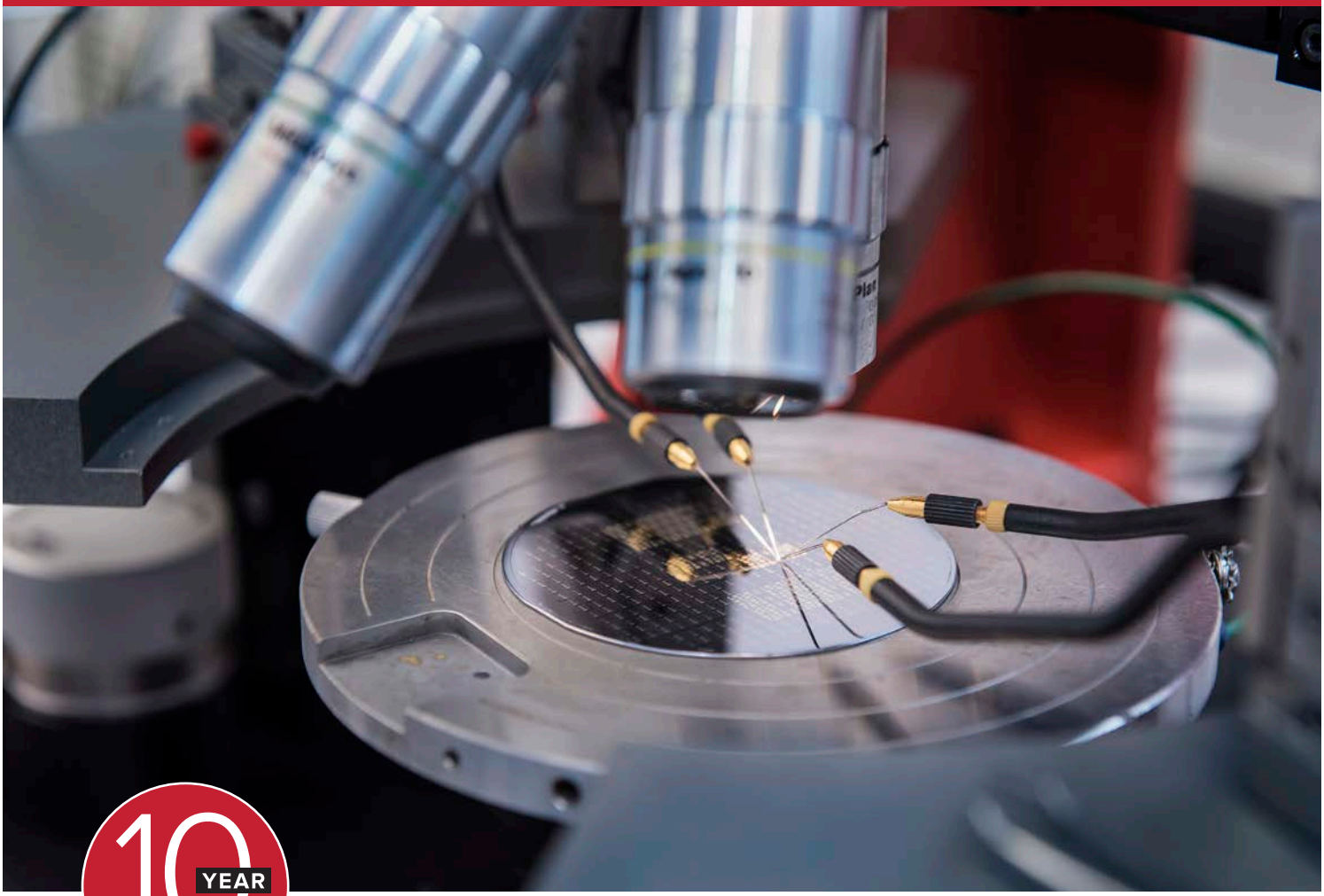
INSTITUTE FOR MATERIALS RESEARCH

FISCAL YEAR 2016 ANNUAL REPORT



10 YEAR ANNIVERSARY

THE OHIO STATE UNIVERSITY

INSTITUTE FOR MATERIALS RESEARCH

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The Ohio State University's Institute for Materials Research (IMR) is a campus-wide, multidisciplinary institute that promotes and coordinates research activities and infrastructure related to the science and engineering of materials throughout The Ohio State University. Established in 2006, IMR is a unit of the university's Office of Research, and is also supported by the College of Engineering, College of Arts and Sciences, and the Office of the Provost. More than 230 Ohio State faculty members from 22 academic departments and six colleges are IMR members. The institute manages extensive internal programs to support its faculty and students through seed grant funding, conference and workshop development, proposal development for major block proposals, and outreach efforts including industrial and international cooperative agreements. IMR also operates and/or supports a broad collection of shared core research facilities which allow Ohio State's materials community to carry out state-of-the-art research while providing world-class educational experience to students through the use of these facilities. The Materials and Manufacturing for Sustainability (M&MS) program is a university-wide initiative coordinated by IMR supporting Ohio State's goal to become pre-eminent in the field of advanced materials and technologies for sustainability. M&MS is building on Ohio State's existing interdisciplinary strengths in materials, world-class facilities and nationally-recognized centers of excellence, and exploiting industrial consortia and existing strategic investments to enable a paradigm of discovery-to-deployment.

For more information: imr.osu.edu

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

Highlights of our first 10 years

2005

SEPTEMBER 2005
Ohio State Materials Vision Committee final report recommends establishment of the Institute for Materials Research to coordinate materials activities across the university

2006

JUNE 2006
OSU awards Advanced Materials Initiative through Targeted Investments for Excellence (TIE); funds contribute to IMR's initial operations

OCTOBER 2006
IMR opens administrative offices in Scott Laboratory

DECEMBER 2006
State establishes Wright Center for Photovoltaics Innovation and Commercialization (PVIC), with $6.8M of the $18.6M award going to Ohio State node

2007

FEBRUARY 2007
IMR awards first Facility Grants, with 16 internal seed grants supporting Ohio State researchers; IMR seed grant program later includes Interdisciplinary Materials Research Grants (IMRGs) and Industry Challenge Grants

APRIL 2007
IMR coordinates internal, pre-proposal process for NSF Materials Research Science and Engineering Center (MRSEC) competition

AUGUST 2007
IMR Colloquia Series (now the IMR Distinguished Lecture Series) welcomes Dr. Robert Chau of Intel as first speaker

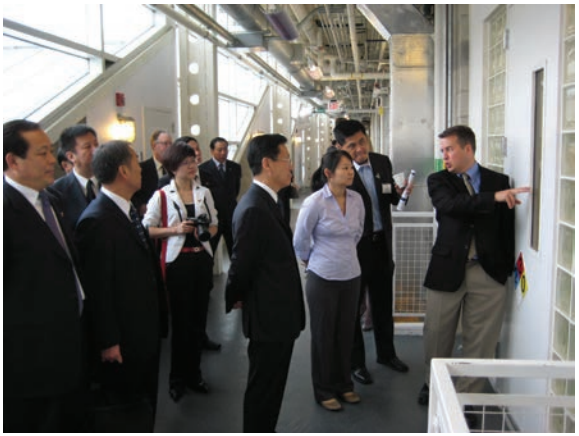
2008

JUNE 2008
State awards IMR-led Ohio Research Scholars Program in Technology-Enabling and Emergent Materials, totaling $18.1M; 5 Scholars will be hired, including 3 at Ohio State

JULY 2008
National Science Foundation announces Ohio State's first NSF MRSEC award, establishes Center for Emergent Materials with a six-year, $10.8M award

SEPTEMBER 2008
First OSU Materials Week conference takes place, with Dr. Jerry Woodall as Keynote

2009



APRIL 2010
State of Ohio names OSU a Center of Excellence in Materials, Manufacturing Technologies, and Nanotechnology

SEPTEMBER 2013
Grand opening of Center for Electron Microscopy and Analysis (CEMAS), Ohio State's new microscopy facility with nearly $30M in equipment

OCTOBER 2016
Materials Innovation Greenhouse (MIG) to open, creating innovative collaboration space for public-private partnerships to address global advanced materials challenges

2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016

JUNE 2011
Nanotech West Laboratory officially becomes part of IMR

AUGUST 2011
CEM, ENCOMM and IMR combine seed programs and establish OSU Materials Research Seed Grant Program

DECEMBER 2011
IMR awards its 100th Facility Grant

AUGUST 2014
Discovery Themes Initiative establishes Materials and Manufacturing for Sustainability (M&MS) focus area, opens up to 30 new materials-allied faculty positions across the university

NOVEMBER 2014
Center for Emergent Materials MRSEC renewed by NSF and expanded by 50%

Fiscal Year 2016 Figures

MEMBERSHIP

233
IMR members

From
26
departments

In
7
colleges

PUBLICATIONS

15
publications per IMR member average[1]

377
citations per IMR member average[2]

1. Source: Google Scholar 2. Source: Web of Science

IMR MEMBERS' INVENTIONS

IMR members filed 78 PATENTS, 52 INVENTION DISCLOSURES, and were issued 27 PATENTS[1]

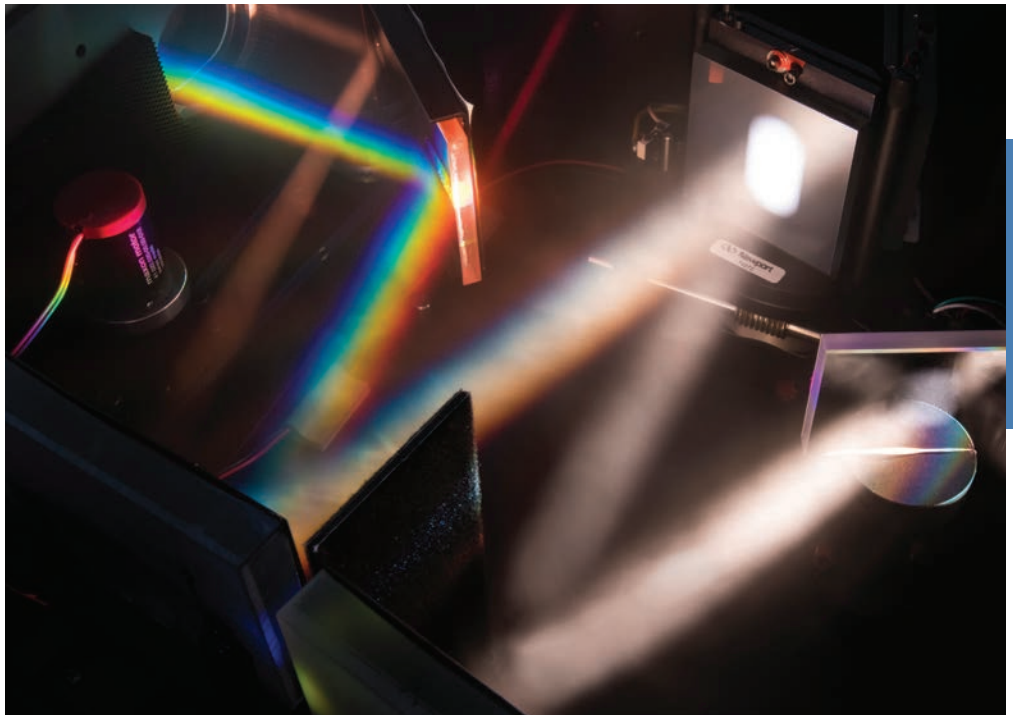
IMR MEMBERS' EXTERNAL FUNDING:

Sponsored projects with awarded budgets over $402.5 MILLION, of which $72.7 MILLION were new projects[2]

Expenditures of $75.7 MILLION on sponsored projects[3]

1. Technology Commercialization Office, The Ohio State University 2. Office of Sponsored Programs, The Ohio State University
3. Office of Sponsored Programs, The Ohio State University

Materials and Manufacturing for Sustainability



The Materials and Manufacturing for Sustainability (M&MS) initiative is focused on enabling Ohio State faculty, students and staff to focus on translational innovation and research in technology, science and manufacturing as they apply to future energy systems and sustainability from the nano-scale to the macro-scale. With the goal to become pre-eminent in the field of advanced materials and technologies for sustainability, M&MS is building on IMR's existing strengths in materials, hiring faculty to advance materials discoveries, developing strategic industrial and global relationships, and accelerating the research process to enable a paradigm of discovery-to-deployment at Ohio State.

INVESTMENTS ARE OCCURRING IN THREE CLUSTER AREAS SPANNING FROM SCIENCE TO MANUFACTURING

- Energy harvesting, storage and systems
- High-performance materials and structures
- Materials for sustainable information processing

These three primary clusters are supported by targeted investment in strategic assets, including a focus on business, policy, and awareness, all of which will connect within the Materials Innovation Greenhouse (MIG), serving as an innovation collaboration model transitioning science to technology to industry with regional, national and global partners.

During Fiscal Year 2016, major advances were made in the successful recruitment of seven additional faculty to join the M&MS cohort as well as the hiring of a new M&MS leader, Dr. Jay Sayre. Our partnerships with Indian materials researchers strengthened, resulting in an Ohio State-IITB joint seminar in March and the development of additional joint workshops, research grants, and collaborations. The Materials Innovation Greenhouse construction is proceeding and the staffing of technology integrators and visiting innovators to support the MIG's activities, M&MS members and partners is a priority for the next year.

JAY SAYRE JOINS IMR AS ASSISTANT VICE PRESIDENT, MATERIALS AND MANUFACTURING FOR SUSTAINABILITY AND DIRECTOR OF INNOVATION

In February 2016, we welcomed **Dr. Jay Sayre** to the newly created positions of Assistant Vice President for Materials and Manufacturing for Sustainability and the IMR Director of Innovation. In this role, Sayre provides vision, leadership and strategy for the overall development, coordination and advancement of the M&MS program in collaboration with M&MS faculty leader Steven A. Ringel, and in conjunction with Discovery Themes leadership. In his first few months in this leadership role, Dr. Sayre has been very actively engaged in M&MS program direction and implementation, faculty cohort development, and the development and implementation of internal and external engagement strategies. Dr. Sayre joins us from Battelle Memorial Institute, the world's largest independent research and development organization, where he was Director of Advanced Materials and Director of Internal Research and Development (IR&D) for Energy, Health and Environment. As the Director of Advanced Materials, he was responsible for the management of Battelle's materials workforce in all disciplines. He also established the Office of the Director of IR&D for Energy, Health and Environment at Battelle, providing technical counsel and thought leadership on technical assessments, intellectual property strategies and strategic relationships with universities.

CLUSTER HIRING LEADS TO SEVEN NEW FACULTY MEMBERS

A major thrust of the M&MS program this year was the focus on faculty recruitment to fill the many key faculty openings made available through the Discovery Themes Initiative. Dozens of Ohio State faculty, administrators, and staff worked countless hours this year on multiple, simultaneous search committees to identify the strongest candidates in manufacturing, energy and sustainability fields. As a result, seven new faculty will join The Ohio State University's materials community during the 2016-2017 academic year through the Materials and Manufacturing for Sustainability focus area. These seven professors join two others hired in 2016 – Ned Hill and Farhang Pourboghrat, featured in our Fiscal Year 2015 report – for a total of nine new faculty positions within the M&MS cohort to date.

Marc Bockrath, Professor, Physics (beginning January 2017)

Carolin Fink, Assistant Professor, Materials Science and Engineering

John Horack, Neil Armstrong Chair in Aerospace Policy and Professor, Mechanical and Aerospace Engineering, Glenn College of Public Policy

Joerg R. Jinschek, Associate Professor, Materials Science and Engineering (beginning January 2017)

Jung Hyun Kim, Assistant Professor, Mechanical and Aerospace Engineering and Materials Science and Engineering

Sanjay Krishna, George R. Smith Chair in Engineering and Professor, Electrical and Computer Engineering (beginning January 2017)

Chun Ning (Jeanie) Lau, Professor, Physics (beginning January 2017)

Materials and Manufacturing for Sustainability *continued*

DEVELOPMENT OF THE MATERIALS INNOVATION GREENHOUSE UNDERWAY

The Materials Innovation Greenhouse (MIG) has always been central to the Materials and Manufacturing for Sustainability program plan, and this year IMR staff have been working diligently to make it a reality. The Materials Innovation Greenhouse is an innovation collaboration model that translates science and engineering discoveries into economic and societal benefits through strategic partnerships.

Building on the strong history of materials research at Ohio State, we aspire to collaboratively redefine the university's land-grant role in the 21st century as we approach its 150th birthday. This redefinition is centered around The Ohio State University serving as the intellectual hub in an innovation ecosystem that spans the continuum from discovery to deployment to meet the grand challenges of our world. We are accomplishing this by building an enhanced innovation culture to perform translational R&D that complements our existing research base, where innovation is defined by connecting ideas to the market as a tangible business outcome for our partners.

The MIG consists of both an innovative physical space and an innovative business model that allow people to collide while fostering their collaboration to maximize innovation impact. It is a place where partners have access to the university and engage with students and faculty in an innovative ecosystem at the nexus of technology, market, and execution. Staff are currently working on the design, renovation and construction of the future MIG space within Nanotech West Laboratory's building on Ohio State's West Campus, and we expect the MIG to be fully completed and operational by the end of 2016.

CONTINUED ENGAGEMENT WITH PARTNERS IN INDIA

The IMR and Materials and the Manufacturing for Sustainability (M&MS) Discovery Theme focus area continue to actively engage with Indian materials science institutions to build fruitful, ongoing collaborations to support sustainability efforts in both countries.

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

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

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

Manufacturing Ecosystem Partnerships

CENTER FOR DESIGN AND MANUFACTURING EXCELLENCE (CDME)

The Center for Design and Manufacturing Excellence (CDME) is a hybrid university-industry applied research center focused on the successful commercialization of innovative research. The center is led by successful entrepreneurs and business leaders who work closely with industry to understand and address their needs. Projects at CDME have been undertaken for companies ranging in size from start-up to Fortune 50. The center also assists in the validation and commercialization of internal Ohio State research programs.

CDME operates around four central tenants: collaboration between different industries, non-competitors, vendors, and customers; commercialization of technologies developed within The Ohio State University, workforce development and regional economic growth. With a dedicated staff of product engineers and participation by research faculty, CDME is able to move at the speed of industry while continuing to innovate. Equipment, facility and staff from The Ohio State University system are all utilized in the most efficient productive manner for any project.

CDME provides industry with a simple expeditious way to access all the intellectual and physical assets of the university and surrounding research community. Easy contract mechanisms and unambiguous business terms allow industry certainty around the value proposition of the engagement before any project begins. Since hiring the first engineer in September 2015, CDME has seen a period of significant growth and currently has 12 employees and is currently recruiting more staff.

CDME FISCAL YEAR 2016 HIGHLIGHTS

- Growth to over 20 center affiliated faculty researchers participating in proposed or ongoing projects.
- Growth to 9 industry members including Honda, EWI, Whirlpool and Rea Magnet Wire.
- Development of a student experiential learning program which teams students from various backgrounds on real world engineering and business programs. CDME employs 20 undergraduates and 5 graduate/PhD students.
- Acquisition and renovation of over 40,000 square feet of engineering and applied research workspace.
- Development of an integrated additive manufacturing for agile tooling and dies program which includes over 12 specialized 3D printers housed at CDME and related in-house expertise.
- In place acquisition and operation of equipment utilized for manufacturing commercialization. These include injection molding, forming, welding, shaping, testing and various integration work cells for mechanical and electrical systems.
- The center launched 66 projects for industrial and internal customers in FY16.
- Award of a $1,010,000 State of Ohio Advanced Manufacturing Program (AMP) grant to assist in the commercialization of Dr. Glenn Daehn's, MSE, Vaporizing Foil Actuator Welding (VFAW) technology.
- Award of a $690,978 State of Ohio Advanced Manufacturing Program (AMP) grant to assist in the commercialization of Dr. Yuan Zheng's, ECE, Circular Wave Drive Technology. This technology has been licensed to a start-up which is continuing commercialization.

- Proposal development which led to an award of a State of Ohio Technology Validation Fund (TVSF) Phase 1 grant and a subsequent Ohio State Accelerator grant to assist in the commercialization of Dr. Avraham Benatar's Ultrasonic Composite Processing technology.

- Proposal development which led to an award of an Ohio State Accelerator grant to assist Dr. Vish Subramaniam's Non-Invasive Malaria detection technology.
- Led or assisted in the development of proposals to over 15 federal or state programs with a funding success rate in excess of 50%.
- Participated in internal and external commercialization programs such as I-Corps@ Ohio, TCO's BOSS competition, the Ohio Federal Research Network and others.

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. Ohio Manufacturing Institute's manufacturing-based economic development research is focused on advancing best-practice ecosystems in which small- to mid-sized manufacturers thrive and helping them to engage in next-generation manufacturing and access a skilled workforce needed to support this enterprise. Major highlights during FY2016 include the following:

OHIO STATE RECEIVES SHARE OF $8M TO HELP COMPANIES AFFECTED BY DEFENSE CUTS

Ohio Manufacturing Institute is managing a $2.24 million program to assist companies and communities in the state that have been impacted by defense cuts resulting in reduced sales and job losses. The second phase of the U.S. Department of Defense's Office of Economic Adjustment joint program with Purdue University and University of Michigan will help 30 companies and six communities to support more than 4,500 employees and help retain $2.4 billion in sales.

OMI ENGAGED BY STATE DEVELOPMENT AGENCY ON MANUFACTURING ROADMAPS

The Ohio Development Services Agency engaged the Ohio Manufacturing Institute to develop industry-vetted policy roadmaps focused on small- to mid-sized manufacturers (SMMs) in the manufacturing supply chain. The roadmaps determined that the issues faced by SMMs include workforce and training resources, advanced materials, Industry 4.0 and innovation and commercialization. OMI presented recommendations on how they can best access the technical resources available in the manufacturing ecosystem (MEP centers, universities, public/private labs, industry/tech organizations, technical centers, and community colleges).

LIGHTWEIGHTING AND ADVANCED MANUFACTURING CO-LOCATED INTERNSHIPS OFFERED

The Ohio Department of Higher Education Ohio Means Internships and Co-ops (OMIC) program funded OMI as a lead organization offering co-located and regular student internships in lightweighting and advanced manufacturing. The Columbus Region LIFT OMIC program has offered 80+ co-located regular internships so that community college, OhioTechnical Center, and university students can work closely with industries on advanced manufacturing projects. The co-located internships are connected to the federal Lightweight Innovations for Tomorrow (LIFT) program, a partnership between University of Michigan, Edison Welding Institute and The Ohio State University.

Center for Emergent Materials

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

The Center for Emergent Materials (CEM) was established in 2008 through the National Science Foundation MRSEC program, which creates centers to engage researchers from multiple disciplines to work in teams on scientific problems too complex for a single researcher to solve.

The CEM employs innovative multidisciplinary and interdisciplinary science to discover and engineer emergent materials that reveal novel phenomena and phases. CEM research is focused on understanding and controlling magnetism in novel materials and materials systems, and on exploration of emergent electronic and magnetic phenomena. Interdisciplinary teams of faculty, students and postdoctoral researchers are addressing the multi- faceted scientific issues this challenge presents by integrating materials synthesis/growth, characterization, novel probe development, and theory and modeling. CEM seeks to maintain and enhance the strong scientific community that will be the heart of this endeavor, so the center is vigorously engaged in improving participation by the relatively untapped resources of women and underrepresented racial and ethnic minorities. These programs integrate the excitement and potential of the center's research into public outreach and education programs that dovetail with recruitment and teaching of diverse communities at all levels — from K-12 students extending through undergraduates, graduates, and postdocs.

CEM IS ESTABLISHING SCIENTIFIC FOUNDATIONS IN THREE AREAS OF MATERIALS RESEARCH, ORGANIZED IN INTERDISCIPLINARY RESEARCH GROUPS (IRGS):

IRG-1: Spin-Orbit Coupling in Correlated Materials: Novel Phases and Phenomena

IRG-1 is focused on novel oxides composed of materials with various 5d electronic configurations allowing interplay between fundamental interactions that is predicted to lead to new electronic phases. IRG-1 researchers discovered that, contrary to previous expectations, osmate pyrochlores, $Y_2Os_2O_7$ and $Ho_2Os_2O_7$, exhibit local magnetic moments and theoretically explained the result. They developed a clearer picture of the orbital interactions and grew and characterized epitaxial films of the iridate pyrochlore $Nd_2Ir_2O_7$ for the first time.

In a striking result published in *Nature Materials,* IRG-1 researchers discovered a new phase of matter known as a topological Weyl semimetal. Using theoretical modeling and angle-resolved photoemission spectroscopy, the team identified the first type-II Weyl semimetal phase in the layered transition metal compound $MoTe_2$. Type-II Weyl semimetals possess electron and hole pockets which touch at topologically protected points in momentum space and form unusual surface states resulting in unique transport properties. Additionally, these Weyl excitations are robust against external perturbations, providing a resilient platform for electronic applications.

IRG-2: Control of 2D Electronic Structure and 1D Interfaces by Surface Patterning Group IV Graphane Analogues

IRG-2 is creating and studying single atom thick materials reminiscent of graphene but composed of heavier atoms that bring spin-orbit interactions to bear. This can alter fundamental aspects of electronic structure and create new opportunities for understanding spin behavior in reduced dimensions. Through control of covalent surface termination and proximity effects this could lead to unprecedented tunability of band structure, spin-orbit coupling, and other spin-based phenomena in 2D materials.

IRG-2 has advanced understanding of band structure tuning by optimization of the growth of ligand terminated sp^3 germanane materials with minimal defects, development of synthesis and studies of tin-based group IV graphane materials, STM tip-induced functionalization and ARPES studies of graphene and sp^2 germanium graphene analogues, and predictions of 1D spin-polarized channels at interfaces of lateral heterostructures. IRG-2 also created a novel class of exfoliatable 2D crystal building blocks from van der Waals Zintl phases, developed the methodology to measure spin dynamics of 2D materials via time-resolved Kerr rotation mapping, demonstrated the layer-dependent superconductivity in 2D $NbSe_2$, and controlled valley Hall effects with vertical electrical fields in bilayer MoS_2.

IRG-3: Spin Flux Through Engineered Magnetic Textures: Thermal, Resonant, and Coherent Phenomena

IRG-3 seeks to enable a new regime of spin transport by studying spin fluxes in magnetically textured materials which, if successful, could enable new paradigms for spin transport and new approaches to manipulation and control in spintronic devices. A particular focus is the creation and understanding spin flux in engineered magnetic textures that will reveal collective and coherent magnetic excitations that could realize new spin transport mechanisms that enable high efficiency, long-range spin conduction. IRG-3 researchers recently revealed new regimes of dynamic coupling between carrier spins in semiconductors and adjacent ferromagnetic layers, pointing toward the potential for strong nuclear magnetic fields in providing controllable static and dynamic magnetic textures

Leveraging complementary expertise in the sample fabrication and a suite of characterization techniques, IRG-3 has extensively studied magnetic heterostructures providing insights into various magnonic spin fluxes in ferromagnetic and antiferromagnetic insulators that are excited by ferromagnetic resonance, thermal gradients, and spin-microscopy probes.

EDUCATION, OUTREACH, & DIVERSITY

During this reporting period, the CEM engaged in education, training, and outreach programs that impacted over 2,300 K-12 students, 43 K-12 teachers, over 4,500 undergraduates in classes, 3 undergraduate researchers, 45 graduate students, and 14 postdoctoral researchers. CEM's innovative Materials Science Education Research program is working with CEM faculty to improve teaching in advanced undergraduate laboratory classes and CEM faculty are developing and implementing a set of guided group work sessions for graduate quantum mechanics, as well as upper level undergraduate quantum mechanics, electrodynamics, and classical mechanics. The CEM also continues to be substantially engaged in the Ohio State department of Physics M.S.-to-Ph.D. Bridge Program. One of six APS-supported bridge programs, it is in its third year, currently includes four Bridge fellows and since inception, the department's acceptance rate of underrepresented minorities has increased from less than 1 to more than 6 acceptances per year. Finally, a highly successful regional midwest Conference for Undergraduate Women in Physics, (CUWiP), was held at Ohio State in January 2016, and was chaired and organized by a CEM postdoc and faculty member.

CEM's Science Day—a yearly culmination of the Scientific Thinkers program—was held in May at Innis Elementary School in Columbus. This science-themed field day had 13 CEM students and 1 faculty member working with teachers and students as they rotate through 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.

2016 OSU Materials Research Seed Grant Program

The OSU Materials Research Seed Grant Program provides internal research funding opportunities through two distinct Funding Tiers — Exploratory Materials Research Grants and Multidisciplinary Team Building Grants — designed to achieve the greatest impact for seeding and advancing excellence in materials research of varying scopes. The goal of the program is to support the generation of materials research in new directions that extend beyond the boundaries of existing research programs. The OSU Materials Research Seed Grant Program is jointly funded and managed by IMR along with the Center for Emergent Materials (CEM), and the Center for Exploration of Novel Complex Materials (ENCOMM).

After a thorough internal and external review process, eleven awards were made to fund exceptionally promising, innovative materials research on campus through the 2016 OSU Materials Research Seed Grant Program. These awards total $500,000 in internal research funding to 25 Ohio State researchers from ten departments in five colleges.

2016 EXPLORATORY MATERIALS RESEARCH GRANTS

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

- **Direct Structural Determination of Individual DNA Molecules Using Electron Nanodiffraction,** PI: Jinwoo Hwang, Materials Science and Engineering; Co-Investigator: Kichoon Lee, Animal Sciences
- **Molecular Beam Epitaxy Growth of 2D Ferromagnetic Semiconductors,** PI: Roberto Myers, Materials Science and Engineering; Co-Investigators: Roland Kawakami, Physics; Wolfgang Windl, Materials Science and Engineering
- **An Integrated Experimental-Computational Approach for Determining the Phonon Mean Free Path Spectrum in Semiconductors,** PI: Sandip Mazumder, Mechanical and Aerospace Engineering; Co-Investigator: Marat Khafizov, Mechanical and Aerospace Engineering
- **Effects of Polymer Adsorption on Dynamics of Model Polymer Nanocomposites for Design of Advanced Tire Tread Compounds,** PI: Kurt Koelling, Chemical and Biomolecular Engineering; Co-Investigator: Lisa Hall, Chemical and Biomolecular Engineering
- **Uncertainty Quantification for Model Selection: Evaluating Material Constitutive Models based on Available Data,** PI: Stephen Niezgoda, Materials Science and Engineering; Co-Investigator: Oksana Chkrebtii, Statistics
- **Development of a Nanoscale Rheology Sensor in a Microphysiological Model of Tumor Stroma,** PI: Jonathan Song, Mechanical and Aerospace Engineering; Co-Investigators: Carlos Castro, Mechanical and Aerospace Engineering; Michael Ostrowski, Cancer Biology and Genetics
- **Synthesis and Design of Novel Graphyne and Graphdiyne-Based Metal-Organic Frameworks,** PI: Psaras McGrier, Chemistry and Biochemistry
- **The Effect of Abutment Material on Wear of Internal Engaging Features of Implants under Cyclic Loading,** PI: Fengyuan Zheng, Restorative Sciences and Prosthodontics; Co-Investigators: Damian Lee, Restorative Sciences and Prosthodontics; Jinwoo Hwang, Materials Science and Engineering

2016 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:

- **Ultra Wide Band Gap III-Nitride Semiconductor Materials and Devices,** PI: Siddharth Rajan, Electrical and Computer Engineering; Co-Investigators: Jinwoo Hwang, Materials Science and Engineering; Aaron Arehart, Electrical and Computer Engineering
- **Magnetic Dynamics and Excitations in Skyrmions Stabilized by Thin Films and Multilayers,** PI: Chris Hammel, Physics; Co-Investigators: Vidya Bhallamudi and Fengyuan Yang, Physics; David McComb, Materials Science and Engineering
- **Halide Double Perovskites: A New Class of Lead-free Compound Semiconductors,** PI: Patrick Woodward, Chemistry and Biochemistry; Co-Investigators: Joseph Heremans, Mechanical and Aerospace Engineering; Roberto Myers and Wolfgang Windl, Materials Science and Engineering

IMR Facility Grants

IMR Facility Grants make shared campus research facilities more accessible to Ohio State researchers wishing to demonstrate materials-related research results with the goal of strengthening near-term research proposals for external support. Each Facility Grant provides $2,000 to offset the cost of user access fees and related minor charges such as materials and supplies, with the goal of seeding new, innovative materials research at Ohio State. IMR offers two rounds of IMR Facility Grants each fiscal year, with deadlines in the fall and spring. During Fiscal Year 2016, IMR awarded eleven new Facility Grants, for a total investment of $22,000 to support new research efforts. Abstracts for each of these research projects can be found on IMR's website.

- **Analytical TEM for Physiological vs. Pathological Iron Core** – Gunjan Agarwal, Biomedical Engineering; Co-Investigators: David McComb, Materials Science and Engineering; Dana McTigue, Neuroscience
- **LIPSS and SIPSS: Novel Surface Patterning Processes for Materials** – Sheikh Akbar, Materials Science and Engineering; Co-Investigator: Enam Chowdhury, Physics
- **A Micro/Nanofabricated Platform for Enhanced Gene Delivery: Applications in Cell-based Therapies** – Daniel Gallego Perez, Surgery; Co-Investigator: Savita Khanna, Surgery
- **Development of Photonic Crystals for the Investigation of Magneto-Optical Properties in 2D Materials** – Ezekiel Johnston-Halperin, Physics
- **Quantification of the Effect of Active Beta Phase Grain Boundary Coverage on Fatigue in Simulated Marine Environments** – Jenifer S. Locke, Materials Science and Engineering
- **Sample Fabrication for BEEM Studies of Contacts to 2D Materials** – Jonathan Pelz, Physics; Co-Investigator: Roland Kawakami, Physics
- **Developing Nonlinear MEMS** – Hanna Cho, Mechanical and Aerospace Engineering
- **A Correlative Study of the Skyrmion Phase Diagram for FeGe Thin Films** – Sarah Dunsiger, Physics and Center for Emergent Materials; Co-Investigator: Robert Williams, Center for Electron Microscopy and Analysis
- **Atomic Scale Chemical Ordering and Structural Distortion in High Entropy Alloys** – Maryam Ghazisaeidi, Materials Science and Engineering; Co-Investigator: Jinwoo Hwang, Materials Science and Engineering
- **Quantifying cell-matrix remodeling during angiogenesis in a microfluidic vessel bifurcation system** – Jonathan Song Mechanical and Aerospace Engineering; Co-Investigator: Shaurya Prakash, Mechanical and Aerospace Engineering
- **Selective Electrohydrodynamic Deposition (SED) for Creating 3D Hybrid Microstructures** – Yi Zhao, Biomedical Engineering

Nanotech West Laboratory

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 administrative 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 Ohio State's West Campus, Nanotech West provides substantial impact and continues to be a centerpiece of collaborative research to OSU's materials research community.

Location: Science Village
1381 Kinnear Road, Columbus, Ohio 43212
Website: nanotech.osu.edu
Contact: Dr. Robert J. Davis, Director,
(614) 292-7309, davis.2316@osu.edu
Dr. John Carlin, Associate Director
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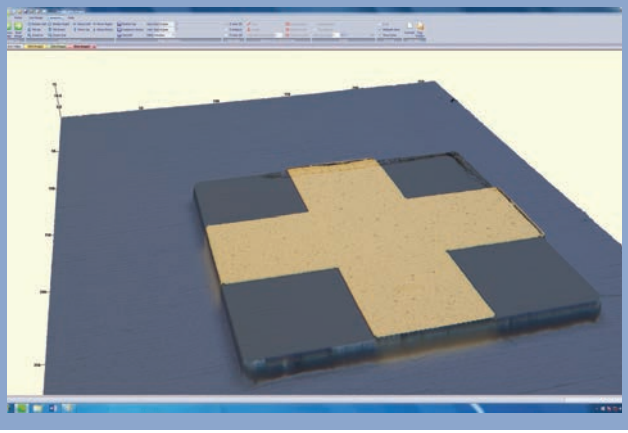
NANOTECH WEST LABORATORY FY16 HIGHLIGHTS

- Nanotech West Lab supported more than 200 Ohio State users representing 110 research projects in the Colleges of Engineering, Arts and Sciences, and Medicine, impacting more than $30M of sponsored research, as well as 50 non-OSU users

- Installed a Zeta-30 optical profilometer, an instrument that can provide 3D images of surfaces down to a ~15 nm (z-axis) resolution, and built an electro-optical test capability that in wavelength ranges from the visible to ~2.3 microns (infrared); both through the Ohio Sensor and Semiconductor Innovation Platform (OSSIP) program, funded by the Ohio Third Frontier program and Ohio Development Services Agency



3D image of a metal photo-lithography alignment mark (cross) on a III-V compound semiconductor photovoltaic (solar) cell, imaged in 3D by the new Zeta-20 optical profilometer at the Nanotech West Lab. The alignment mark is located on a dry-etched mesa of ~8 microns height.

Image by David Hollingshead

- Developed an atomic-layer-deposited zinc oxide diffusion doping process for lithium niobate, a new process resulting in modulators that can handle 10 times the optical power of conventional modulators based on titanium doping. The research and development was done in close collaboration with Srico, Inc., a local small company that manufactures niobate-based devices including high-speed electro-optic modulators. The work resulted in new products and two new, significant federal R&D grants for Srico, which will expand their use of Nanotech West. In addition, the research was published in Proceedings of SPIE, Integrated Optics: Devices, Materials and Technologies Proceedings with Nanotech West Research Associate Jay DeLombard as a co-author (Proc. SPIE 9750, March 2016; doi:10.1117/12.2210999)
- Nanotech West staff members continued to extend their reach outside of the lab and engage in additional university-wide activities —Administrative Associate Mary McCleery serves on a committee advising the university on its move to a new enterprise-level software system; Associate Director John Carlin served on an Office of Research committee that restructured the onboarding process for new hires; Research Associate Aimee Price is a member of the University Energy Committee; and Director Robert Davis is Chair of the University Laboratory Safety Committee (ULSC) that advises the OSU Department of Environmental Health and Safety
- Nanotech West became the first user facility to achieve Green Buckeye Certification, a university designation reserved for facilities which implement best practices to improve the sustainability performance of their laboratory. The facility is one of only nine Green Buckeye Certified Laboratories on campus. Nanotech West staff continue to work with the Green Buckeye team to identify ways to increase sustainability efforts in campus research environments within the over 3,000 laboratories at The Ohio State University.

Center for Electron Microscopy and Analysis (CEMAS)

The Center for Electron Microscopy and Analysis (CEMAS) is the materials characterization hub for business and academia. With one of the largest concentrations of electron and ion beam analytical microscopy instruments in any North American institution, CEMAS brings together multidisciplinary expertise to drive synergy, amplify characterization capabilities, and challenge what is possible in analytical electron microscopy.

This microscopy facility's point of difference is their world-class multidisciplinary approach that enables academic and business partners to "see" more than ever before. CEMAS is the center that breaks through the current characterization limitations in medicine, environmental science, energy materials and beyond. The full-service facility – from extensive sample preparation laboratories to post-processing tools and support – allows researchers to carry out their entire microscopy and analysis program at CEMAS. Located in a highly customized facility on The Ohio State University's West Campus, every instrument in the facility meets or exceeds manufacturer performance specifications. A support team of technical, research, administrative and academic staff based at CEMAS provides comprehensive support to all users through a variety of mechanisms from contract research to collaborative projects.

CEMAS FISCAL YEAR 2016 HIGHLIGHTS

- The CEMAS facility supported 254 Ohio State University researchers and 15 users from external academic institutions and industry partners, for a total of 269 users during FY16.
- The Ohio State – FEI Electron Microscopy Collaboratory was completed in January 2016. This digital theater is an electron microscopy training feature unique to CEMAS and the cornerstone of the facility's commitment to providing full-service microscopy services to business and academia. CEMAS hosted a plaque dedication ceremony on June 13, 2016 to dedicate and thank FEI company for their ongoing support in developing the new digital learning environment. The digital theater's name, the Ohio State – FEI Electron Microscopy Collaboratory, reflects the efforts of CEMAS and FEI Company to expand the accessibility of electron microscopy to students, researchers, and industrial partners.
    - The collaboratory was used to teach over 100 students in the first semester during three separate classes (MSE2331, MSE6715, and MSE6741).
    - CEMAS launched several more remote stations at The Ohio State University campus in Wooster, as well as another station in the microscopy facility at the University of Dayton. These remote stations allow even more students and researchers to remotely access CEMAS's world-class microscopy instruments, and CEMAS staff continue to work with several other partners to collaborate remotely in the future.
- CEMAS hosted two professional workshops to enhance the skills of students and other researchers. An Ultramicrotomy workshop was held at CEMAS at the end of October 2015 with leading expert Helmut Gnaegi of Diatome exhibiting the various capabilities of the Diatome diamond knives and the Leica ultramicrotome. CEMAS also hosted a Rigaku XRD workshop in January where samples of thin films were tested and new methods of x-ray diffraction were demonstrated by Aya Takase.

OHIO STATE – FEI ELECTRON MICROSCOPY COLLABORATORY

World-class microscopy education in the theory of electron microscopy and all aspects of its use and operation is also available at CEMAS, both in-house and remotely, through our digital theater. Students have live access to CEMAS instruments in real time within a state-of-the-art classroom environment to meet every microscopy training need. Video wall technology provides multiple display screens and projectors, allowing simultaneous display of microscope controls, microscope outputs and lecture slides. Students and lecturers can interact with and operate electron and ion microscopes from within the digital theater in a live, seamless manner – as if one were sitting in front of the instrument. Control of the microscope can be transferred to members of the audience using wired and wireless connectivity.

The microscopes can also be shared with students and researchers at geographically distant locations. Remote operation capabilities connect directly to the 100 Gb/s Ohio OARnet network, providing a unique opportunity for remote teaching and research to partners across the state of Ohio. CEMAS is pioneering the practical application of this technology for research and training of the next generation of electron microscopy specialists, providing an environment to facilitate world-class collaborative research, and maximizing productivity while minimizing economic and environmental impact. This remote electron microscopy collaboratory system has been installed at the University of Dayton, The Ohio State University's Wooster campus and the Air Force Research Laboratory at Wright-Patterson Air Force Base (Dayton), with additional locations planned for the near future.

- Senior Research Scientist, Henk Colijn, has been working closely with Oleg Lourie from EDAX to test a TEM EDX detector prototype on the FEI Tecnai T20 at CEMAS. This work promises to extend the range of X-ray detection in the STEM to energies as high as 100keV.
- Communications officer, Isabel Boona, and Senior Research Officer, Frank Scheltens, worked together to develop a two-lecture outreach opportunity for local high school students at Metro High School. In May 2016, the students were introduced to the field of materials science and engineering as well as electron microscopy. The students made their own samples during the first lecture and were invited to operate the Quanta scanning electron microscope in the new digital theater at CEMAS to observe their own samples during the second lecture. This successful program is being expanded in the coming year.

Location: 1305 Kinnear Rd, Suite 100,
Columbus, Ohio 43212
Website: 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 photolithography, 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.

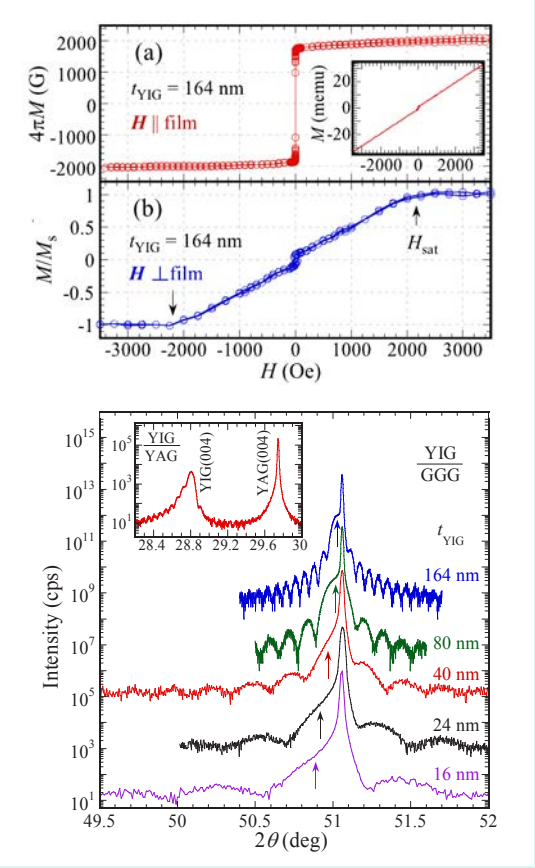
NANOSYSTEMS LABORATORY FISCAL YEAR 2016 HIGHLIGHTS

- NanoSystems Laboratory provided research services totaling $215,000 and supported 185 users (including 40 female researchers) from 61 research groups during FY16. Most of those researchers supported were from 12 departments at The Ohio State University, with 4 external groups from industry and other educational institutions.
- The NSL facility acquired a new Trion Minilock — Phantom III Reactive Ion Etch (RIE) System from Trion Technology. This instrument provides users with state-of-the-art plasma etch capability using single wafers, dies or parts using fluorine and oxygen based chemistries, including etch applications that require corrosive chemistries. The gases available in the system include CI2, BCI3, SF6, CHF3 and CF4. Acquisition of the system was jointly funded by the Center for Emergent Materials (CEM) NSF MRSEC and the Center for Exploration of Novel Complex Materials (ENCOMM). The system is now installed and being tested, and staff expect it to become operational in the fall of 2016.
- This year the NSL also acquired two new furnaces from MIT Corporation. These furnaces will enable a new capability for high temperature processing of materials at the facility. The KSL-1800X furnace is a compact muffle furnace with operating temperature up to 1800 C., which the GSL-2000X-25 is a compact ultra-high temperature tube furnace with operating temperature up to 2000 C. Acquisition of these furnaces was funded by the Center for Emergent Materials (CEM) NSF MRSEC.

NANOSYSTEMS LAB RESEARCH HIGHLIGHT

Observation of exceptionally high magnetization of stoichiometric $Y_3Fe_5O_{12}$ epitaxial films grown on $Gd_3Ga_5O_{12}$

The saturation magnetization of $Y_3Fe_5O_{12}$ (YIG) epitaxial films 4 to 250 nm in thickness has been determined by complementary measurements including the angular and frequency dependencies of the ferromagnetic resonance fields as well as magnetometry measurements. The YIG films exhibit state-of-the-art crystalline quality, proper stoichiometry, and pure Fe^{3+} valence state as characterized by high resolution X-ray diffraction, X-ray reflectivity, ferromagnetic resonance, magnetometry, and scanning transmission electron microscopy measurements. The values of YIG magnetization obtained from all the techniques significantly exceed previously reported values for single crystal YIG and the theoretical maximum, suggesting that epitaxial growth of excellent quality YIG films on $Gd_3Ga_5O_{12}$ (GGG) may be responsible for the surprising enhancement of YIG magnetization. This research was completed at NanoSystems Laboratory using NSL's instrumentation and expertise in x-ray diffraction, x-ray reflectivity, ferromagnetic resonance, and SQUID magnetometry, including the x-ray diffraction of the YIG films shown in the image to the right.



Room temperature in-plane and out-of-plane hysteresis loop of a 164 nm YIG film with observed saturation magnetization of as high as 2020 G. From "Exceptionally high magnetization of stoichiometric $Y_3Fe_5O_{12}$ epitaxial films grown on $Gd_3Ga_5O_{12}$", J. C. Gallagher, A. S. Yang, J. T. Brangham, B. D. Esser, S. P. White, M. R. Page, K.-Y. Meng, S. S. Yu, R. Adur, W. Ruane, S. R. Dunsiger, D. W. McComb, F. Y. Yang, and P. C. Hammel, Appl. Phys. Lett. 109, 072401 (2016).

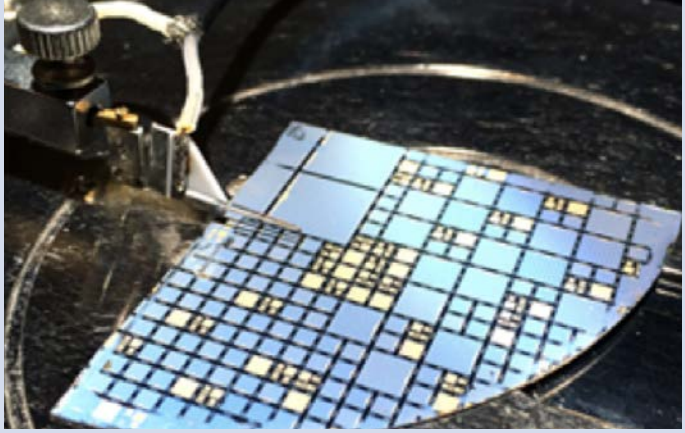
Location: Physics Research Building
First floor and Lower Level,
191 West Woodruff Avenue,
Columbus, Ohio 43210
Website: ensl.osu.edu
Contact: Dr. Denis V. Pelekhov, Lab Manager
(614) 292-9125, pelekhov.1@osu.edu

Semiconductor Epitaxy and Analysis Laboratory (SEAL)

The Semiconductor Epitaxy and Analysis Laboratory (SEAL) is Ohio State's primary facility for molecular beam epitaxy (MBE). 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 a broad range of semiconductor materials, including AlGaInAsP, AlGaInNx and SiGe. Several chambers are integrated into ultra-high vacuum (UHV) cluster tools enabling an unusual range of hybrid structures and devices. 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 heterostructures 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.

SEMICONDUCTOR EPITAXY AND ANALYSIS LABORATORY FISCAL YEAR 2016 HIGHLIGHTS

- SEAL provided $122,000 in research services in FY16 that enabled more than $10M of external research funding to SEAL faculty and industry clients. The facility expanded its reach to include external engineering service contracts, which brought in over 20% of SEAL's total revenue in FY16.
- The Rajan group utilized MBE3 to produce ground breaking work developing high efficiency tunnel injection of UV light emitters. These researchers are pioneering a novel device architecture and developing emitters that are radically different from conventional UV LEDs, employing a tunnel-junction to improve hole transport through the heterostructure. With the goal of reducing or even eliminating the barriers to widespread adoption of UV LEDs, their device has the potential to slash the cost of the UV LED while delivering a tremendous increase in its efficiency. This achievement was featured in the June 13, 2016 issue of Compound Semiconductor magazine.
- Installation was completed on MBE5, a new Veeco Gen 930 MBE chamber which enhances SEAL's cadre of instrumentation by offering two-dimensional semiconductor material exploration. This instrument was acquired through a National Science Foundation grant, and the current focus is toward 2D growth of MoWSe2 based materials. Additionally, SEAL researchers are developing an optical Raman setup for this system to provide real time in-situ analysis of the 2D materials growth. This year SEAL researchers have grown initial layers of MoSe2 based material and also researched GaSe material using MBE5, and publication on this work is forthcoming.
- Operational tests and successful growth of Ga2O3 within the MBE4 instrument have been achieved. β-Ga2O3 is an ultra-wide band gap material with application in high power electronics and solar-blind ultra violet photodetectors. This is currently a very active area of research in its nascent stage and SEAL researchers are working towards developing doping techniques and device fabrication processes for β-Ga2O3- based devices. Joint projects and collaborations related to these doping techniques are underway.



SOLAR CELL RESEARCH FIRSTS HAVE ORIGINS AT SEAL

The world's first true epitaxial GaAsP/Si dual-junction and GaInP/GaAsP/Si triple-junction Si tandem solar cells were designed, grown, fabricated, and characterized by SEAL and Nanotech West researchers, who have been leaders in the field for nearly two decades. The image shows a processed solar cell wafer being tested under a simulated solar spectrum. This work is the culmination of numerous developments and discoveries made via SEAL and other IMR facilities. This work was funded by the DOE-EERE SunShot Initiative (DE-EE0005398), with contributions over the years by NASA, AFRL, ARO, and the State of Ohio. The demonstration of these breakthrough devices represents an important step forward in the development of next-generation high-efficiency, low-cost photovoltaics. For more information, see:

T. J. Grassman, D. J. Chmielewski, S. D. Carnevale, J. A. Carlin, and S. A. Ringel, "$GaAs_{0.75}P_{0.25}$/Si Dual-Junction Solar Cells Grown by MBE and MOCVD," IEEE J. Photovolt. 6(1), 326 (2016).

Location: SEAL Molecular Beam Epitaxy (MBE) Lab
Cleanroom: 095 Dreese Laboratories,
2015 Neil Avenue, Columbus, Ohio 43210
SEAL Analysis Lab: 360 Caldwell Laboratory,
2024 Neil Avenue, Columbus, Ohio 43210
Website: seal.osu.edu
Contact: Mark Brenner, Lab Manager
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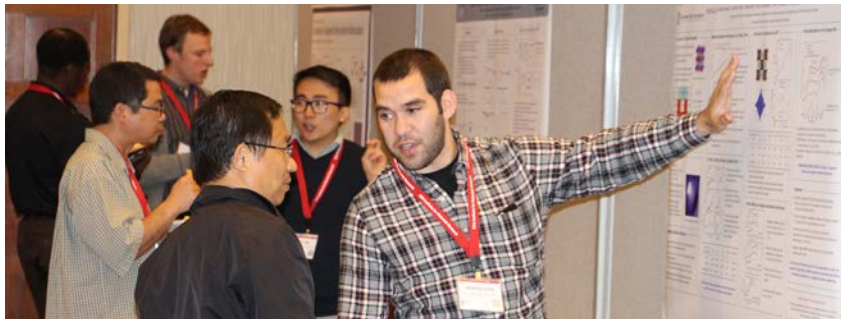
2016 OSU Materials Week



Our 8th annual Materials Week was held May 10-13, 2016 at the Blackwell Inn and Conference Center on Ohio State's Columbus campus. Materials Week is an annual event to share innovative research, enable collaborations, and celebrate the breadth and depth of Ohio State's multi-dimensional materials community. The conference brings together hundreds of researchers from academia, government labs and industry to discuss the latest materials advances across the wide spectrum of materials-allied fields. 2016 OSU Materials Week welcomed over 300 participants who attended a Keynote Address, two Crosscutting Sessions, six Focus Sessions and two Student Poster Sessions.

Ohio State President Michael Drake attended the closing session, saying a few words about the importance of materials research and sustainability on society, and congratulating our Student Poster Award winners. In addition to 15 Student Poster Awards, Above and Beyond awards were given to four IMR staff and Yeoman awards were given to search committee and department chairs involved in the extensive faculty searches as part of the Materials and Manufacturing for Sustainability Discovery Theme focus area. The 2016 OSU Materials Week conference was organized by the Institute for Materials Research and the Materials and Manufacturing for Sustainability Discovery Theme focus area, with additional sponsorship by the Center for Emergent Materials and Office of Energy and Environment at Ohio State.

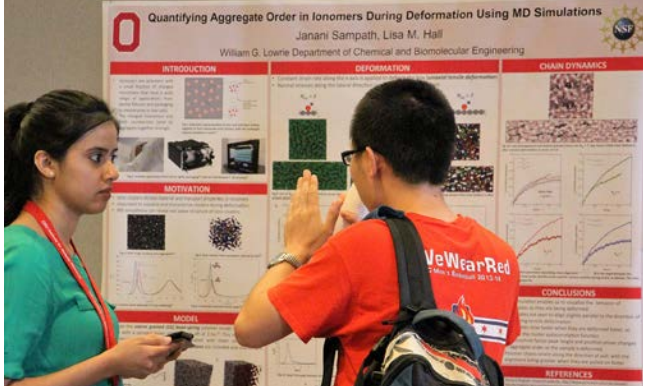
2016 OSU MATERIALS WEEK INCLUDED A TOTAL OF 36 SCIENTIFIC PRESENTATIONS IN EIGHT TECHNICAL SESSIONS:

- Two Crosscutting Sessions on Innovation, Entrepreneurship and Materials and Innovation in Materials Education
- **Six Focus Sessions**
  - Energy Harvesting and Storage
  - Developing New Ways to Manufacture Light, High-Performance Structures
  - Role of Corrosion on the Sustainable Use of Materials
  - Topological Materials
  - Simulation and Data Analytics
  - Nanotechnology in Medicine

IMR KEYNOTE ADDRESS

Rechargeable Batteries for Electric Cars
John Goodenough
Virginia H. Cockrell Centennial Chair in Engineering
University of Texas at Austin

We were fortunate and honored that the IMR Keynote Address, "Rechargeable Batteries for Electric Cars," was given by John Goodenough, University of Texas at Austin. Dr. Goodenough is responsible for developing world-leading advances in ionic conducting solids and electrochemical devices over a career spanning 7 decades, and might be most famous for his development of the lithium-ion battery, powering most all portable electronics today, netting him numerous recognitions such as the Charles Stark Draper Prize, the National Medal of Science and the Enrico Fermi Award.



2016 OSU MATERIALS WEEK – STUDENT POSTER AWARDS

Over 110 research posters were presented by Ohio State students from across the university at Materials Week's two poster sessions. Each poster and presentation was evaluated by volunteer judges and the top fifteen posters were recognized by Ohio State President Michael Drake during our Student Poster Awards at the conference's closing ceremony.

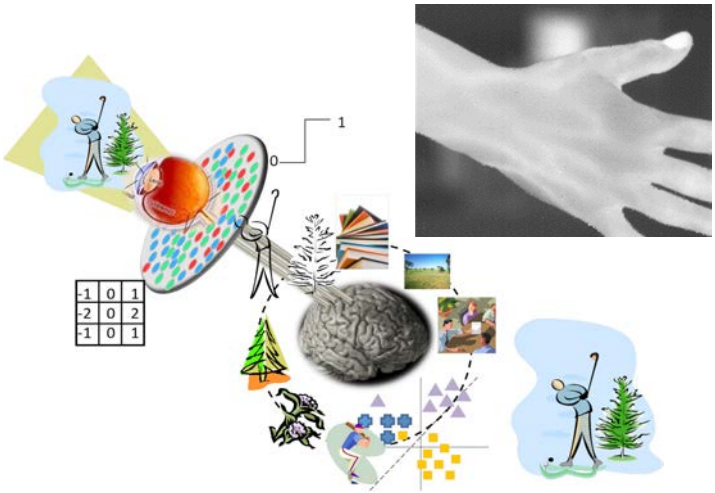
- **Michael Page, Physics,** "Optically Detected Ferromagnetic Resonance Using Nitrogen Vacancy Centers in Diamond," Advisor: P. Chris Hammel, Physics
- **Sarah Watzman, Mechanical and Aerospace Engineering,** "Magnon-Drag as a Pathway to High-Efficiency Thermoelectric Materials," Advisor: Joseph Heremans, Mechanical and Aerospace Engineering
- **Kevin Galiano, Physics,** "Spatial Localization of Electron Traps in GaN," Advisors: Jonathan Pelz, Physics and Steven Ringel, Electrical and Computer Engineering
- **Paul Gilmore, Mechanical and Aerospace Engineering,** "A Conducting Polymer Composite Cathode for Potassium-Air Batteries," Advisors: Vishnu Sundaresan, Mechanical and Aerospace Engineering and Yiying Wu, Chemistry and Biochemistry
- **Jose Lorie Lopez, Chemistry and Biochemistry,** "Evidence of capacity fade during delithiation of LixSn by in-situ 7Li NMR," Advisors: Philip J. Grandinetti, Chemistry and Biochemistry and Anne C. Co, Chemistry and Biochemistry
- **Brandon Giles, Materials Science and Engineering,** "Temperature Dependence of Magnon Spin Diffusion in Yttrium Iron Garnet," Advisor: Roberto Myers, Materials Science and Engineering
- **Steven Tjung, Physics,** "Crystalline Hydrogenation of Graphene Grown on Cu(111)," Advisor: Jay Gupta, Physics
- **John Jamison, Materials Science and Engineering,** "Investigation of the Picosecond Timescales of the Spin-Seebeck Effect in Pt/YIG," Advisor: Roberto Myers, Materials Science and Engineering
- **William McCulloch, Chemistry and Biochemistry,** "A Potassium-Ion Oxygen Battery Based on a High Capacity Antimony Anode," Advisor: Yiying Wu, Chemistry and Biochemistry
- **Chris Ehemann, Physics,** "A novel empirical potential for modelling martensitic transformations in Ti-Nb alloys," Advisor: John Wilkins, Physics
- **Elizabeth Bushong, Physics,** "Imaging Spin Dynamics in Monolayer WS2 by Time-Resolved Kerr Rotation Microscopy," Advisor: Roland Kawakami, Physics
- **Janani Sampath, Chemical and Biomolecular Engineering,** "Aggregate Alignment in Ionomers During Deformation from MD Simulations," Advisor: Lisa Hall, Chemical and Biomolecular Engineering
- **Travis Hery, Mechanical and Aerospace Engineering,** "Conducting Polymer as a Voltage-Gated Membrane Separator for Regulated Ion Transport in Energy Storage Devices," Advisor: Vishnu Baba Sundaresan, Mechanical and Aerospace Engineering
- **Maxx Arguilla, Chemistry and Biochemistry,** "Electrochemistry-Enabled Band Gap Modification of Organic Functionalized Two-Dimensional BN-Like (SnR)/P/As/Sb Graphane Derivatives," Advisor: Joshua Goldberger, Chemistry and Biochemistry
- **James Rowland, Physics,** "Skyrmions in Thin Film Magnets," Advisor: Mohit Randeria, Physics

Distinguished Lecture Series

The Institute for Materials Research hosts a Distinguished Lecture Series which brings world renowned materials researchers to The Ohio State University each year. IMR Distinguished Lecturers discuss cutting-edge materials research with Ohio State students, faculty and staff in an effort to broaden our information base beyond our campus by meeting some of the top scientists in their fields.

ANTIMONIDE MATERIALS FOR MID-INFRARED PHOTONIC DETECTORS AND FOCAL PLANE ARRAYS

Sanjay Krishna, Director, Center for High Technology Materials, Professor and Regents' Lecturer, Department of Electrical and Computer Engineering, University of New Mexico April 12, 2016



21.25% WORLD EFFICIENCY RECORD WITH MULTI-CRYSTALLINE P-TYPE SILICON SOLAR CELLS: CLOSING THE GAP WITH N-TYPE MONO

Pierre Verlinden, Vice President, Chief Scientist and Vice-Chair of State Key Laboratory, Trina Solar June 17, 2016

IMR-Supported Workshops and Seminars

The Institute for Materials Research continued to provide administrative and financial support to strategic workshops and seminars.

The **American Physical Society Conference for Undergraduate Women in Physics (CUWiP)** took place at The Ohio State University January 15-17, 2016. This conference included speakers, workshops and panels showcasing diversity in the physics field. CUWiP had about 250 participants who were given numerous opportunities to learn, network and mentor one another with the goal of recruiting and retaining females in the physics professions. IMR was one of several Ohio State University units who contributed financially to support this important event.

This fiscal year, IMR was also able to provide financial, logistical and financial support to another strategic workshop, the **2015 Non-linear Spin-heat Workshop** held on September 16 - 17, 2015, at The Ohio State University. Participants discussed theoretical an experiment work in the field of spin caloritronics, which was sparked by the discovery of the spin-Seebeck effect in 2008. With two days of 14 scientific talks, two panel discussions and a student poster presentation, this Army Research Office event included dozens of scientists from around the world.

GRO HARLEM BRUNDTLAND JOINS OHIO STATE'S SUSTAINABILITY DISCUSSIONS

On October 8, 2015, Dr. Gro Harlem Brundtland, former Prime Minister of Norway and Chair of the United Nations World Commission on Environment and Development, visited Ohio State's Columbus campus for a powerful day of discussions and lectures addressing the challenges of global sustainability and dramatic climate change.

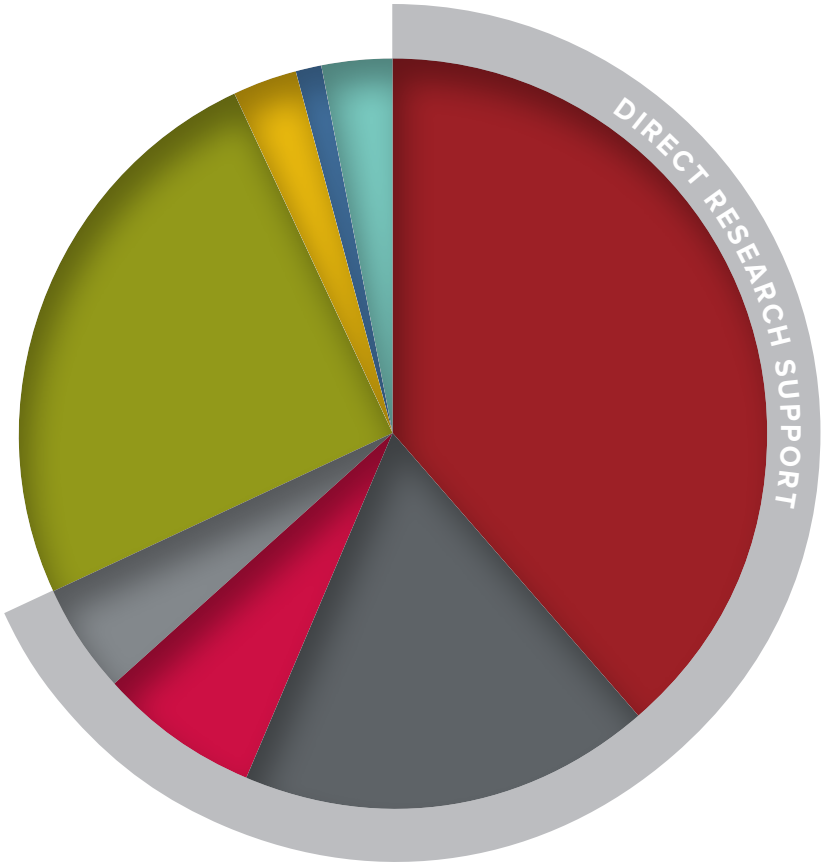
The morning began with a roundtable program on *Responding to Global Challenges of Sustainability and Resilience: The Nexus of Science, Technology, and Society,* a panel discussion including Dr. Brundtland and Ohio State faculty involved in the leadership of Ohio State's Discovery Themes Initiatives.

Dr. Bundtland 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. After sharing her speech to the United Nations just the day before, panelists discussed sustainability issues from their academic area's perspective, then answered questions from the audience of Ohio State faculty, staff and students. Panelists from agricultural, engineering, economic and legal disciplines participated, including Steve Ringel, IMR Executive Director and faculty lead of the Materials and Manufacturing for Sustainability (M&MS) Discovery Theme, who provided 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. At this lecture, attended by several hundred audience members, 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, and outlined goals to address climate change and the need for public funds targeted to supporting those goals.

Dr. Bundtland's visit to Ohio State was supported by several university departments and centers, including IMR.

IMR FY 2016 Financial Overview



70% DIRECT RESEARCH SUPPORT

- Technical Personnel $1,062,948 (39%)
- NTW Core Operating Expenses $494,804 (18%)
- Seed Grants $202,000 (7%)
- Additional Support of Prime Materials Research Centers $144,834 (5%)

30%

- Administrative Personnel $667,960 (25%)
- Outreach and Engagement $69,109 (3%)
- Strategic Workshops $5,950 (<1%)
- Core Operating Expenses $69,478 (3%)

In its first ten years of operations, Fiscal Years 2007 – 2016, IMR has seen a 10.3:1 return on investment

Institute for Materials Research Strategy

The Institute for Materials Research's strategic plan is driven by the goal to support and grow research excellence and impact by our students, staff and faculty to position Ohio State as a world-leader in materials research and innovation. The plan revolves around these core tenets:

- Programmatic alignment with university, college and department strategic plans,
- Enablement of interdisciplinary research,
- Development, support and advancement of prime research centers,
- Assurance of world-class core facilities, and
- Development of new strategic opportunities for the OSU materials community.

During the past year, the Materials and Manufacturing for Sustainability (M&MS) Discovery Theme program led by IMR has started in earnest. The hiring of our first cohort of M&MS faculty and innovation leaders has begun, the planned Materials Innovation Greenhouse is now a reality, our global partnership program is now vibrant, and the growth in IMR staffing has allowed us to lead massive initiatives that a year ago would have been impossible; all of this while our existing centers continue to push the leading edges of their fields and our seed programs are building the teams and centers of the future. Thus, with the IMR now 10 years old, the next 1 -3 years are pivotal, since now for the first time IMR has the capacity and resources to add to and complement its more internally-focused agenda with an external engagement strategy that leverages all that IMR has done to date.

Below is an outline of our set of rolling 1-3 year strategic objectives, which is updated annually to maintain relevancy.

PROGRAMS AND CENTERS

- Deliver on the Materials and Manufacturing for Sustainability (M&MS) objectives
- Expand strategic international collaborations
- Establish innovation partnerships through the Materials Innovation Greenhouse
- Sustain impact of existing research centers
- Develop at least two major block proposals

CORE MATERIALS FACILITIES

- Establish the Energy Storage Hub as a new core facility
- Improve operations and best practices across core facilities

COMMUNITY EVENTS

- Attract high-profile international conferences
- Launch Materials Innovation Greenhouse sessions, seminars and workshops

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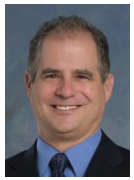

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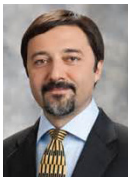

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