemical Engineering, University of Notre Dame
February 18, 2015

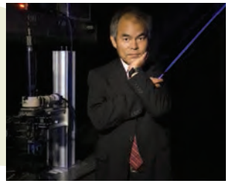
IMR-Supported Conferences and Workshops

This fiscal year, the OSU Institute for Materials Research continued to provide administrative, logistical and financial support to bring scientific conferences and workshops to Ohio State's Columbus campus. Both of the events described in detail below brought together international groups of experts to discuss new technologies in emerging scientific fields.

57TH ELECTRONIC MATERIALS CONFERENCE (EMC)

The 57th annual Electronic Materials Conference (EMC), the premier annual forum annual forum on the preparation and characterization of electronic materials, was held on Ohio State's Columbus campus from June 24-26, 2015. In the electronic materials and devicecommunity, holding both EMC and the associated Device Research Conference (June 22-24, 2015) at OSU was a significant achievement as it is an indicator of OSU's central role in the field and further validation of OSU's capacity as a hosting institution for a major conference. IMR acted as the enabling intermediate organization between The Materials Research Society (MRS), the professional organization to which EMC reports, and the university. This conference featured the latest research over a wide range of topics including Semiconductor and Oxide Materials and Devices, Materials for Energy Storage and Conversion, Nanoscale Science and Technology, Organic and Thin Film Technology.

The conference featured a plenary session, parallel topical sessions, a poster session and an industrial exhibition. 2014 Nobel Laureate in Physics Shuji Nakamura gave the plenary address, "The History and Developments of InGaN-based LEDs and Laser Diodes," which provided an entertaining perspective of his research leading to his Nobel Prize and his experience after the award. Student authors had the opportunity to compete in the Best Student Presentation Award as well as apply error analysis techniques to their research for the NIST Uncertainty Analysis Student Award. The meeting and student support was sponsored by IMR, Northrop Grumman, United Mineral & Chemical Corp., FOM Technologies, American Elements, The Minerals, Metals & Materials Society, Sandia National Laboratories and The Materials Research Society.

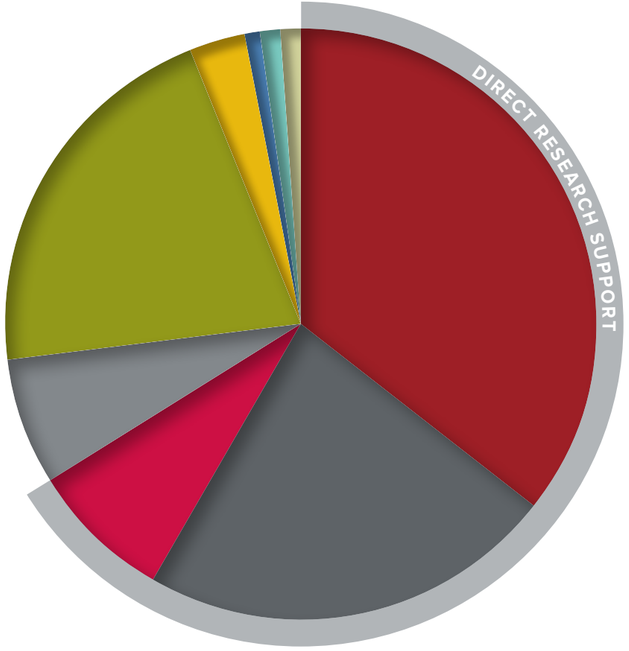


SPIN-ORBIT COUPLING AND MAGNETISM IN CORRELATED TRANSITION METAL OXIDES WORKSHOP

The Spin-orbit Coupling and Magnetism in Correlated Transition Metal Oxides Workshop took place May 4 - 7, 2015 at The Ohio State University, bringing together scientists with diverse expertise working on the interplay of spin-orbit coupling and correlations in transition metal oxides, which leads to novel metallic, magnetic and topological states. The workshop was preceded by pedagogical tutorials on May 3 with topics related to the conference specifically aimed at graduate students and post-doctoral scholars. The topics covered included recent advances in materials, measurements, phenomena, theory and computation. Over 90 attendees

participated in invited talks and discussion sessions to identify open questions and future directions, as well as a poster session. This workshop was supported by the Institute for Complex Adaptive Matter, the Center for Emergent Materials, an NSF MRSEC, the U.S. Department of Energy, and the Gordon and Betty Moore Foundation, with additional support from the Department of Physics, the Institute for Materials Research, and the Women's Place at OSU.

Financial Overview



74% DIRECT RESEARCH SUPPORT

- Technical Personnel $1,039,525 (36%)
- NTW Core Operating Expenses $663,738 (23%)
- Seed Grants $226,000 (8%)
- Additional Support of Prime Materials Research Centers $187,000 (7%)

26%

- Administrative Personnel $604,862 (21%)
- Outreach and Engagement $87,417 (3%)
- Strategic Workshops $21,185 (1%)
- Core Operating Expenses $20,684 (1%)
- Proposal Development Support $7,365 (<1%)

In its first nine years of operations, Fiscal Years 2007-2015, IMR has seen a **10.7:1** return on investment

Future Plans

THE INSTITUTE FOR MATERIALS RESEARCH'S PLANS TO SUSTAIN AND DRIVE EXCELLENCE AND IMPACT IN THE NEXT 1-3 YEARS REVOLVES AROUND 4 CORE TENETS:

1. Programmatic alignment with university, college and department strategic plans,
2. support and advancement of prime research centers,
3. assurance of state of the art core facilities, and
4. development of new strategic opportunities for the OSU materials community.

During the past year, the successful award of the Materials and Manufacturing for Sustainability (M&MS) Discovery Theme program, the formal renewal of the NSF-supported Center for Emergent Materials MRSEC, the rapid advance of CEMAS, etc. have combined to provide a certain clarity of near term plans for IMR.

IN THE NEXT 1-3 YEARS, WE WILL:

- Establish and implement the framework for the Materials and Manufacturing for Sustainability (M&MS) program, including staff hiring, program deployment, development of the Materials Innovation Greenhouse (MIG), and faculty cluster hiring
- Establish Executive in Residence and Visiting Innovator Programs
- Restructure business operations to accommodate center growth, particularly on west campus
- Integrate the Center for Design and Manufacturing Excellence (CDME) within the broader IMR community so that it becomes the nexus for innovation via IMR, the Materials Innovation Greenhouse (MIG) and the colleges
- Implement a clear, approved industry engagement strategy for our centers, by working with the appropriate OSU offices and colleges
- Establish the Energy Storage Hub as a core facility
- Establish and implement the planned IIT-Bombay/IMR seed grant program for joint PhD projects
- Land at least two new large companies as major partners and facilitate overall increases in the total number of industry partners across our affiliated centers
- Coordinate at least two strategic workshops per year, focused toward external, teamed funding opportunities
- Coordinate the development of at least two major block grant proposals

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