INSTITUTE FOR MATERIALS RESEARCH

FISCAL YEAR 2020

ANNUAL REPORT

THE OHIO STATE UNIVERSITY
INSTITUTE FOR MATERIALS RESEARCH

Letter from Executive Director Steven A. Ringel

The 2020 fiscal year has been like no other. With the onslaught of COVID-19, IMR reacted the only way it knows how: confronting the challenge, listening to the needs, and responding with high-impact contributions. IMR galvanized a national supply chain to manufacture and deliver more than half a million swabs for COVID-19 test kits to Ohio hospitals in a critical time of short supply. IMR leadership (Jay Sayre) was tapped by Ohio's governor to represent the university on the state's manufacturing task force against COVID-19, which activated many of our core facilities and personnel who not only managed the supply chain, but locally qualified the manufacturing process at the Center for Design and Manufacturing Excellence. Important new relationships were formed as a result and new research teams were established, which will greatly enhance IMR in the future.

Through all this, IMR had a spectacular year, as you will read in our spotlights section: large programs awarded, major equipment acquired and major centers funded anew, like our NSF-funded MRSEC. We also established Ohio State's first offshore research center: the IIT Bombay-Ohio State Frontier Center. We accelerated innovation engagements in areas ranging from energy to manufacturing, while our outstanding M&MS faculty members continued delivering best-in-class research. This report showcases a range of accomplishments, portraying the interdisciplinary breadth and depth of the institute and its vital role to Ohio State's strategic growth.

Of course, great accomplishments are built on the shoulders of giants and, sadly, Ohio State's materials research community lost two giants of our own in the past year: Arthur J. Epstein, Distinguished University Professor and Professor of Physics and Chemistry, and John Wilkins, Ohio Eminent Scholar and Professor of Physics. These pioneers laid the foundation for the creation of IMR and Ohio State's interdisciplinary materials community from 1990 to 2005. Art founded the Center for Materials Research (CMR), an innovative move from a true leader who recognized the power and potential of multi-college materials research at Ohio State. He happened to also recruit yours truly as an assistant professor into Ohio State's Electrical Engineering department, a department in a different college (Engineering) than his own (Arts & Sciences). From where I view things today, this was an amazing thing at a time when multi-college collaboration, much less recruiting into a different college, was virtually non-existent. But this was pure Art; he had a vision to seed electronic materials research at Ohio State and simply got it done. He took a few hits for being a pioneering agent of change, like all great leaders do, and then he nurtured the launch of a juggernaut. John Wilkins shouldered his fair share of Ohio State's burgeoning materials research community. John was Art's closest partner and confidante in the growth of CMR, and was the most uniquely interdisciplinary condensed matter theorist I have known. John used to question why anyone would ever need more than one theorist per 10 experimentalists and he proved his point by sending many of his students to spend countless hours with my group and our experiments. John and Art were not just giants, they were great friends who took me under their collective wing many years ago. I am forever grateful and IMR would not be what it is today without them.

Sincerely, Steven A. Ringel, Ph.D.

Executive Director, Institute for Materials Research
Distinguished University Professor
Neal A. Smith Chair Professor, Electrical and Computer Engineering

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A CLOSER LOOK

The Institute for Materials Research (IMR) was established at The Ohio State University in 2006 with a central goal: to guide Ohio State's materials-allied research enterprise to be among the very best in the nation. IMR steers this enterprise to continually impact the forefront of materials research; win the most competitive, prestigious research programs and centers; and enable the attraction of top talent in areas that exploit the multi-college breadth of the university. This institute brings together a large, diverse interdisciplinary community consisting of 274 faculty members from 38 departments and 10 colleges, all of whom are actively engaged in research and innovation across the materials continuum.

ABOUT IMR

The Ohio State University's Institute for Materials Research (IMR) is a multi-college, university-level institute that leads materials-related research and innovation through interdisciplinary collaboration. With research teams and centers that cross department and college boundaries, IMR provides a dimension to Ohio State's materials-related research community that transcends traditional academic structures. This has led to the creation of a research and innovation ecosystem that spans from fundamental science to engineering to translational interfacing with industry. As a result, IMR provides an array of support mechanisms, shown on the right, which sustains the growth and impact of the community.

The success of IMR's interdisciplinary approach has enabled partnerships with colleges and departments to co-lead faculty hiring programs, including the Targeted Investment in Excellence program, the Ohio Research Scholars program, and, most recently, our Materials & Manufacturing for Sustainability (M&MS) Discovery Theme program.

MATERIALS & MANUFACTURING FOR SUSTAINABILITY

The M&MS Discovery Theme program shifted IMR's paradigm with an expansive research and innovation focus targeting global challenges surrounding energy transitions and environmental sustainability. This program has led to the establishment of IMR's Innovation Lab and Ohio State's first global research center of excellence: the IIT Bombay-Ohio State Frontier Center. Additionally, the M&MS Discovery Theme enabled IMR to recruit two dozen new faculty members. This cohort stimulates new interdisciplinary activity to address the grand challenges facing our society in the 21st century.

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

SIGNATURE AREAS & STRATEGIC THEMES

IMR derives its strengths from its interdisciplinary nature. This is true whether at the level of established centers of excellence or at the level of small teams. IMR's Signature Areas, and the more narrowly scoped Strategic Themes within them, represent areas of existing national and international prominence, unique capabilities and emerging strategic directions. As such, the Signature Areas help to guide IMR's primary directions of activities and allocating resources in research and innovation. The list is dynamic and is reviewed periodically to ensure we are sustaining and growing existing strengths, while being responsive to emerging topics of national and global impact that intersect with our capabilities and that of Ohio State.

ELECTRONIC AND PHOTONIC MATERIALS & DEVICES

Compound semiconductors and nanostructures;
Epitaxy, heterointegration, and device fabrication;
Optoelectronic emitters, detectors, and energy devices;
Wide bandgap electronics and photonics

EMERGENT MATERIALS

2D materials: electronic, spin and topological states;
Biomaterials and materials-health science interface;
Hybrid functional materials;
Quantum materials and systems

MAGNETIC MATERIALS AND PHENOMENA

Energy efficient high speed information technology;
Gigahertz to terahertz magnetic dynamics and spin transport;
Interfacial magnetism and spin-orbit coupling;
Quantum spin phenomena

MANUFACTURING AND PROCESSING

Additive manufacturing and data science integration;
Advanced & high-entropy alloys and lightweight structures;
Biofabrication and polymer composites;
Corrosion

MATERIALS CHARACTERIZATION

Electronic, magnetic, optical and structural characterization;
Atomic-resolution and cryo-electron microscopy;
Scanning probe microscopy and spectroscopy;
Ultrafast dynamics from nanoseconds to attoseconds

MATERIALS FOR ENERGY AND SUSTAINABILITY

Electrochemical energy storage;
Materials in harsh environments;
Photovoltaics, thermoelectrics and energy conversion;
Power electronics, low energy devices and integrated systems

IMR 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 The Ohio State University as a world-leader in materials research and innovation.

VISION

To be the exemplar, interdisciplinary, academic research institute, which by building across colleges, creates a global reputation of excellence and impact at Ohio State through world-class basic and applied materials research, technology advancement, and innovation.

MISSION

- Lead an interconnected, interdisciplinary materials research **community** across Ohio State's colleges and centers;
- Nurture, grow, and support **excellence** in materials research through team development, establishing centers of excellence, and ensuring world-class research infrastructure;
- Drive an **innovation** ecosystem to connect, create and deliver value for our students, staff, faculty and external partners.

To realize success for the IMR vision, we have developed three goals, as shown below.

1. Lead the Ohio State materials research **community** to deliver scholarly impact on a national and global scale.

2. Grow global reputation of **excellence** in materials research by establishing and maintaining centers of excellence in signature areas and ensuring world-class research infrastructure is sustained.

3. Create a sustainable **innovation** ecosystem that provides value for our students, staff, faculty and external partners.

BY THE NUMBERS

ANNUAL EXPENDITURES ON PROJECTS*

$85.5M

TOTAL PROJECT VALUE*

$468.4M

NEW AWARDS*

$119M

* Sponsored projects only

274 FACULTY MEMBERS

38 DEPARTMENTS

10 COLLEGES

9.7 PUBLICATIONS PER MEMBER [1]

511 CITATIONS PER MEMBER [1]

135 PATENTS FILED [2]

60 PATENTS ISSUED [2]

142 INVENTION DISCLOSURES [2]

[1] Average of researchers found on Google Scholar in CY19
[2] Office of Economic and Corporate Engagement


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RESEARCH & INNOVATION HIGHLIGHTS

IMR strives to identify, nurture and establish high-impact research and innovation programs that build from the broad interdisciplinary strengths at Ohio State. From exploratory research by individual faculty members, to research teams, research centers, strategic partnerships and innovation engagements, and even to Ohio State's first global research center, IMR's community of faculty, staff and student researchers have excelled in this mission. This section provides a glimpse of the many highlights in research and innovation that occurred this past fiscal year.

COVID-19: THE RACE TO RESPOND

COVID-19 took many things from us this year. But, with its emergence, the pandemic also brought many opportunities. For IMR, facing this new reality meant refocusing our efforts to fuel innovation and impact the community. IMR led, joined and advised new collaborations, funded new projects, and supported innovative R&D endeavors to fight the coronavirus. Our facility directors led massive closure and re-opening campaigns, their staff members educated themselves to stay abreast of and implement the latest safety recommendations, and their users strategically but aggressively sought out some of society's greatest problems to solve, from critical shortages in personal protective equipment to the need for faster testing technologies.

IMR LEADS TEAM TO ADDRESS CRITICAL SHORTAGE IN COVID-19 TESTING SUPPLIES

MORE THAN HALF A MILLION SWABS NEEDED FOR COVID-19 TESTING ACROSS OHIO ARE DELIVERED AFTER TEAMS GATHER TO PERFORM RAPID PROTOTYPING AND CREATE NEW SUPPLY CHAINS

Inconsistent access to testing kits to detect the virus that causes COVID-19 posed an increasingly dire problem in health care, in the initial weeks of the burgeoning pandemic. A lack of testing impeded the ability to accurately identify patients for proper isolation and treatment, observe the spread of the virus and, in turn, reshape the disease curve.

The Ohio State University Wexner Medical Center foresaw not being immune to those shortages either. The medical center urgently needed a solution — not just more test kits for its own use, but a new supply chain capable of producing them for the Ohio Department of Health for further distribution throughout the state.

IMR took on the duties of launching and leading an initiative to begin rapid prototyping nasopharyngeal swabs — long, thin tools commonly used by health care providers to swab a person's nasal cavity. The collaborative first included the Center for Design and Manufacturing Excellence (CDME) and Infectious Diseases Institute (IDI), but quickly gained university scientists, engineers and manufacturers who joined with collaborators from the state and private industry.

By mid-April, wave after wave of urgently needed shipments of 3D-printed swabs used in COVID-19 test kits began arriving at Ohio State.

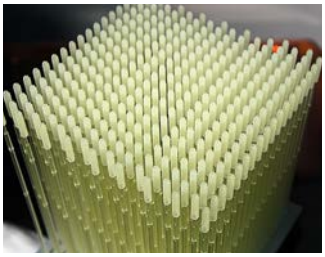
The shipments wouldn't stop until more than 500,000 swabs had been manufactured, sterilized and made available to waiting health care workers.

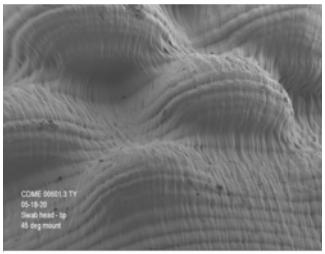
"Here, at Ohio State, we have the environment to take on these challenges, to meet these needs," said IMR Director of Innovation Jay Sayre. "We have the people, the capabilities and the experience."

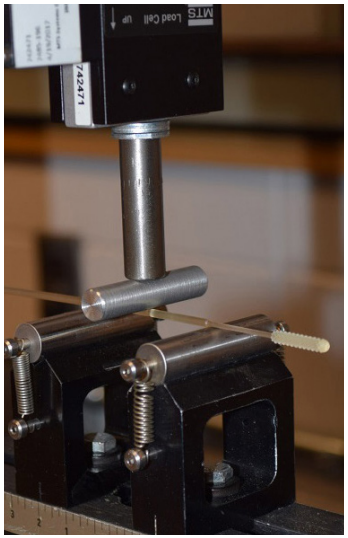
WATCH NOW: Ohio State receives swabs for COVID-19 test kits

Use your phone's camera app to scan the QR code ...or visit go.osu.edu/covid-swabs

COVID-19: THE RACE TO RESPOND







Top left: 3D-printed swabs. Bottom left: SEM image of swab head from Nanotech West Lab. Middle: Dentistry staff packing swabs. Right: Flex test of prototype.

IMR began working in mid-March, after being alerted to the critical need by Peter Mohler, Vice Dean of Research at the College of Medicine and Director of the Dorothy M. Davis Heart and Lung Research Institute.

The institute immediately brought in CDME and IDI. IMR coordinated the teams, and defined the scope of the project and elements of production needed for rapid product development. CDME owned the management and coordination of manufacturing resources and external partnerships, while IDI covered clinical testing and management with medical professionals.

"Almost every faculty member and researcher on campus who can is running toward the problem," said Nate Ames, Executive Director of CDME.

To cover 3D printing and delivery of the swabs, IMR worked with two Ohio-based companies: Formlabs, a leading manufacturer of 3D printing systems, and Concordance Healthcare Solutions.

Upon receiving early prototypes, clinicians from Ohio State Wexner Medical Center and experts from IDI raced to test their samples and relay data back to engineers working with IMR and CDME. With the green light from Ohio State Wexner Medical Center, row after row of 3D printers kicked on and ran around the clock in the Formlabs facility, in Millbury.

Next, the College of Dentistry and the College of Veterinary Medicine carried out the crucial step of repackaging the bulk shipments into individual swabs, then sterilizing each one before sending them on to the medical center for kitting with vials of transport medium.

Researchers in Materials Science and Engineering analyzed the material performance of swab prototypes, as prototyping processes continued to evolve.

Formlabs and Concordance and, later, ROE Dental Laboratory continued to steadily produce and deliver the swabs, ultimately surpassing the half-million mark.

Ohio Gov. Mike DeWine described the initiative as "Ohioans coming together to solve a problem," an example of "Ohio ingenuity."

Our staff's connections across the university and experience in mobilizing teams put us in the best possible position to fight these kinds of fires. We want to solve problems. And we have the relationships with centers and institutes across Ohio State to create the kinds of extraordinary collaborations needed to do that.

— Jay Sayre, IMR Director of Innovation

COLLABORATORS

State of Ohio • Ohio State Wexner Medical Center • the Center for Design and Manufacturing Excellence • Infectious Diseases Institute • College of Engineering • College of Medicine • College of Dentistry • College of Veterinary Medicine • Office of Research • Formlabs • Concordance • ROE Dental Laboratory

COVID-19: THE RACE TO RESPOND

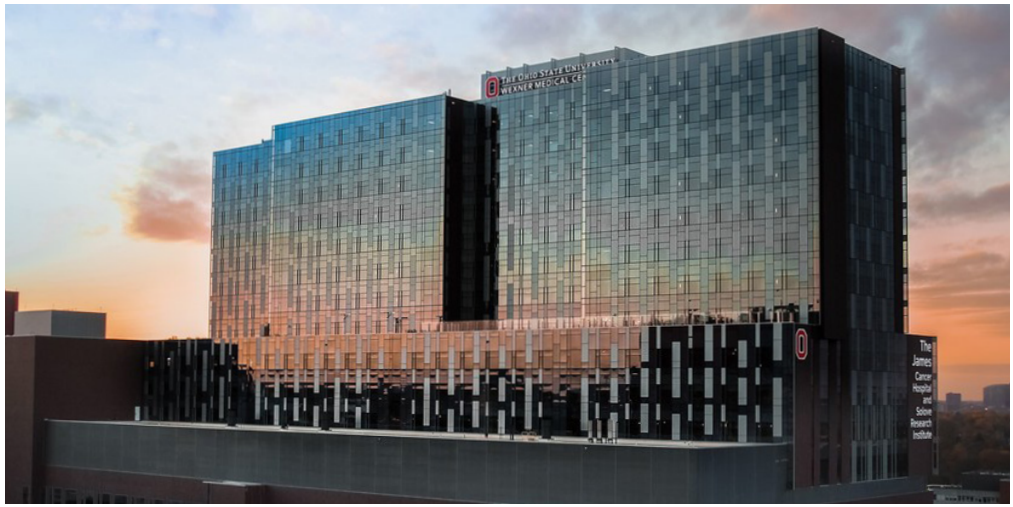
IMR LAUNCHES GRANT PROGRAM TO FUND INNOVATIVE PROJECTS AIMING TO COUNTER THE SPREAD OF CORONAVIRUS

IMR is directing more than $100k in funding to projects that leverage the expertise and technical capabilities of researchers at Ohio State to contribute to Ohio's response to the COVID-19 pandemic.

The newly developed IMR CV-19 Grant will support a team from IMR, Ohio State's Center for Design and Manufacturing Excellence, the Infectious Disease Institute and Wexner Medical Center to continue to work on eliminating swab manufacturing and design constraints through a rapid product development cycle, including clinical testing.

The grant funds allow the team to secure critical equipment and materials, and helps facilitate access to and usage of several of IMR's core facilities to carry out the effort.

In addition to this targeted seed grant, IMR is also contributing to the Office of Research to support funding of long-term research related to COVID-19 from across the university.



OHIO STATE JOINS NATIONAL CONSORTIUM TO FIND PANDEMIC SOLUTIONS

IMR, the Center for Design and Manufacturing Excellence, and the Infectious Diseases Institute are collaborating in an academic-industry-government consortium to rapidly deploy a design and testing program, resulting in new manufacturing capacity which can fill national supply needs.

The results of the Ohio State team's efforts were crucial in meeting the supply need for nasopharyngeal swabs needed for COVID-19 testing at the Wexner Medical Center and throughout the state of Ohio.

The consortium is led by Harvard University, and includes Beth Israel Deaconess Medical Center, Desktop Metals, Envisiontec, Formlabs, Hewlett Packard, Neurophotometrics, Opt Industries Origin, Resolution Medical in partnership with Carbon, Inc., USF Health, Stanford University, and the Army's Natick Soldier Systems Center.

Ohio State's College of Dentistry and Battelle are also involved in this project, along with doctors and nurses from Ohio State's Emergency Department and COVID-19 testing tents who volunteered as test subjects to confirm the new swab as an adequate collection device.

"We're fortunate to have the scientists and the resources at Ohio State's seven health sciences colleges and across campus to create these vital materials and to be able to serve other hospital systems in Ohio and around the country that need them," said Dr. Hal Paz, executive vice president and chancellor for Health Affairs at The Ohio State University and CEO of the Ohio State Wexner Medical Center.

"This is what Buckeyes do. We collaborate to solve society's biggest problems. We're all in this together."

NED HILL DISCUSSES HISTORIC ECONOMIC IMPACT OF COVID-19 IN OHIO AND US

Soon after the inital wave of consequences related to COVID-19 swept across the U.S., the country found its disrupted economy in a wake of upheaval.

Ned Hill, a professsor and expert on economic development in the John Glenn College of Public Affairs who was hired through IMR's M&MS Discovery Theme, shared his thoughts on the recession, its impact on different industry sectors, and what the United States needs to do to get things back on track.

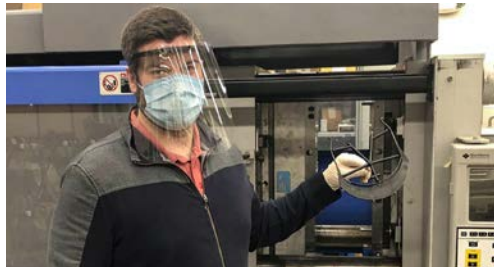
WATCH NOW: Glenn College Policy Brief: a discussion with Ned Hill
Use your phone's camera app to scan the QR code
...or visit
go.osu.edu/hill-policy-brief

COLLEGE OF ENGINEERING DESIGN REVIEW TEAM, OHIO MANUFACTURING ALLIANCE ELEVATE AND AID URGENT PROJECTS

IMR Director of Innovation Jay Sayre lent his expertise and experience in innovation to two panels tasked with prioritizing research and manufacturing projects aiming to combat the spread and impact of the coronavirus.

First, within Ohio State, Sayre was asked to join the College of Engineering's Design Review Team to help evaluate and prioritize ideas generated by faculty and staff related to personal protective equipment (PPE) and other COVID-19 supply needs. The group rapidly moved promising ideas from across the university into the prototyping process. Sayre, who also serves as an associate research professor in Materials Science and Engineering, was sought because of his experience in product design, materials and manufacturing.

Additionally, Sayre served as Ohio State's representative in the Ohio Manufacturing Alliance to Fight COVID-19. The alliance is a collaborative effort engaging companies interested in repurposing their manufacturing operations to aid in the production of in-demand products and materials critical to protecting the community and our health care workers responding to COVID-19.



Carlos Castro, associate professor in Mechanical and Aerospace Engineering, was part of an interdisciplinary team that developed and implemented a plan to produce thousands of 3D-printed face shields that could be utilized safely by health care workers at The Ohio State University Wexner Medical Center and OSUCCC – James.

COVID-19: THE RACE TO RESPOND

RESEARCHERS EXPLORE THE POTENTIAL OF ORIGAMI-BASED, POP-UP DESIGN FOR MEDICAL MASKS

MAE assistant professor Renee Zhao

Researchers at Ohio State are exploring design alterations that may enable a self-assembling, pop-up structure for medical masks critically needed in the fight against COVID-19. Face masks are effective tools in helping protect health care workers and the community against the further spread of COVID-19. However, the curved 3D shape of the protective material designed to fit one's face can also make the equipment difficult to efficiently pack and transport.

Now, Renee Zhao, an assistant professor of Mechanical and Aerospace Engineering, and her team will explore the fundamental mechanisms and design that allow the rapid transformation of pop-up structures from a nearly flat shape to a three-dimensional one, which has the curvature distribution of a N95 respirator. Investigators hope the research can allow for novel innovation in the design of personal protective equipment (PPE).

Researchers will work to identify the limitations of origami design folding paths to overcome constraints imposed by the interactions among origami rings that affect the folding and unfolding of the structure's face.

Zhao is principal investigator on the project. She joined Ohio State in 2018 through IMR's Materials and Manufacturing for Sustainability Discovery Theme.

Funding for the project, "Origami-Based Extremely-Packed Multistable Pop-Up Design for Medical Masks," was awarded through a National Science Foundation (NSF) funding mechanism called EAGER, or Early-concept Grants for Exploratory Research. This award includes funding from the Coronavirus Aid, Relief, and Economic Security Act.

IMR LEADS RESEARCH TEAM EXPLORING MANUFACTURING ALTERNATIVES FOR COVID-19 TESTING SUPPLIES

IMR again teamed up with centers and institutes across Ohio State to rapidly respond to shortages of nasopharyngeal swabs used in testing for the causative agent of COVID-19.

Led by IMR, researchers from the Center for Design Manufacturing Excellence (CDME), Infectious Diseases Institute (IDI) and The Ohio State University Wexner Medical Center will work to increase the production and improve the effectiveness of COVID-19 testing by redesigning the swabs, while re-imagining the manufacturing process by which those swabs are mass-produced.

The alternative manufacturing route is called injection molding, which could provide a more practical, a manufacturing process in which molten materials, such as plastic, are injected into a cavity, where the product's shape stabilizes as it cools and hardens.

Investigators on the project, funded by the Office of Research, and colleges

of Engineering and Medicine, include IMR Director of Innovation Jay Sayre, research associate professor in Materials Science and Engineering; Nate Ames, CDME Executive Director; Seth Faith, IDI Strategic Alliance Officer; and Eric Adkins, Associate Chief CIO at Wexner Medical Center.

The research team expects this process to eliminate constraints that come with 3D printing techniques by developing a new, rapid product development and clinical testing cycle.

"Additive manufacturing and 3D printing are well tailored for rapid prototyping and low volume serial production," Ames said. "But injection molding is the go-to manufacturing technology for producing millions of polymer components at an affordable cost point."

The group aims to reduce the frequency of false-negative results that can occur in testing by improving the efficiency and effectiveness of the sample collection process. Engineers will focus on identifying design options and material alternatives for the swab heads, as well as testing new manufacturing processes that inject two or more different materials into a single cavity mold.

Researchers redesigning the swabs will also consider other infectious agents and biospecimen types beyond those typically considered in relation to coronavirus testing, so that the new devices may be utilized in a wider range of cases and procurement in the future.

PERENA GOUMA LEADS GROUP EXPLORING BREATHALYZER TO DETECT COVID-19

A research team at Ohio State is developing a breathalyzer device to detect COVID-19.

The device could offer a quick and easy alternative to nasopharyngeal swabs, a more common means to test for the causative agent of COVID-19. Drawing from just a single exhaled breath, the device is designed to enable rapid detection of biomarkers of the coronavirus infection.

Perena Gouma in the lab with the prototype.

The team developing the breathalyzer is led by principal investigator Perena Gouma, the Edward Orton, Jr., Chair in Ceramic Engineering and director of the Advanced Ceramics Research Laboratory. She joined Ohio State in 2017 through IMR's Materials and Manufacturing for Sustainability Discovery Theme.

The project received a $199,359 National Science Foundation (NSF) EAGER grant. The funding mechanism supports early-stage but likely transformative projects deemed potentially "high risk-high payoff," meaning investigators are expected to take radical approaches and novel perspectives in their research. Andrew Bowman, associate professor in Veterinary Preventive Medicine, is a co-investigator on the project.

"Breath analysis is not really a technique that is used widely in the medical field yet, so it is considered early-stage work," Gouma said. "[We] have a sensor device that detects nitric oxide and VOCs (volatile organic compounds) in breath and can be used to tell you about the onset of an infectious disease."

Gouma invented the handheld single exhale breathalyzer in 2004 at Stony Brook University (SUNY at Stony Brook). More recently, she demonstrated a device for infectious diseases, such as the flu.

SEED GRANT AWARDS

IMR SUPPORTS 14 PROJECTS IN FY20

Fourteen new projects led or co-led by researchers at Ohio State received seed funding support in FY20 through IMR grant programs.

Many of the novel projects require interdisciplinary teams, bringing together researchers from a myriad of fields spanning Materials Science to Physics.

In FY20, six projects grew from international teams composed of researchers from the U.S. and India, collaborating within the Ohio State-IIT Bombay Frontier Center. These Frontier Center Scholar Grants were awarded $103K to push science and engineering research beyond what could be accomplished at a single university.

Additionally, IMR awarded $20K in funding through its Kickstart Facility Grant Program, which assists Ohio State faculty with facility user access fees and related minor charges associated with conducting innovative materials-allied research with the goal of obtaining external research funding.

GLOBAL PARTNERSHIP GRANTS

Global Partnership Grants (GPGs) establish global impact in research and development, technology innovation and shared multinational education following the themes defined by the M&MS Discovery Themes program. Six GPGs were awarded this year:

Additive Manufacturing of Lightweight High Entropy Alloys – Principal Investigators: Alan Luo, Ohio State Materials Science and Engineering; Asim Tewari, IIT Bombay Mechanical Engineering. Co-investigators: Edward Herderick, Ohio State, and and Sushil Mishra, IIT Bombay.

Emergent Quantum Spin Liquid Phases in Quantum Materials – Principal Investigators: Ohio State Nandini Trivedi, Physics; Avinash Mahajan, IIT Bombay Physics

Integration of Zero-Leakage NEMS Switch With a Flexible Antenna for RF Energy Harvesting – Principal Investigators: Nima Ghalichechian, Ohio State Electrical and Computer Engineering; Maryam Shojaei Baghini, IIT Bombay Electrical Engineering

Modeling Polymer-Grafted Nanoparticle Phase Behavior – Principal Investigators: Lisa Hall, Ohio State Chemical and Biomolecular Engineering; Mukta Tripathy, IIT Bombay Chemical Engineering

Selling Renewable Generation to Flexible Consumers with a Data-Driven Tariff Scheme – Principal Investigators: Abhishek Gupta, Ohio State Electrical and Computer Engineering; Ankur A. Kulkarni, IIT Bombay Systems and Control Engineering

Towards Rugged SiC Technology for Electric Transportation – Principal Investigators: Anant Agarwal, Ohio State Electrical and Computer Engineering; Swaroop Ganguly, IIT Bombay Electrical Engineering

KICKSTART FACILITY GRANTS

Kickstart Facility Grants strengthen near-term research proposals for external support by helping offset costs associated with research facilities and making shared campus research facilities more accessible. Eight Kickstart Facility Grants were awarded this year:

Investigating the Role of Collagen Piezoelectricity in Force-modulated Biomineralization – Principal Investigator: Hanna Cho, Mechanical and Aerospace Engineering

Synthesis and Characterization of High-energy Cathode Materials Prepared by Co-Precipitation Reactor – Principal Investigator: Jung-Hyun Kim, Mechanical and Aerospace Engineering

Exploration of ZnO/Si Heterojunctions as Biocompatible and Wavelength Tunable Light-emitting Diodes – Principal Investigator: Jinghua Li, Materials Science and Engineering

Microstructure Evolution and Mechanical Behavior of Laser Welded Dual-phaseDP590 steel joint – Principal Investigator: Ali Nassiri, Integrated Systems Engineering

Deformation Behavior of Nano-Architectured Liquid Crystal Elastomers – Principal Investigator: Xiaoguang Wang, Chemical and Biomolecular Engineering

Chemical Vapor Deposition Synthesis of Polymeric Organic Semiconductor – Principal Investigator: Xiaoxue Wang, Chemical and Biomolecular Engineering

How Morphology Affects Optical Properties of DNA-templated Silver Nanoclusters – Principal Investigator: Yuyuan Zhang, Chemistry and Biochemistry

Direct ink writing (DIW) of the Magnetic Shape Memory Polymer for Programmable Biomedical Robot – Principal Investigator: Renee Zhao, Mechanical and Aerospace Engineering

SPOTLIGHTS

Each year, IMR highlights a range of research and innovation accomplishments and activities that demonstrate the depth, breadth and impact of Ohio State's materials-allied research community. Here, we provide a summary of some of those "spotlights" on IMR's staff, multidisciplinary faculty members and their students from this past year.

SPACEX-NASA LAUNCH CARRIES OHIO STATE'S RECORD-SETTING SOLAR CELLS INTO ORBIT FOR TESTING

The NASA-contracted Dragon capsule carried a unique device among its payload when SpaceX's Falcon 9 rocket lifted off from Cape Canaveral Air Force Station in Florida on March 6: a solar cell developed by researchers at The Ohio State University.

The photovoltaic cell, part of the MISSE-18 test mission, was rocketed into orbit with more than 4,500 pounds of equipment, supplies and science experiments to the three crew members in orbit on the International Space Station. The cargo on board for NASA's 20th resupply mission included research related to particle foam manufacturing, water flow and droplet formation, heart cell growth, and the effects of microgravity on 3D colloidal structures. The research is expected to not only lead to technological and medical advancements down here, on Earth, but aid NASA's Artemis missions to the Moon and Mars. Developing more efficient solar energy converters could prove integral to the establishment of sustainable space exploration.

At Ohio State, Tyler Grassman and other researchers in the Electronic Materials and Devices Laboratory, are pushing the envelope in photovoltaics performance by developing more efficient and affordable ways to harness the power of the sun. Grassman is an assistant professor in Materials Science and Engineering with a joint appointment in Electrical and Computer Engineering. "We want to study how the performance of the cells are impacted by the harsh conditions of space, which includes drastic swings in

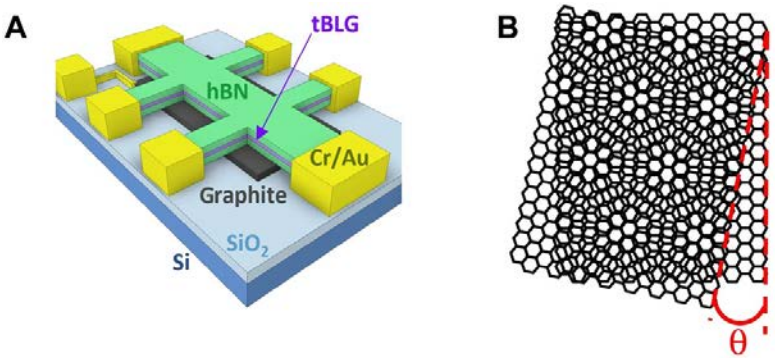
temperature and damaging radiation," said Grassman, who led both projects that enabled the cell's development and production.

The solar cell that emerged due to the collaboration of teams led by Grassman and IMR executive director Steven Ringel that are now attached to the side of the ISS are sourced from the batch that earned a world record efficiency of 20.1% in terrestrial test conditions back in 2018. Each monolithic, direct epitaxial GaAsP/Si tandem cell was grown at Ohio State via metal-organic chemical vapor deposition (MOCVD), and recent progress from the team produced a new record of 23.4% earlier this year.

This is not the first time solar cells from the Buckeye State made their way to the ISS. In a 2005 Ringel-led project, the space shuttle Discovery carried prototype cells into orbit to learn how the cells might operate during longer, more complicated deployments.

Tyler Grassman, assistant professor in Materials Science and Engineering

FINDING THE 'MAGIC ANGLE' TO CREATE A NEW SUPERCONDUCTOR



(A) Schematic diagram of device geometry. (B) Schematic diagram of moiré superlattice formed by the twisted graphene layers.

Researchers at Ohio State, in collaboration with scientists around the world, have made a discovery that could provide new insights into how superconductors might move energy more efficiently.

Their work showed that graphene, a material composed of a single layer of carbon atoms, is more likely to become a superconductor than originally thought possible.

Their paper, published in the journal Science Advances, was co-authored by Physics professors Jeanie Lau and Marc Bockrath, both hired through the M&MS Discovery Theme, operated by IMR.

"Graphene by itself can conduct energy, as a normal metal is conductive, but it is only recently that we learned it can also be a superconductor, by making a so-called 'magic angle' – twisting a second layer of graphene on top of the first," Lau said. "And that opens possibilities for additional research to see if we can make this material work in the real world."

That magic angle, scientists thought, was between 1 and 1.2 degrees. This work found that graphene layers still superconducted at a smaller angle, approximately 0.9 degrees. But that small difference could allow new experiments to investigate graphene as a potential superconductor.

"This research pushed our understanding of superconductors and the magic angle a little further than the theory and prior experiments might have expected," Bockrath said.

Ohio State researchers collaborated with Fan Zhang at the University of Texas, Dallas, and Takashi Taniguchi at the National Institute for Materials Science in Japan.

SPOTLIGHTS

FRONTIER CENTER ESTABLISHED AS OHIO STATE'S FIRST RESEARCH CENTER SHARED OUTSIDE US; INAUGURAL ROUND OF SEED GRANTS AWARDED

Buckeye Nation is not defined by borders. At Ohio State, neither is research.

This year, IMR continued carrying out its mission to establish centers of excellence while widening opportunities for collaborative research by strengthening links between Ohio State and international investigators with the launch of what is believed to be the university's first academic research center shared outside the U.S.

The IIT Bombay-Ohio State Frontier Science and Engineering Research Center is a joint, collaborative research center shared by Ohio State and the Indian Institute of Technology Bombay. It is set to provide grant funding and foster new research projects related to advanced technologies from both institutions.

IIT Bombay is a public institution of higher education, internationally recognized as a leader in engineering education and research. It is located in Mumbai, the capital city of Maharashtra, India.

"We are excited to collaborate through the Frontier Center to create a global community of researchers, students and industry that builds on the existing strengths of both universities to advance the well-being of our world," said Steven Ringel, IMR executive director and Ohio State distinguished university professor. "This collaboration between Ohio State and IIT Bombay is really a beautiful match. Both universities have complementary assets and strengths, but a lot of shared goals and visions."

The center will kick start innovative, interdisciplinary research projects within the broad areas of materials, devices, components and systems, while designated research spaces at both campuses are set to give professional and student researchers greater access to new facilities and expertise.

The Frontier Center also announced its first round of awards to six collaborative research teams under the Frontier

ARDESHIR CONTRACTOR, *OHIO STATE CO-LEAD OF THE IIT BOMBAY-OHIO STATE FRONTIER CENTER*

Ardeshir returned to his alma mater in 2018 as a professor of practice in Ohio State's Mechanical and Aerospace Engineering, after an illustrious career in India's private sector. He founded and was CEO of Kiran Energy, and has partnered with the Indian government to develop policy, standards and opportunities for solar manufacturers.

Center Scholars Program.

Funded projects bring together investigators with complementary expertise from across the globe to enable unique projects that could not be accomplished separately. Each team is comprised of a pair of principal investigators, one from IIT Bombay and another from Ohio State, as well as one doctoral student.

Both institutions focus research in areas of strength and strategic growth. Initial supported research will be in renewable energy, advanced manufacturing, electronics, photonics, and emergent materials. Supported research areas will continue to expand in response to societal needs and research discoveries.

"There is a significant innovation ecosystem around IIT Bombay's campus, which is often called the 'Silicon Valley of India,'" Ringel said. "Columbus is a growing entrepreneurial, high-tech city, with a significant innovation ecosystem forming on its own as well."

Collaborators from Ohio State and IIT Bombay after the Frontier Center signing ceremony in Mumbai.

Frontier Center kicked off with a leadership team consisting of two faculty members from each institution: Ardeshir Contractor, professor of practice in Ohio State's Mechanical and Aerospace Engineering; Sanjay Krishna, Ohio State's George R. Smith Chair in Engineering and professor in Electrical and Computer Engineering; Saurabh Lodha, IIT Bombay professor in Electrical Engineering; and Raghavan Sunoj, institute chair professor in IIT Bombay's Department of Chemistry.

SHIYU ZHANG AWARDED NSF GRANT TO STUDY ENZYME ENVIRONMENTS

Research led by Shiyu Zhang, an assistant professor in Chemistry and Biochemistry at Ohio State, aims to uncover, explain and, ultimately, apply fundamental rules that enzyme active sites employ in achieving challenging cellular reactions.

Zhang's project, "Applying Rules of Life to Catalysis: Significance of Distorted Coordination Environments in Enzyme Active Sites," was awarded a three-year, $440,000 grant from the National Science Foundation (NSF). Zhang joined Ohio State through the M&MS Discovery Theme, operated by IMR.

The study will exploit structure-function relationships of enzymes and will be directed toward identifying new strategies to reproduce the reactivity of enzymes and the discovery of broadly generalizable rules for catalyst design that are applicable beyond the scope of the biological systems used as inspiration. The project integrates with a collaborative outreach activity-based educational program.

SPOTLIGHTS

NEW OHIO STATE AGREEMENT WITH HONDA R&D AMERICAS, INC. TO ADVANCE NEXT-GENERATION ENERGY SYSTEMS RESEARCH

Accelerating research pertaining to advanced materials and technologies for sustainability is a key goal of the Materials and Manufacturing for Sustainability Discovery Theme, operated by IMR.

Now, Ohio State is joining Honda R&D Americas, Inc. in a new collaboration that will advance next-generation energy systems research at the university by building on the strength of the existing partnership long held by the two institutions.

IMR worked with Honda and Ohio State's Corporate Engagement Office to broker the one-year agreement that secures nearly half a million dollars in financial support to further experimental energy systems research at the university.

"This mutually beneficial agreement with Honda R&D Americas will further IMR-supported efforts at Ohio State that explore new energy storage and conversion devices capable of helping create a sustainable future through research, education and collaboration," said IMR Director of Innovation Jay Sayre. "IMR's continual efforts to advance innovation related to energy research is made possible by our Materials and Manufacturing for Sustainability Discovery Theme."

Along with supporting new, collaborative R&D, testing and services projects, the agreement includes funding for the hiring of a new research scientist at Ohio State.

Nanotech West Laboratory on Ohio State's West Campus.

IMR welcomed its newest technical staff member Qingmin Xu into the university's growing materials research community in summer FY20. She works at Nanotech West Laboratory, on West Campus.

There, Xu will perform fundamental and applied energy systems research in conjunction with Honda. She comes to Ohio State with nearly 20 years of experience in renewable energy. Xu was previously a scientist and project leader at Honda Research Institute USA, Inc., where she headed projects focusing on next-generation batteries.

At Ohio State, Xu is set to work on battery development research and work in areas related to energy storage and conversion, with the assistance of a network of Ohio State faculty, staff, and graduate students.

The Honda-Ohio State Partnership is a collaboration between the university, Honda of America Manufacturing, Honda R&D America, Inc. and Honda North America, Inc. that dates back to 1988. Alissa Comella serves as Ohio State co-director.

IMR's strategic partnership with Honda R&D Americas, Inc. has grown through a myriad of collaborations, including IMR innovation events joining Ohio State and Honda researchers, and M&MS faculty research receiving funding from Honda.

CENTER FOR EMERGENT MATERIALS AWARDED $18 MILLION NSF GRANT TO SUPPORT HIGH-IMPACT, CUTTING-EDGE SCIENCE

This year, Ohio State's Center for Emergent Materials (CEM) was awarded Materials Research Science and Engineering Center (MRSEC) funding from the National Science Foundation (NSF) for the third time since 2008.

The new six-year, $18 million grant will fund transformative science and complex materials discovery by two multidisciplinary, collaborative groups of researchers and includes funding to help ease entry into science from underrepresented groups.

"We are excited to have won this highly prized funding because it enables scientists to undertake complex and transformative projects at the scientific frontiers, and provides sustained support for diverse teams to collaboratively synthesize new understanding and open new research topics," said P. Chris Hammel, Ohio Eminent Scholar, Physics professor and director of the Center for Emergent Materials.

From 2006 to 2007, IMR led a university-wide, two-year process that landed Ohio State's first NSF MRSEC, establishing the CEM with a $10.8 million award in 2008, in conjunction with ENCOMM (the Center for Exploration of Novel Complex Materials). The CEM has kept the ball rolling and the center growing ever since.

"Back in 2005 or so, Steven Ringel and I collaborated on a TIE (Targeted Investment in Excellence) proposal, from which IMR and ENCOMM (the Center for Exploration of Novel Complex Materials) were born. ENCOMM was the seed from which our NSF-funded Materials Research Science and Engineering Center, named the Center for Emergent Materials or CEM, was born," Hammel said. "CEM's collaboration with IMR continues to this day to enrich and invigorate materials research at Ohio State."

"The continued presence of an NSF MRSEC within the Ohio State materials community demonstrates OSU's leadership position in the field and the huge research and educational impact of CEM," said IMR Executive Director Steven Ringel. "The MRSEC is arguably NSF's most competitive and prestigious program in all of materials science and engineering, and I congratulate Prof. Hammel and the entire CEM team on their accomplishment that extends the CEM for at least 18 years since its inception!"

IMR continues to support all levels of CEM activities, from team building seed grant programs and the annual OSU Materials Week with its student poster competition, to support of the NanoSystems Lab, which is CEM's primary shared core research facility, and other shared facilities around campus used by the CEM. In fact, both of the two IRGs awarded in the current cycle were nucleated in our Materials Research Seed Grant Program that is jointly administered by IMR, CEM and ENCOMM to nurture and develop cutting edge research by interdisciplinary teams.

Left to right: CEM Director P. Chris Hammel and CEM Associate Director Jessica Winter.

SPOTLIGHTS

CDME OPENS NEW ARTIFICIALLY INTELLIGENT MANUFACTURING SYSTEMS LAB ON WEST CAMPUS

The Center for Design and Manufacturing Excellence (CDME) is tapping into the power of artificial intelligence to transform the future of manufacturing. The newly opened Artificially Intelligent Manufacturing Systems Lab (AIMS) on West Campus houses three large robot arms that stretch to the ceiling of the 1,500-square-foot space.

The lab is jointly managed by Walt Hansen, CDME senior lead engineer for student programs, and Michael Groeber, an associate professor in Integrated Systems Engineering hired through the IMR-operated M&MS Discovery Theme.

"The AIMS lab aims, pun intended, to be the bridge to these two communities and provide each of them an environment that would be difficult to create on their own," Groeber said.

The space will serve as a test site for industry and academia studying and developing manufacturing systems that incorporate or are controlled by AI.

"What is happening here with Ohio State and the College of Engineering is exactly what needs to happen here in Ohio – collaborating with industry partners, working to build the talent of the future, innovating and trying to find ways to be competitive and serve their customers," Ohio Lt. Gov. Jon Husted said at the lab's ribbon cutting ceremony.

Ohio Lt. Gov. Jon Husted speaks at the Artificially Intelligent Manufacturing Systems Lab dedication.

IMR SUPPORTS OHIO STATE SUSTAINABILITY GOALS WITH OSEP AWARD

IMR Director of Innovation Jay Sayre received funding allowing researchers at Ohio State a new route in developing solutions to some of the most pressing challenges of sustainability.

The one-year Ohio State Energy Partners (OSEP) award is helping IMR refurbish and reinstate a fuel cell test station, expected to support new fuel cell programs at the university.

Funding will also allow open access to the state-of-the-art equipment, meaning Ohio State students, faculty and staff can utilize the station to conduct research and learn about this growing area.

Hydrogen and fuel cells play a critical role in building a sustainable energy future, Sayre said. He leads the project with more than 20 years of experience in fuel cell technologies.

"There is a need to reduce the world's use of natural gas and pure oil to decrease greenhouse gas emissions by shifting to low- and zero-carbon power generation," he said. "A fuel cell combines hydrogen and oxygen to produce electricity through an electrochemical reaction. Because the byproducts are only water and heat, there are no carbon emissions."

$27M IN NSF MID-SCALE INFRASTRUCTURE FUNDING AWARDED TO OHIO STATE FOR TWO NEW RESEARCH AND LEARNING SPACES

As part of IMR's mission to nurture and grow excellence in materials research by ensuring world-class research infrastructure at Ohio State, the institute spearheaded a proposal building campaign in pursuit of two grants from the National Science Foundation (NSF) Mid-scale Research Infrastructure program.

Both grants were won, with awarded funding dedicated to the development of two new facilities led by faculty in the Department of Chemistry and Biochemistry and the Department of Physics.

More than $17.5 million is set to implement the National Gateway Ultrahigh Field NMR Center, which will enhance the university's nuclear magnetic resonance (NMR) infrastructure by hosting the most advanced NMR instrument in North America. Funds totaling $9.5 million will develop the NSF National EXtreme Ultrafast Science (NEXUS) Facility, which will include a one-of-a-kind ultrafast laser, roughly 200 times more powerful than a typical ultrafast laser that generates extremely fast light pulses, to allow researchers unparalleled capabilities in the study of electron movement.

A key contributor to these awards was TJ Ronningen, a research scientist in the Department of Electrical and Computer Engineering. IMR brought in Ronningen to develop the required project execution plans for both proposals, a plan more common to industry projects than university ones.

"It was a real boon to find IMR and get their feedback that yes, we understand how to do this, we understand what is being asked, and we have points of contact within the university who are able to step in and help manage the project through the proposal stage and if the projects are awarded," he said.

Ronningen, who works in Ohio State's Krishna Infrared Detector Laboratory with George R. Smith Chair in Engineering and M&MS faculty member Sanjay Krishna, brought years of experience in leading industry projects to drafting project execution plans and shaping the full proposals for both teams. He continues to work with both facility development teams as a project manager.

***TJ RONNINGEN**, RESEARCH SCIENTIST WITH ELECTRICAL AND COMPUTER ENGINEERING*

TJ's research focuses on sensor development and applied spectroscopy. TJ has collaborated across many fields of science, engineering, medicine, and mathematics. His work with the Frontier Center and the mid-scale facilities continue this goal of promoting collaboration to impact science and society.

SPOTLIGHTS

IMR LAUNCHES QUANTUM TASK FORCE

In FY20, Ohio State asked IMR to create a task force that could coordinate and focus its efforts in Quantum Information Science and Technology (QIST) by building on the university's existing multidisciplinary strengths. Quantum research is a rapidly accelerating field, with value evident to university leaders and even highlighted in the passing of the National Quantum Initiative Act.

Physics professor Ezekiel Johnston-Halperin leads the campaign to articulate university strengths in physics, mathematics, computer science, engineering, and others into an interdisciplinary assemblage able to deliver impactful projects that advance our understanding of quantum's potential to improve information transmission and processing.

INTERDISCIPLINARY TEAM EXPLORES SOLID STATE INTEGRATION OF MOLECULAR QUBITS

Researchers from Ohio State, Northwestern University and the University of Iowa are coming together to advance the potential of Quantum Information Science and Technology (QIST).

Through work supported by a grant from the National Science Foundation (NSF), researchers will focus on learning the "design rules" for molecular quantum systems and designing new approaches to initialize and measure quantum information by studying molecules that are prime candidates for the design of customized qubits and quantum systems in device-like environments. Physics professor Ezekiel Johnston-Halperin (pictured above on the right) serves as the project's principal investigator, working with co-PIs Michael Flatte, professor of physics and astronomy at the University of Iowa, Danna Freedman, professor of chemistry at Northwestern University, and Jay Gupta, associate professor of physics at Ohio State (left). The project will also help develop the next generation of the quantum workforce by providing training opportunities for undergrad and grad students, and postdoctoral researchers.

RENEE ZHAO EARNS 2 NSF AWARDS IN SPRING 2020 TO STUDY MAGNETIC SOFT MATERIALS

Renee Zhao, an assistant professor of Mechanical and Aerospace Engineering (MAE), has received two awards from the National Science Foundation (NSF) in Spring 2020. Zhao first received a five-year, $562,511 NSF Faculty Early Career Development (CAREER) Award for her research in the mechanics of soft intelligent materials.

Soon after that, NSF announced she would be awarded $398,773 over three years for the project "Micromechanics of Interactions Between Hard Magnetic Particles and Soft Matrix on Magneto-Mechanical Actuation."

"The two grants will facilitate the investigation of the mechanical behavior of the magnetic soft materials. These materials are composites with hard-magnetic particles embedded in soft matrixes. Upon the application of an external magnetic field, the composite could provide untethered, fast and reversible deformation with large shape changes. The magnetic soft materials have already demonstrated potentials in designing morphing structures and actuators for various engineering applications," Zhao said.

MAE asst. prof. Renee Zhao (center), with postdoc Qiji Ze (left) and doctoral student Shuai Wu (right).

"These two grants will bridge fundamental mechanics with multifunctional material design, which will further advance the magnetic soft materials' applications in the next-generation soft robotics and biomedical devices."

Zhao joined Ohio State in 2018 through the M&MS Discovery Theme, operated by IMR. She is the director of the Soft Intelligent Materials Laboratory in the Department of Mechanical and Aerospace Engineering.

The NSF CAREER award is NSF's most prestigious award in support of junior faculty who exemplify the role of teacher-scholars through outstanding research, excellent education and the integration of both, according to the agency's website.

Zhao's project, "Multiphysics Mechanics of Magnetic Shape Memory Polymers," seeks to create a wide understanding of the materials, a model to demonstrate the magneto-thermo-visco-elastic behavior, as well as a simulation platform to increase interest in possible uses. The NSF Career Award will support the fundamental mechanics study of this novel soft intelligent material, the magnetic shape memory polymers, which was recently developed and published as a cover article in Advanced Materials.

SPOTLIGHTS

Left to right: Mechanical and Aerospace Engineering prof. Amos Gilat, Windpact chief executive Shawn Springs, and research assoc. prof. Jeremy Seidt.

BUCKEYE ALL-AMERICAN SHAWN SPRINGS TURNS TO RESEARCH AT HIS ALMA MATER TO PROTECT AGAINST HARD HITS

Shawn Springs has spent his career focused on impact.

Springs was an All-American and twice earned All-Big Ten honors playing for the Ohio State Buckeyes. After that, he held his ground as cornerback for three teams, made the Pro Bowl and snatched 33 interceptions during his 13-season career in the NFL.

Now, Springs is bringing his drive for impact back to his alma mater, where he is collaborating with university researchers within the College of Engineering to change the game, and science, affecting how we better protect ourselves from concussion and impacts that affect our everyday lives.

Springs is the founder and chief executive of Windpact, a technology and applied science company focused on the analysis, design and implementation of impact protection solutions. The company developed a new impact-mitigating technology and maintains a database of characterized foam materials. Windpact has received grants from the NFL and, more recently, secured a two-year U.S. Department of Defense contract to produce new padding solutions for soldiers' combat helmets.

IMR connected the company's team to engineers at Ohio State who could further Windpact's mission to solve some of the most challenging impact problems.

"When I first started Windpact, I had no idea of the important role The Ohio

State University would play in our growth and success," Springs said. "Discovering the immense talent and resources that the school has to offer has allowed us to put together one of my all-time favorite teams."

Researchers at Ohio State have been collaborating with Windpact to characterize materials used for that potentially life-saving technology through the university's Dynamic Mechanics of Materials Laboratory, directed by professor Amos Gilat. The lab specializes in mechanical characterization of materials to measure ranges in force and strain rates.

Jeremy Seidt, a research associate professor in mechanical and aerospace engineering, works with Windpact and other companies to conduct tension, compression and shear experiments with the lab's advanced instrumentation.

"There are a lot of reasons to come here," Seidt said. "We have a pretty wide range of testing equipment to utilize, including custom devices that nobody else has."

In the lab, researchers put that equipment to use, applying force to materials and collecting precision data on how they perform under stress. The work is critical to Windpact's business," Springs said. The characteristics of each foam sent to Ohio State gives the company valuable data used in modeling.

"My father was a professional athlete, and I followed in his footsteps to Ohio State and the NFL. What it does is put into perspective that, one, life is short and, two, traumatic brain injury is real," Springs said. "It's real and it is not going away. But there will be innovative companies like Windpact that will continue to work with the brightest minds to help mitigate the impacts. The opportunity to come back to my alma mater to help build my business feels like life is coming full-circle."

INNOVATION LAB TO PROVIDE TRAINING SPACE FOR NSF STEM RESEARCH TRAINEESHIP PROGRAM

The IMR Innovation Lab accelerates research processes and cultivates an innovation ecosystem, as a stimulating environment that encourages collaboration.

Now, the Innovation Lab will play an important role in the new EmPOWERment program, supported through a recently won National Science Foundation Research Traineeship (NRT) grant to develop and implement transformative models for STEM graduate education training. The $2.98 million in new funding will support Ohio State's new interdisciplinary graduate specialization in sustainable energy.

The IMR team will engage with external partners in a customer-discovery process to curate real problems to be tackled in the program's capstone course, "Hacking for Sustainable Energy." During the course, students in the Innovation Lab will learn from new collaboration experiences, and create e-portfolios showcasing their work for future employers. The program engages 16 faculty from seven colleges, including IMR Director of Innovation Jay Sayre and M&MS faculty members Anant Agarwal and Christian Blanco.

SPOTLIGHTS

DURIP AWARD TO INCREASE CDME MANUFACTURING CAPABILITIES

Left to right: Antonio Ramirez, Michael Groeber and Jacob Rindler at CDME.

An interdisciplinary team of researchers at Ohio State earned a highly competitive grant for new lab equipment that will add what is believed to be an internationally unique capability to the university's advanced metal additive capabilities.

The $500K DURIP (Defense University Research Instrumentation Program) award through the Office of Naval Research will allow the purchase of an openly-controlled and monitored, multibeam laser additive manufacturing system — the first multilaser, open-architecture and fully instrumented powder-bed system in the U.S. and, possibly, the world.

"This system will allow us to push the limits of what is possible in additive manufacturing of metallic components," said PI Michael Groeber, an associate professor in Integrated Systems Engineering, and Mechanical and Aerospace Engineering hired via the M&MS Discovery Theme.

"This system provides an opportunity to locally tune material structure and performance. The combination of the open control of processing strategies with robust in-process monitoring creates a testbed for discovering process-structure relationships needed to insert materials and manufacturing into the component design process."

The system will be housed in the Additive Manufacturing Lab at Ohio State's Center of Design and Manufacturing Excellence (CDME). Co-PIs include Jacob Rindler, a lead engineer at CDME, and Antonio Ramirez, a professor in Materials Science and Engineering.

"This DURIP award creates an amazing opportunity for Ohio State, the state of Ohio and the Department of Defense," said CDME executive director Nate Ames. "In no other ITAR-compliant institution that I'm aware of can industry and academia access nearly every modality of commercial scale additive manufacturing equipment for fundamental research, product development and undergraduate student training. With this award, we add an unparalleled open architecture to our suite of technologies."

The system is expected for inclusion in additive manufacturing curricula, and integrated feature of CDME outreach programs that connect K-12 STEM students to real-world manufacturing equipment and expertise. It will also be part of a CDME-operated professional short courses for industry partners and federal research labs led by Additive Manufacturing director Edward Herderick with Ohio startup The Lanterman Group.

IMR CREATES OHIO STATE MANUFACTURING TASK FORCE

Beginning in FY20, IMR created and counseled a task force aiming to unify Ohio State's vision and efforts in manufacturing-related research and development.

This undertaking includes differentiating the various manufacturing efforts already advancing innovation and education at the university.

The IMR Manufacturing Task Force is led by Michael Groeber, an associate professor in Integrated Systems Engineering and Mechanical & Aerospace Engineering. The task force grew out of the IMR's Materials and Manufacturing for Sustainability Discovery Theme, through which Groeber was recruited to Ohio State.

INNOVATE-O-THON PARTICIPANT JEN SCHLEGEL FEATURED IN WASHINGTON POST

Jen Schlegel, a graduating senior in biomedical engineering, was featured in a Washington Post article shining a light on efforts to improve the accessibility of autonomous vehicles.

Schlegel took part in an IMR INNOVATE-O-thon event, an innovation event organized by the IMR Innovation Lab. There, students were challenged to help shape DriveOhio's tech strategy by imagining a future with self-driving shuttles on Ohio State's Columbus campus.

Schlegel and her team pitched an idea for a paratransit system with self-driving vehicles. It was so well received that she was invited to share her passion about improving mobility and access to a packed ballroom of government representatives and community members at a DriveOhio Alliance quarterly meeting.

"I spend more hours in my day in transportation than I do any other activity," she said. "Being able to have an opportunity to share that experience with a group of people that are interested in having that conversation about what transportation looks like in the future for all populations, especially my own personal disabled population, is really something that I care about."

IMR coordinates events like INNOVATE-O-thon to give students exposure to working with external partners who are engaged and eager to connect with undergraduates at Ohio State, said IMR Director of Innovation Jay Sayre.

Schlegel subsequently joined the Ohio Department of Transportation as a workforce and innovation intern with DriveOhio, where she consults on smart mobility and accessibility in paratransit and helps projects related to STEM education and workforce development.

Schlegel received the 2020 President's Prize for her dedication to improving lives through accessible educational experiences. She will lead a team in developing Handicom, a software/mobile application that facilitates connection between ideas and written work. It's expected to be a finger tap-based app allowing users to import homework, equations, diagrams, images and more.

Jen Schlegel (center) and a fellow President's Prize recipient are honored by President Michael V. Drake during a game at Ohio Stadium.

SPOTLIGHTS

NEW MASKLESS ALIGNER SYSTEM BOOSTS LITHOGRAPHY CAPABILITIES AT NANOTECH WEST LABORATORY

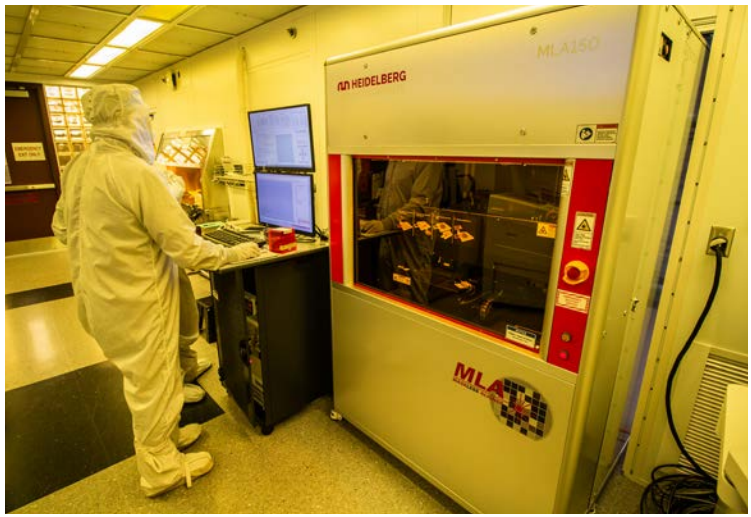
Nanotech West Laboratory has substantially expanded its lithography capabilities with the recent installation of an advanced maskless aligner system.

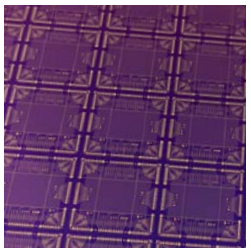
The state-of-the-art maskless technology of the recently acquired MLA150, from Heidelberg Instruments, allows researchers to leave traditional photomasks at the cleanroom door. The photolithography system is ideal for rapid prototyping due to its ease of use, high-speed performance and non-contact exposure.

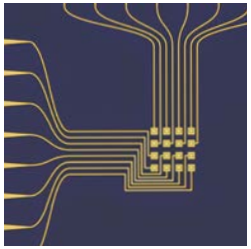
"Researchers can now go from idea to design to finished product seamlessly," said Dave Hollingshead, a senior research associate at Nanotech West Lab, which is operated by IMR. "This greatly speeds up the development of all the chips, sensors and devices that we make here every day."

The MLA150 is capable of patterning features as small as 0.6 µm and includes the options for grayscale patterning and backside alignment. Samples up to 150mm x 150mm can be exposed. Potential applications include 2D materials, opto-electronics, high-power transistors, and infrared detectors.

In contrast to a traditional mask aligner, this system exposes electronic patterns directly onto a sample quickly, with zero contact, and without the need to produce a physical mask. The system also allows faster alignment and inspection, with an overview camera and real-time autofocus.







The new Heidelberg MLA150 (left) is utilized to create an array of electrical fanout chips (top-right). Details of the gold electrical contacts and interconnects shown in the (bottom-right) 20x micrograph.

Sanjay Krishna, George R. Smith Chair in Engineering, said he expects the new tool to be an asset in his research on infrared detectors and focal plane arrays, and have a broader impact on the advancement of materials research at Ohio State.

"The fact that we can make extremely small feature sizes, and do this rapidly, helps us materialize our ideas into rapid prototypes. This will not only help my research group at the KIND Laboratory, but will help the whole IMR community," he said.

The intuitive design and software is expected to allow for a better experience for users, from professional researchers in academia to students to industry researchers.

The addition of the new maskless aligner system gives the Nanotech West Lab on West Campus a range of capabilities, from contact aligners to elec-

tron-beam lithography tools and the new direct laser writer, said Aimee Price, Nanotech West Lab senior research associate.

"The new system is going to extend our capabilities and range of lithography tools for our researchers," she said. "It is really important for the breadth and mix of users that we have here at Ohio State, so we are really excited for the new system."

WATCH NOW: Nanotech West installs new photolithography system

Use your phone's camera app to scan the QR code ...or visit go.osu.edu/ntw-litho

SHAMSUL ARAFIN RECEIVES NSF EAGER AWARD TO ADVANCE FUTURE QUANTUM TECHNOLOGIES

Shamsul Arafin, an assistant professor in Electrical and Computer Engineering (ECE), was awarded a one-year, $165,999 grant from the National Science Foundation (NSF) to fund exploratory research that could advance future quantum technologies.

Arafin, who joined Ohio State in 2018, hired through the M&MS Discovery Theme, is principal investigator on the project, titled "EAGER: Toward Monolithic Optically-Pumped Single-Photon Sources Based on Deterministic InGaN Quantum Dots in GaN Nanowires."

Funding through NSF's EAGER, or Early-concept Grants for Exploratory Research, supports early-stage but likely transformative work. NSF deems these projects potentially "high risk-high payoff," meaning investigators are expected to take radical approaches and novel perspectives in their research approach.

Arafin's project fit the bill.

"The long-term objective of the proposed research is to achieve bright and ultra-spectrally pure single-photon sources that meet aggressive performance specifications," Arafin wrote in his abstract.

Single-photon sources are one of most useful basic building blocks for many future quantum technologies. In particular, leading to revolutionary new communications, computing and sensing possibilities, if successfully developed.

"In this EAGER proposal, we explore a new and unique technique for the growth of nitrogen (N)-polar GaN NWs with InGaN quantum dots deterministically placed inside using a bottom-up approach via plasma-assisted molecular beam epitaxy," Arafin said. "The proposed research will lead to deeper fundamental insights into mechanisms and processes involved in scalable quantum photonic devices and integrated circuits. This inherently interdisciplinary research combines material science, quantum physics, chemical engineering and electrical engineering to generate new fundamental knowledge in several scientific fields."

Shamsul Arafin, assistant professor in Electrical and Computer Engineering

SPOTLIGHTS

CYBERBOTICS LAB AND PARIS-BASED STARTUP COLLABORATE TO TAKE ROBOTIC EXOSKELETONS A STEP FURTHER

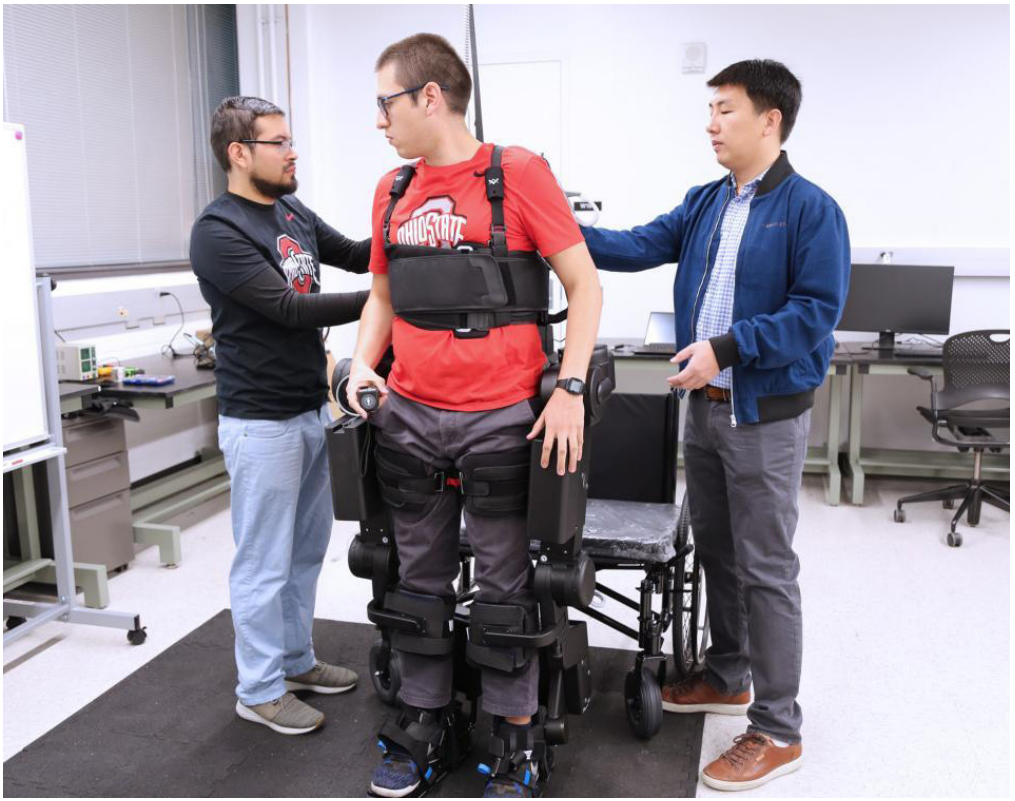
A team of researchers at Ohio State are collaborating with a robotic exoskeleton startup company to develop new technology that could assist mobility for those confined to a wheelchair.

Currently, wearable technologies aiming to improve mobility and limb movement are predominantly dependent on aids, such as crutches, to maintain support and balance for the user.

"The exoskeleton we're developing can help the patient walk autonomously without any external support, freeing their hands to complete other tasks," said Ayonga Hereid, an assistant professor in Mechanical and Aerospace Engineering. "My main role in this project is to develop computationally efficient motion planning algorithms and robust feedback control for the entire human-exoskeleton system."

Hereid, the principal investigator in Ohio State's Cyberbotics Lab, began working with his startup collaborator, Wandercraft, while he was a doctoral student at the Georgia Institute of Technology. He purchased one of the company's robotic exoskeletons to continue his research related to assisted mobility, soon after joining Ohio State through the M&MS Discovery Theme in 2019.

"Right now, in our lab, we're working on making the walking algorithm more robust and dynamic, so that patients can walk much faster, and we're trying to develop control algorithms that can guarantee it won't fall," Hereid said.



Ayonga Hereid (right) works with the robotic exoskeleton in his lab, along with graduate research associates Victor Paredes Cauna (left) and Guillermo Castillo Martinez (center).

Hereid and his team are also developing a bi-pedal robot that can be used to complete tasks that are dangerous for humans, such as space exploration or disaster rescue.

SANJAY KRISHNA DEVELOPS NEW COURSE: "EMPOWERING THE ENTREPRENEUR ENGINEER"

Ohio State students now have a chance to explore the intersection of engineering and entrepreneurship in a new course taught by Sanjay Krishna, George R. Smith Chaired Professor in Electrical and Computer Engineering.

Krishna, hired through the M&MS Discovery Theme, initiated the innovative course after not only forging a career in academia, but launching his own successful startup company 10 years ago.

The course, "Empowering the Entrepreneur Engineer (ECE)," is offered through the Department of Electrical and Computer Engineering. In it, students come up with their own startup ideas and present them to the class, asking questions like, "What does the customer want?" or "What does the customer need?"

"I feel there is a need right now. Not every Ph.D. student wants to become faculty. As the marketplace is changing, the demands on the current engineer are also changing. A lot of them want to start their own company," Krishna said. "The basic idea of this course is to teach our engineering students the concept of entrepreneur-minded learning. You have an idea? Is it a business idea? Is there a market? What is capital and how do you raise it?"

To accomplish this, however, an engineer must have both technical and business savvy to enhance their degree. Many of the top-ranked national schools already offer student entrepreneurship training.

Fourth-year graduate ECE student and doctoral candidate Ramy Tantawy launched an image sensor design startup company two years ago. He took Krishna's pilot entrepreneurship course in 2018 and found the experience useful.

Krishna brings in guest lecturers to talk about their experiences. Students also get the opportunity to pitch to actual investors from the Ohio Innovation Fund.

Krishna tries to incorporate his real-world experience when he can. Students tell him there is a lot to learn from the textbook, but when he talks about his own startup company, all those off-the-cuff remarks are what make the course hit home.

"Being an entrepreneur has actually made me a better professor," Krishna said.

JUVENILE DIABETES RESEARCH FOUNDATION FUNDS OHIO STATE ELECTROMAGNETIC INSULIN MICRO-PUMP

About one in 10 Americans have diabetes, a disease that can cause health complications, such as nerve damage, blindness or stroke.

Now, through a $330,000 award from the Juvenile Diabetes Research Foundation, Ohio State researchers are working to miniaturize an implantable pump that can function automatically within the body to safely deliver insulin.

Assistant professor Liang Guo is principal investigator on the project "Tetherless Magnetic Actuated Micropump for Continuous Intraperitoneal Insulin Infusion."

Renee Zhao, an assistant professor in Mechanical and Aerospace Engineering hired through the M&MS Discovery Theme, is a co-principal investigator.

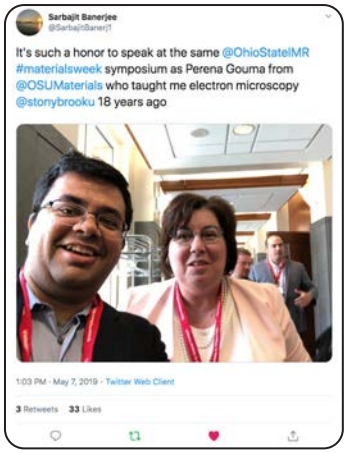
"We propose a new technology that uses magnetically-controlled material, so we can miniaturize the device dimensions." Guo said. "This kind of product can greatly ease the daily management of blood glucose in the patient population."

COMMUNITY

The breadth of the Ohio State materials-allied research community reaches across colleges. To promote this diversity of disciplines, and to identify and establish critical areas of research at their intersections, IMR hosts several outreach and engagement events each year. Although the global coronavirus pandemic forced considerable changes this year, IMR remained determined to maintain and, even, grow the ties that articulate our strengthening materials research community. While some events were postponed, such as the spring installment of the Distinguished Lecture Series, other events, specifically our annual OSU Materials Week conference, were canceled. Still, IMR continued supporting workshops that promote Ohio State's presence in strategic areas of interest.

OSU MATERIALS WEEK

MORE THAN A DECADE OF COMMUNITY AND CELEBRATION AT OHIO STATE



For the past 11 years, IMR has brought together researchers for OSU Materials Week, a multiday celebration of innovative research and accomplishments by the materials community at Ohio State.

However, in FY20, the COVID-19 pandemic made safely hosting physical conferences all but impossible the world over.

The conference was founded to "encourage the breadth of materials-allied researchers at the university to come together once a year and meet each other, collide, talk and create collaborations," said IMR Executive Director Steven Ringel.

Throughout the week, hundreds of guests are offered a myriad of activities and interactions that include cross-cutting and focus sessions, IMR's keynote address, multiple evenings of student poster sessions, appearances from university leaders, an exciting competition in which graduate students are challenged to present their thesis within three minutes, and an awards ceremony to close the final day of the conference.

IMR solicits topics of interest from faculty to be featured throughout the week to ensure the wide range of research areas covered each year reflects the breadth of the materials community while always being different.

OSU Materials Week was first held in 2008, hosting 185 attendees and dozens of national experts for three days of symposia at Ohio State's Physics Research Building. This inaugural event not only allowed IMR an opportunity to showcase Ohio State's toured facilities and extraordinary materials-allied research being conducted in them, but helped prepare the university to become accustomed to hosting significant conferences related to materials research — part of IMR's strategic plan to further enhance Ohio State's national reputation in the field.

DISTINGUISHED LECTURE SERIES

"NEW MATERIALS AND DEVICES FOR QUANTUM COHERENT TECHNOLOGIES"

PRESENTED BY MICHAEL E. FLATTÉ

Quantum is booming. And researchers are continuously charting new paths to develop novel materials and devices to achieve versatile quantum technologies.

In FY20, IMR welcomed Michael E. Flatté to Ohio State to present "New Materials and Devices for Quantum Coherent Technologies," during its Distinguished Lecture Series. Flatté is a professor of physics and astronomy at the University of Iowa.

The field has all the ingredients to allow major advances in a short period of time, he said. "There are systems, which we know work, but we also know that the reasons they work are not unique — so, there should be many other configurations, many other materials, many other devices that would work just as well, which we haven't discovered yet."

Left to right: professors Joseph Heremans, Ezekiel Johnston-Halperin, Michael Flatté and IMR assoc. dir. Fengyuan Yang.

That potential, combined with the prospect of commercial applications and support from research foundations, are the main drivers, Flatté said, adding that the development of quantum technologies requires an interdisciplinary approach.

"The performance of these devices is critically dependent on materials," he said. "The device design is really important to take advantage of the strengths of the different materials that you might have. And some of the goals are going to be informed by what we know from physics for keeping systems coherent for long periods of time."

Flatté is a co-investigator on an Interdisciplinary Research Groups project through the Center for Emergent Materials: Ohio State's NSF MRSEC. "Nonlinear Interactions Between Spin Flux and Engineered Magnetic Textures" is led by Ohio State prof. Joseph Heremans and IMR assoc. dir. Fengyuan Yang.

CONFERENCES & WORKSHOPS

BRINGING IT ALL BACK HOME AT **BIOFABRICATION 2019**

Impactful research with the potential to develop discoveries and new knowledge tends to jump from the pages of journals.

One such paper leapt out at Nate Ames, executive director of Ohio State's Center for Design and Manufacturing Excellence (CDME), while he reviewed literature in consideration of supporting a bid to host the 2019 International Conference on Biofabrication in Columbus, Ohio. The paper focused on additive manufacturing for in situ repair of osteochondral defects, such as when a piece of cartilage and the underlying bone separate — the exact injury Ames' daughter suffered just three months earlier, as a result of a gymnastics accident. "It instantly made hosting this conference at Ohio State a very personal mission," he said.

Ames (pictured top) spoke at the October conference's convocation, along with deans from the colleges of Engineering and Medicine, CEMAS director David McComb (bottom right), and 2019 Biofab Conference Chair David Dean, an associate professor in Materials Science and Engineering (bottom left). More than 250 scientists, engineers and industry experts in biofabrication were welcomed for three days of speakers, poster sessions and exhibitions.

As a researcher and a parent, Ames thanked the attendees at Biofabrication 2019 for their continued work.

"As you publish your research and collaborate on future grants, you're not only raising the bar among your peers, you're creating that little bit of relief that parents, sisters, brothers, aunts, and uncles need when things get really scary," he said. "Be proud of the fact that you're fundamentally changing the medical industry in a way that will make our children's lives better."

IMR co-sponsored the event and hosted visitors during campus tours that included Nanotech West Laboratory.

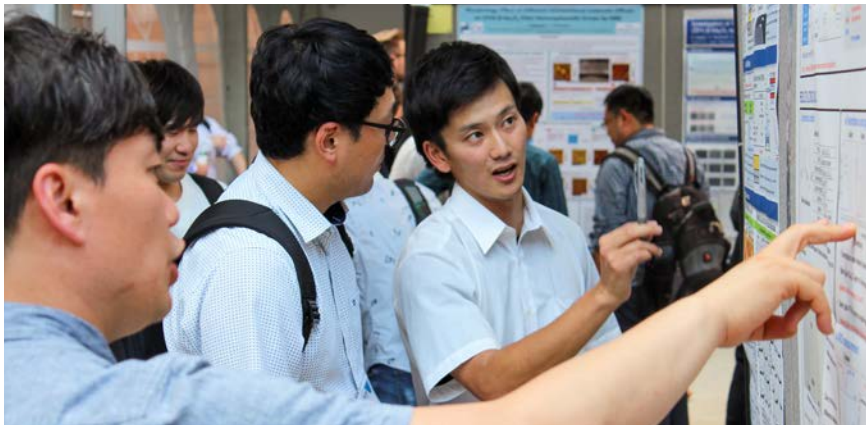
3RD INTERNATIONAL WORKSHOP ON GALLIUM OXIDE AND RELATED MATERIALS PROVIDES PLATFORM FOR A NEW, PROMISING SEMICONDUCTOR MATERIAL

Ohio State welcomed hundreds of researchers and other experts from around the world for a four-day workshop focused on a new and promising semiconductor material, gallium oxide.

The 3rd International Workshop on Gallium Oxide and Related Materials (IWGO-3), held Aug. 12 to 15, provided a platform across government, industry and academia to discuss recent advances related to the semiconductor system and identify scientific gaps demanding attention.

"IWGO gave an opportunity for the world's leading gallium oxide research groups to meet and discuss their newest discoveries and ideas. While these researchers are studying various aspects of gallium oxide technology, their expertise spans many technical disciplines and interests, and this breadth of expertise is what makes IWGO such a great meeting," said Ohio State professor Siddharth Rajan.

Ohio State's Nanotech West Lab installed a gallium oxide-capable MOCVD system earlier that year, enabling state-of-the-art growth capabilities in the ultra-wide band-gap range. It is utilized as part of a MURI award sponsored by the Air Force Office of Scientific Research. Ohio State researchers on the project "Gallium Oxide Materials Science and Engineering – GAME" include faculty members Jinwoo Hwang, Rajan, IMR Executive Director Steven Ringel and Hongping Zhao.



Zixuan Feng, a doctoral student in Ohio State's Electrical and Computer Engineering, earned the best student paper award for "MOCVD Epitaxy of Si-doped β-Ga2O3 Thin Films with Record High Electron Mobilities." Feng works in the Zhao Laboratory with associate professor Hongping Zhao. Pictured left: Riena Jinno, a doctoral student at Cornell University, was also awarded.

CONFERENCES & WORKSHOPS

INDO-US SCIENCE AND TECHNOLOGY FORUM PROMOTES INTERNATIONAL COLLABORATION

The newly launched IIT Bombay-Ohio State Frontier Center organized an international workshop promoting collaboration and interaction between scientists and engineers from the United States and India.

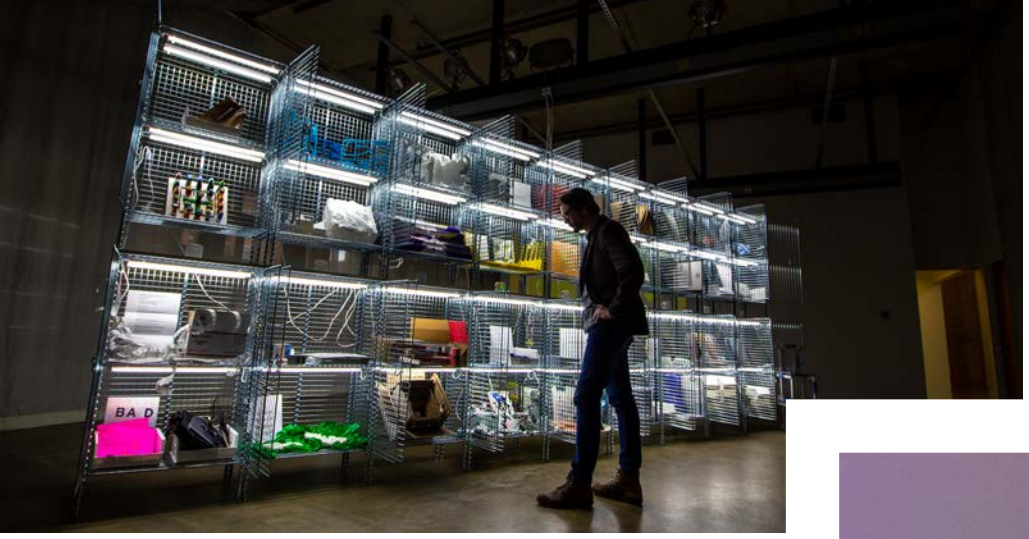
The Indo-U.S. Science and Technology Forum on "Frontiers of Excellence Win Wide & Ultrawide Bandgap Semiconductors and Electronic Systems" brought together hundreds of scientists from academia and industry during the two-day event in December at the Indian Institute of Technology Bombay (IIT Bombay) campus in Mumbai, India.

The forum served to facilitate a better understanding and exchange of information about state-of-the-art power devices and power electronic systems, as well as identify challenges and opportunities in the field. Ultimately, the workshop aimed to benefit research, development and deployment of power semiconductor devices and power electronics technologies in the immediate future in both countries.

Wide bandgap materials and devices are a key thrust area due to their applications in energy-efficient power electronics, high frequency communications and solid state lighting.

Four faculty members, two from IIT Bombay and two from Ohio State, sat on the forum's organizing committee: IIT Bombay professors Swaroop Ganguly and Saurabh Lodha, and Ohio State professors Siddharth Rajan and Steven Ringel, who is also IMR executive director.

The forum was established under an intergovernmental agreement between India and the United States in March 2000, according to the IUSSTF website.



WHAT DOES IT MEAN TO BE **FULFILLED**?

A bag of water from Lake Michigan. A cube-shaped lamp fashioned from a coiled nest of orange electrical cord. A matryoshka series of snuggly fit shipping boxes sitting within a principal flat-rate package. Those pieces joined dozens more mailed in by experts from across the U.S. to be part of an installation displayed on stacked rows of metal-wire shelves at Ohio State; a carefully curated, LED-lit invitation to "consider the role of architecture in a culture shaped by the excessive manufacture and assuagement of desire."

This February exhibition bookended the two-day Fulfilled Symposium organized by Ashley Bigham (seen right), an assistant professor at the Knowlton School of Architecture who was hired through IMR's M&MS Discovery Theme.

Hundreds of experts gathered to examine architecture through three themes of fulfillment: material, logistical and cultural. In these discussions, experts explored global logistics, cultures of excess, and "fulfillment networks" of warehouses, shopping malls and, of course, boxes.

The event brought together two Discovery Theme programs: M&MS and the Global Arts + Humanities. Both supported Fulfilled with the Knowlton School and Ikea.

M&MS FACULTY

IMR faculty members are central to the strength and success of Ohio State's expanding materials community. In the past four years, the Materials and Manufacturing for Sustainability Discovery Theme has enabled IMR to carry out the careful, strategic recruitment and selection of 24 new faculty members. These new hires now work in a myriad of departments in colleges across Ohio State, with foci spanning from engineering and manufacturing to business and architecture; a multidisciplinary cohort of talent that truly reflects the university-wide scope of the Discovery Theme's aim to stimulate interdisciplinary activity to address the grand challenges facing our society in the 21st century. This fiscal year, IMR welcomed its 24th and final hire to Ohio State: Brian Skinner, who now serves as an assistant professor in Physics. This M&MS hiring initiative is the third major talent scouting campaign IMR has led at the university. In FY15, IMR completed the hiring of five Ohio Research Scholars within its state-funded Technology-Enabling and Emergent Materials program. In 2006, IMR began collaborating with two Ohio State colleges to hire technical staff and faculty through its Targeted Investment in Excellence program, part of a five-year initiative funded by the Office of the Provost.

ANANT AGARWAL
Professor, Department of Electrical and Computer Engineering

MARC BOCKRATH
Professor, Department of Physics

SHAMSUL ARAFIN
Assistant Professor, Department of Electrical and Computer Engineering

VICKY DOAN-NGUYEN
Assistant Professor, Department of Materials Science and Engineering, and Department of Mechanical and Aerospace Engineering

ASHLEY BIGHAM
Assistant Professor, Austin E. Knowlton School of Architecture

CAROLIN FINK
Assistant Professor, Department of Materials Science and Engineering

CHRISTIAN BLANCO
Assistant Professor, Fisher College of Business

PELAGIA-IREN (PERENA) GOUMA
Orton Jr. Chair in Ceramic Engineering; Professor, Materials Science and Engineering

MICHAEL GROEBER
Associate Professor, Department of Integrated Systems Engineering, and Department of Mechanical and Aerospace Engineering

JOERG JINSCHEK
Associate Professor, Department of Materials Science and Engineering

ERIN MCKIE
Assistant Professor, Fisher College of Business

ALOK SUTRADHAR
Assistant Professor, Department of Mechanical and Aerospace Engineering

AYONGA HEREID
Assistant Professor, Department of Mechanical and Aerospace Engineering

JUNG-HYUN KIM
Assistant Professor, Department of Mechanical and Aerospace Engineering

FARHANG POURBOGHRAT
Chair, Department of Integrated Systems Engineering; Professor, Department of Mechanical and Aerospace Engineering

SHIYU ZHANG
Assistant Professor, Department of Chemistry and Biochemistry

NED HILL
Professor, John Glenn College of Public Affairs and College of Engineering's Knowlton School of Architecture

SANJAY KRISHNA
George R. Smith Chair in Engineering; Professor, Department of Electrical and Computer Engineering

ZACHARY SCHULTZ
Associate Professor, Department of Chemistry and Biochemistry

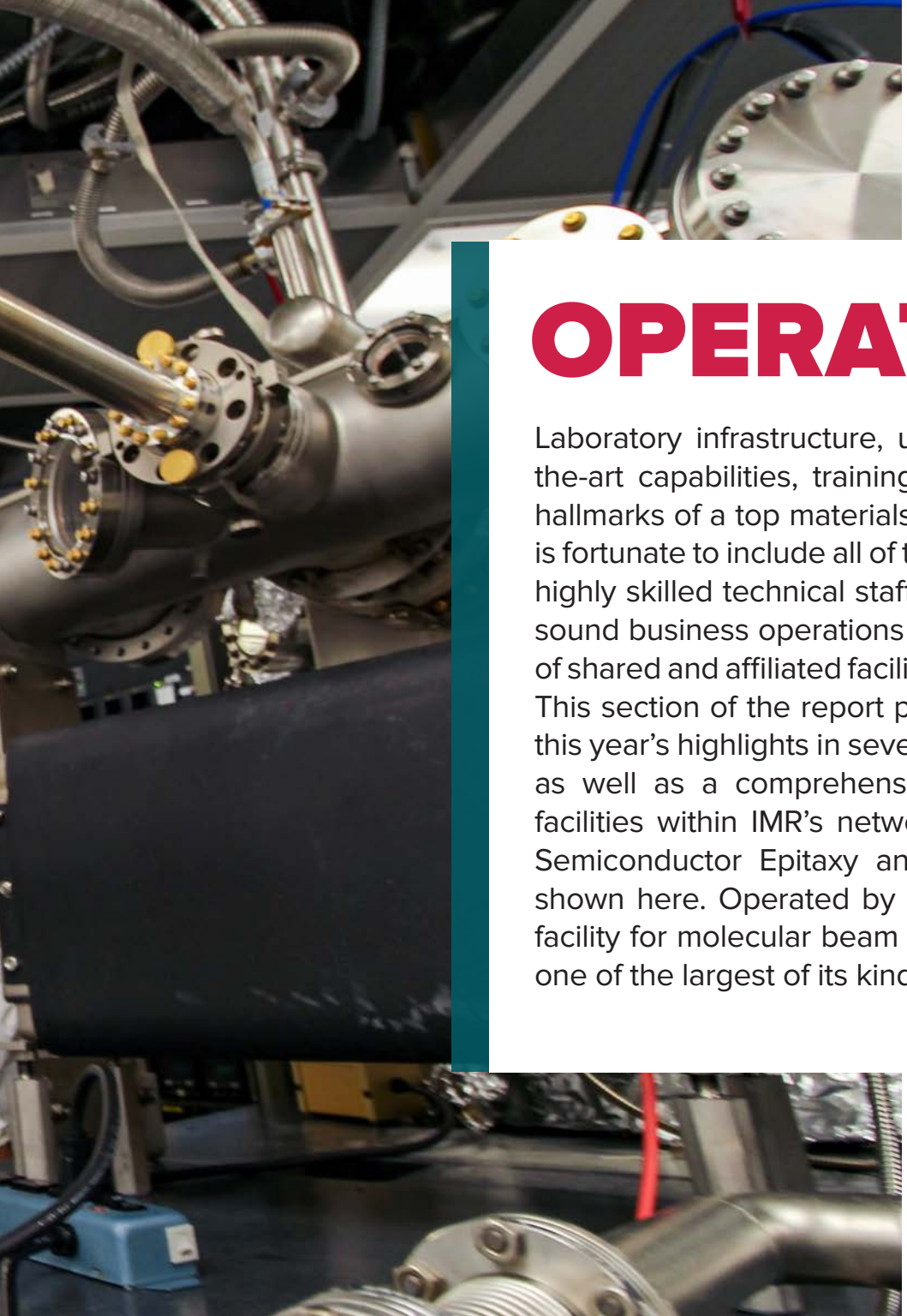
HONGPING ZHAO
Associate Professor, Department of Electrical and Computer Engineering

JOHN HORACK
Senior Associate Dean of the College of Engineering, Neil Armstrong Chair in Aerospace Policy and Professor, Mechanical and Aerospace Engineering; Professor, John Glenn Dean's Office

CHUNNING (JEANNIE) LAU
Professor, Department of Physics

BRIAN SKINNER
Assistant Professor, Department of Physics

RENEE ZHAO
Assistant Professor, Department of Mechanical and Aerospace Engineering



OPERATIONS

Laboratory infrastructure, user accessibility, state-of-the-art capabilities, training and safety — these are hallmarks of a top materials research enterprise. IMR is fortunate to include all of that, plus a terrific cohort of highly skilled technical staff, administrative support, a sound business operations unit, and a broad network of shared and affiliated facilities open to IMR members. This section of the report provides just a selection of this year's highlights in several of our primary facilities, as well as a comprehensive list of other affiliated facilities within IMR's network. One such facility, the Semiconductor Epitaxy and Analysis Laboratory, is shown here. Operated by IMR staff, it is the primary facility for molecular beam epitaxy at Ohio State, and one of the largest of its kind in the country.

NANOTECH WEST LABORATORY

Nanotech West Laboratory (NTW) is the largest, most comprehensive micro- and nanofabrication user facility in Ohio. The 36,000-square-foot shared user facility is open to both academia and industry. Managed by IMR, NTW is an extensively equipped and fully staffed space where researchers can access laboratories and equipment, as well as take advantage of in-house training, process and project support. NTW's user-accessible facility resources include a 6,000-square-foot cleanroom, major shared facilities for semiconductor and oxide epitaxy, materials and device characterization, and shared labs for research of energy storage materials and devices.

Driven by IMR's Materials and Manufacturing for Sustainability Discovery Theme and its strategic faculty recruitment, NTW continues to expand its impact by continually installing new equipment and lab enhancements to support cutting-edge capabilities and additional research thrusts. Developing laboratories that continue to expand capabilities offered within the user facility include: IMR's Innovation Lab (dedicated to collaborative industry interactions and outreach), the Mid-Infrared Characterization and Application Lab (enabling infrared pixel and full array characterization), the Energy Storage Hub (dedicated to battery related materials synthesis and test) and the metal organic chemical vapor deposition lab (providing semiconductor and oxide epitaxy).

Research activities at Nanotech West span a range of cutting-edge materials research that is rather extraordinary for a single facility – from GaN/AlGaN and β-Ga_2O_3 materials and devices, solar cells and infrared focal plane arrays to microfluidics, biotechnology, material synthesis, and testing for energy storage and 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, NTW provides substantial impact and continues to be a centerpiece of collaborative research to the university's materials research community.

Learn more at nanotech.osu.edu.

WORLD-RECORD ULTRA-WIDE BANDGAP SEMICONDUCTOR DEVICES FABRICATED AT NANOTECH WEST

The exploration of new materials, heterostructure designs, and device engineering concepts are helping lay the foundation for a new class of ultra-wide band gap semiconductor-based electronic systems with unprecedented functionality and performance, and a hub of Ohio State researchers leading the way.

Ultra-wide band gap semiconductors, materials with energy band gaps higher than 4 eV, could potentially enable higher performance than state-of-art power and communication electronics based on Si, SiC, and GaN. At Ohio State, research is being done on ultra-wide semiconductors such as beta-Gallium Oxide (β-Ga_2O_3) and AlGaN by several research groups including those of professors Hongping Zhao, Wu Lu, Steven Ringel, and Siddharth Rajan. This collection of research has enabled many exciting advances in ultra-wide band gap semiconductor device design and fabrication.

One of the key attributes of ultra-wide band gap semiconductors is the theoretically expected high breakdown field (20-50 times higher than conventional Si). Key device metrics like efficiency and power density rely on achieving high breakdown fields in a device but until recently it was an unrealized challenge to design devices that could use the extreme field strengths. Working at IMR's Nanotech West, Zhanbo Xia and Towhidur Razzak, graduate students advised by Rajan in Electrical and Computer Engineering, demonstrated novel heterostructures that combine high-permittivity dielectrics (using ion sputtering) with β-Ga_2O_3 and AlGaN to realize $BaTiO_3$/β-Ga_2O_3 and $BaTiO_3$/AlGaN dielectric heterojunction diodes with a state-of-art breakdown electric field strengths of 5.7 MV/cm [Xia, Z., et al. Applied Physics Letters 115.25 (2019): 252104.]] and 8.5 MV/cm [Razzak, T., et al., Applied Physics Letters 116.2 (2020): 023507]., respectively. Results that represent the highest breakdown field strengths observed in any semiconductor device to date.

Ohio State researchers have also made key advances in realizing state-of-the-art transistor performance in ultra-wide band gap materials. Also advised by Rajan, Xue Hao (ECE) demonstrated the highest current density to-date (900 mA/mm) in an ultra-wide band gap AlGaN device using a novel micro-channel architecture [Xue, H., et al. IEEE Electron Device Letters 41.5 (2020):677-680] while Zhanbo Xia's recent work on highly scaled β-Ga_2O_3 transistors [Xia, Z., et al. IEEE Electron Device Letters 40.7 (2019): 1052-1055.] led to the demonstration of the highest speed transistors in this material system to date, with a cutoff

NANOTECH WEST
AT A GLANCE

- NTW supported more than 220 users from Ohio State, representing 56 PIs and 104 research projects in the colleges of Engineering, Arts and Sciences, and Medicine.

- NTW facilities supported 44 non-OSU researchers (industry, non-OSU academic and government) from 26 organizations with NTW staff supporting 14 additional industry partners with remote fabrication services.

- Staff, aided by senior graduate student superusers and undergraduate engineering interns, trained 66 new users of the NTW facility (52 OSU and 14 non-OSU), totaling more than one thousand researchers trained since 2010.

- NTW lithography capabilities upgraded with the installation of state-of-the-art Heidelberg MLA150 maskless aligner (March 2020)

- NTW characterization capabilities enhanced with installation of Bruker D8 Discover high resolution x-ray diffraction system (June 2020)

- NTW MOCVD laboratory installed high power infrared laser to explore new growth window for MOCVD-grown gallium nitride for high power electronics applications.

- NTW MOCVD laboratory utilized by OSU-led team to achieve new world record for monolithic GaAsP/Si tandem solar cells (https://doi.org/10.1002/pip.3303).

IMR INNOVATION LAB

The IMR Innovation Lab is a 2,500-square-foot, open-area space that encourages collaboration. The lab's vision is for innovation to inform research opportunities while serving as a hub for a vibrant, interdisciplinary innovation community. It is a place where partners have access to the university and engage with students, faculty, and staff. It is focused on convergence and the translation of IMR's knowledge and assets to solve real-world problems. It is the interface that connects, creates, and delivers impactful value derived from interdisciplinary research to meet the market needs through collaboration and strategic partnerships.

Since its inception in late 2016, the impact of the lab is leading to an interdisciplinary, innovation culture that has connected over 50 faculty and research staff and 300 undergraduates, from 43 departments and 6 colleges, spanning from History to Engineering, and everything in between, to companies that range from start-ups to Fortune 500s. This has led to the creation of more than 160 externships and internships and several sponsored projects. The lab has also attracted state and federal funding to engage local community college students and train Ohio State graduate students to attract a wider array of talent and skills for collaborations with regional and global industry partners. Thanks to the Innovation Lab, there are now more than 50 companies engaged in multiple ways that will enable long-term, mutually beneficial relationships with students, faculty and external partners.

TEACHING AND LEARNING

The Innovation Lab is where students wanting real-world, experiential learning connect with companies wanting better access to the university and undergraduates through externship opportunities. Externships, in this context, are a unique type of internship defined as on-campus partnerships between students, the university, and potential employers that formally integrate students' academic study with work during either a weekend or weeklong INNOVATE-O-thon. These INNOVATE-O-thons are the result of a

strong collaboration with the Ohio State Center for Innovation Strategies, industry partners, and the broader Ohio State community that allow students to participate in a distinctive, community-engaged learning environment where the focus is on talent, skills and inclusiveness. Learn more at imr.osu.edu.

LASTING IMPACT OF THE M&MS DISCOVERY THEME

Regarding innovation, the impact of the M&MS Discovery Theme cannot be overstated. By leveraging our research strengths and assets across materials, manufacturing, energy, and sustainability, it has had a transformational effect in achieving a "discovery to deployment" innovation ecosystem that is now a reality via the programming of the IMR Innovation Lab. With a focus on materials and manufacturing innovations to address global imperatives to advance clean energy technologies and ensure sustainability, M&MS has forged new paths for collaboration across Ohio State, and is enabling "beyond the norm" strategies for innovative industry partnerships. From our innovation events to our leading roles in the west campus innovation district, IMR is now at the core of developing unique public-private partnerships that are evolving the university's culture and land grant mission.

INNOVATION WORKSHOPS

IMR hosts several types of events in the Innovation Lab space. Beyond our INNOVATE-O-thons, IMR also connects our industry partners with Ohio State faculty and staff to solve complex, real-world problems. By connecting experts from across our university's interdisciplinary community to these partners through carefully curated innovation workshops, we offer a unique experience and avenue to solving system-level challenges that exceed what can be achieved by a sole researcher or siloed teams with similar backgrounds. These workshops provide a vehicle for faculty to not only make an impact on the market, but identify new research areas and develop new, collaborative research projects. IMR has previously hosted innovation workshops with Scotts Miracle-Gro and, most recently, the ROSEN Group.

Scenes from IMR's workshop with ROSEN in the Innovation Lab. ROSEN focuses on research, service and solutions for complex technical systems, and employs nearly 3,000 workers in more than 120 countries.





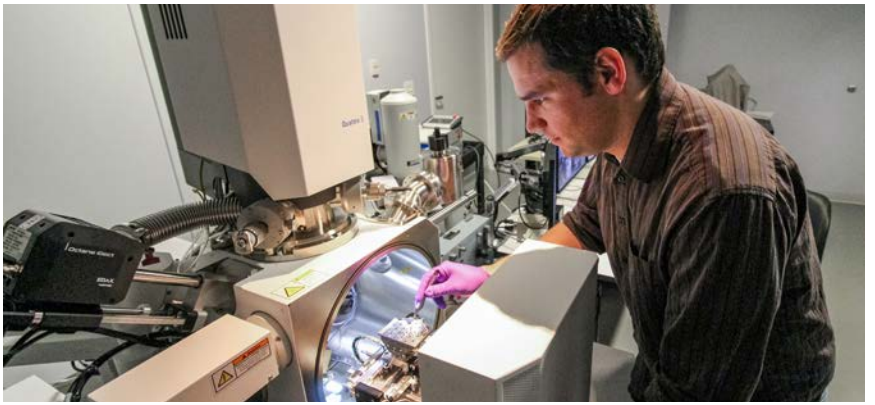


CENTER FOR ELECTRON MICROSCOPY AND ANALYSIS

Ohio State's Center for Electron Microscopy and Analysis (CEMAS) is the preeminent materials characterization hub for business and academia. CEMAS was established to provide a world-class environment for the teaching and practice of advanced microscopy across all scientific disciplines. The point of difference lies in the multidisciplinary approach taken to drive synergy, amplify characterization capabilities, and challenge what is possible in analytical electron microscopy. With one of the largest concentrations of electron and ion beam microscopy instruments for materials characterization, CEMAS strives to be the most advanced microscopy facility in the world. CEMAS was partly funded by IMR's ORSP award – Technology Enabling and Emergent Materials (TEEM), which also provided the position filled by David McComb, who is the CEMAS director and an IMR associate director. CEMAS facilitates electron microscopy application to an incredible breadth of science — from biomaterials and bio-inspired materials to nanoelectronics, energy materials, advanced structural materials, and medicine. Capabilities include scanning electron microscopy (SEM), focused ion beam microscopy (FIB), transmission electron microscopy (TEM), X-ray diffraction (XRD), micro-computed tomography (micro-CT), and cryo-electron microscopy (cryo-EM). Recently installed equipment includes a Thermo Scientific Themis Z S/TEM and Thermo Scientific Glacios Cryo-TEM. CEMAS offers a full-service, expertly designed environment for researchers to execute their entire microscopy and analysis program. During FY20, CEMAS provided research services totaling more than $1.12M and supported 278 users from 134 research groups. Learn more at cemas.osu.edu.

RESEARCH REVIEW: SELF-ACCELERATED CORROSION OF NUCLEAR WASTE FORMS AT MATERIAL INTERFACES

CEMAS facilitated findings demonstrating that the corrosion of nuclear waste storage materials accelerates because of changes in the chemistry of the nuclear waste solution and how the materials interact with one another. The study, published in the journal Nature Materials, was led by Xiaolei Guo. Ohio State researchers involved in the study include Gopal Viswanathan, Tianshu Li, and Gerald Frankel. The long-term plan for high-level defense waste disposal and storage around the globe involves mixing the nuclear waste with other materials to form glass or ceramics, and then encasing those pieces of glass or ceramics — now radioactive — inside metallic canisters. The canisters then would be buried deep underground in a repository to isolate it. In this study, the researchers found that glass and ceramics interact with stainless steel to accelerate corrosion when exposed to an aqueous environment, especially of the glass and ceramic materials holding nuclear waste. Researchers leveraged CEMAS' SEM, FIB, and TEM capabilities, as well as staff expertise.



THE IIT BOMBAY–OHIO STATE FRONTIER CENTER

The IIT Bombay-Ohio State Frontier Science and Engineering Research Center is a joint, collaborative research center shared by Ohio State and the Indian Institute of Technology Bombay. This collaboration with IIT Bombay, an internationally recognized public institution of higher education leading in engineering education and research in Mumbai, is Ohio State's first academic research center shared outside the U.S. It builds on both institutions' research strengths to create a global community of researchers, students and industry, as well as advance the creation and translation of knowledge. The Frontier Center kick starts innovative, interdisciplinary research projects within the broad areas of materials, devices, components and systems, while designated research spaces at both campuses give researchers new access to facilities and expertise. The center is also a catalyst to develop and advance collaborative industry- and government-funded projects. The Center will facilitate courtesy and visiting faculty appointments in strategic areas of interests, is preparing joint-hosted workshops and webinars, and provided seed funding to new research endeavors. The Frontier Center Scholars grant program provides seed funding for cutting-edge research projects led by a pair of principal investigators, one from each institution, as well as a doctoral student from either IIT Bombay or Ohio State. Leadership consists of faculty members from each institution: Ardeshir Contractor, professor of practice in Ohio State's Mechanical and Aerospace Engineering; Sanjay Krishna, Ohio State's George R. Smith Chair in Engineering; Saurabh Lodha, IIT Bombay professor in Electrical Engineering; and Raghavan Sunoj, institute chair professor in IIT Bombay's Department of Chemistry. Learn more at imr.osu.edu/frontier-center.

INAUGURAL ROUND OF FRONTIER CENTER SCHOLAR GRANTS AWARDED

The Frontier Center announced in FY20 its inaugural round of awards to six collaborative research teams under the Frontier Center Scholars Program. The program provides seed funding designed to lay the groundwork for larger, externally funded projects that advance science and technology. Awarded projects bring together investigators with complementary expertise from across the globe to enable unique projects that push the frontier of science and engineering research beyond what could be accomplished separately. Each research team consists of a pair of principal investigators, one from the IIT Bombay and another from Ohio State, as well as one doctoral student.

FY20 AWARDEES

Additive Manufacturing of Lightweight High Entropy Alloys
PIs: Alan Luo (Materials Science and Engineering, Ohio State) and Asim Tewari (Mechanical Engineering, IIT Bombay)
Co-investigators: Edward D. Herderick (Ohio State) and Sushil Mishra (IIT Bombay)
Frontier Center Scholar: Deepak Soman (IIT Bombay)

Emergent Quantum Spin Liquid Phases in Quantum Materials
PIs: Nandini Trivedi (Physics, Ohio State) and Avinash Mahajan (Physics, IIT Bombay)
Frontier Center Scholar: Sanjay Bachhar (IIT Bombay)

Integration of Zero-Leakage NEMS Switch With a Flexible Antenna for RF Energy Harvesting
PIs: Nima Ghalichechian (Electrical & Computer Engineering, Ohio State) and Maryam Shojaei Baghini (Electrical Engineering, IIT Bombay)
Frontier Center Scholar: Sumit Saha (IIT Bombay)

Modeling Polymer-Grafted Nanoparticle Phase Behavior
PIs: Lisa Hall (Chemical & Biomolecular Engineering, Ohio State) and Mukta Tripathy (Chemical Engineering, IIT Bombay)
Frontier Center Scholar: Felipe Fabricio Pacci Evaristo (Ohio State)

Selling Renewable Generation to Flexible Consumers with a Data-Driven Tariff Scheme
PIs: Abhishek Gupta (Electrical & Computer Engineering, Ohio State) and Anku A. Kulkarni (Systems and Control Engineering, IIT Bombay)
Frontier Center Scholar: Anuj S. Vora (IIT Bombay)

Towards Rugged SiC Technology for Electric Transportation
PIs: Anant Agarwal (Electrical & Computer Engineering, Ohio State) and Swaroop Ganguly (Electrical Engineering, IIT Bombay)
Frontier Center Scholar: Suvendu Nayak (IIT Bombay)

WATCH NOW: Visit IIT Bombay, and meet Frontier Center leaders

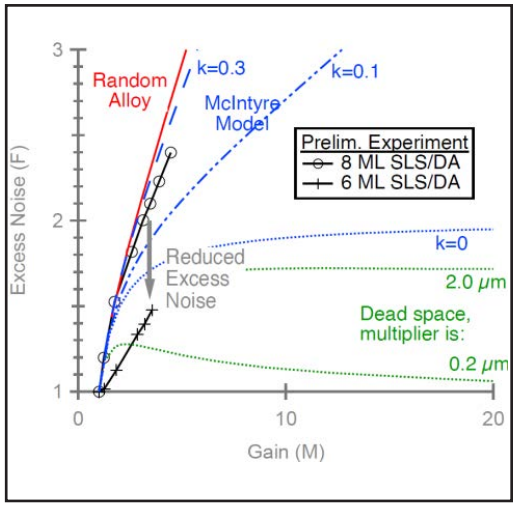
Use your phone's camera app to scan the QR code
...or visit
go.osu.edu/frontier-launch

SEMICONDUCTOR EPITAXY AND ANALYSIS LABORATORY

The Semiconductor Epitaxy and Analysis Laboratory (SEAL) is Ohio State's primary facility for molecular beam epitaxy (MBE). As one of the largest MBE facilities in the U.S., this world-class, shared user facility supports interdisciplinary research and development on epitaxial growth of electronic and photonic materials and devices. SEAL is fully staffed and open to university and industry researchers. SEAL houses six state of the art MBE chambers each dedicated to different, complementary material systems to provide epitaxial growth of crystalline layers, heterostructures, nanostructures and device structures in a variety of material domains. Research focuses on a range of semiconductor materials, including III-V materials based on arsenides, phosphides, antimonides, nitrides, and advanced oxides, SiGe and 2D materials. SEAL is managed by IMR and operates under the guidance of the Department of Electrical and Computer Engineering and College of Engineering. Several chambers are integrated into UHV cluster tools, enabling a 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 for in-situ chemical studies of pristine surfaces and interfaces. Cluster II comprises nitride- and oxide-MBE chambers, the combination of which also enables unique combinations of materials. SEAL has a range of advanced materials characterization tools to support breakthrough epitaxy and electronic materials. Learn more at seal.osu.edu.

RESEARCH REVIEW: STATE-OF-THE-ART INFRARED PHOTODIODES GROWN BY MOLECULAR BEAM EPITAXY

With support from SEAL, Sanjay Krishna, George R. Smith Chair in Engineering, and his research team has demonstrated low noise avalanche photodiodes using superlattices. One of the key material properties that defines the internal gain and multiplication characteristics due to avalanche gain is the low background concentration. This is achieved by low impurity levels and defects achieved in the Antimonide Molecular Beam Epitaxy Reactor (AMBER).



The figure above shows reduction in the excess noise as a function of avalanche multiplication gain by engineering the bandstructure of InGaAs/ InAlAs digital alloy and superlattices on InP substrates.

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, e-beam lithography, Electron Spin Resonance spectroscopy, Physical Vapor material deposition, ion milling, ICP/RIE etching, maskless photolithography, Low-Temperature/ High Magnetic field magnetotransport measurements, diamond CVD growth, material polishing, Kerr microscopy, critical point drying and magneto-optical material studies. NSL also operates two 1,100-square-foot clean room facilities. One clean room houses instruments for material deposition and processing for photo/e-beam lithography, while the other clean room is devoted to processing organic spintronic devices, and other air and moisture sensitive materials. It is equipped with four interconnected gloveboxes with Ar and N_2 atmosphere. In FY20, NanoSystems Laboratory expanded its capabilities through acquisition of a new Broadband 330 GHz Variable Temperature Magnetic Resonance Spectrometer System funded by NSF MRI award obtained by the team of Ohio State researchers led by Fengyuan Yang. The new instrument will allow measurements of material properties in the frequency ranges previously unattainable in a user facility. Final commissioning of the instrument was delayed due to the COVID-19 shutdown, but it is expected to become operational in FY21. Learn more at ensl.osu.edu.

RESEARCH REVIEW: INVESTIGATION OF MAGNETIC SKYRMIONS AND INTERFACIAL INTERACTIONS IN MAGNETIC GARNET EPITAXIAL THIN FILMS CAPPED WITH HEAVY METALS

Supported by DARPA and CEM, Fengyuan Yang's group (Physics) in collaboration with groups of P. Chris Hammel and Mohit Randeria from Physics, David McComb and Jinwoo Hwang from Materials Science & Engineering, Patrick Woodward from Chemistry & Biochemistry, and NSL Director Denis Pelekhov and NSL Staff member Camelia Selcu have investigated magnetic skyrmions and interfacial interactions in magnetic garnet epitaxial thin films capped with heavy metals. NSL provided essential tools to characterize their structural, magnetic, and spin transport properties using X-ray diffraction, atomic/magnetic force microscopy, SQUID magnetometer, and PPMS, as well as lithographical patterning. They observed a novel spin-Hall topological Hall effect, imaged nanoscale skyrmions, and revealed a systematic behavior of strong interfacial magnetic anisotropy in these samples. These results have led to the following recent publications: Nano Letters 19, 5683 (2019); Physical Review Letters 124, 107201 (2020); Physical Review B 101, 184409 (2020); Physical Review Letters, 124, 257202 (2020); and Nano Letters, 20, 4667 (2020).

RESEARCH CENTERS & CORE LABORATORIES

One of IMR's goals is to develop and establish externally-supported research centers and centers of excellence. It is also critical to our mission that our core research facilities are at the leading edge, operating at peak conditions, and available to the community. This section briefly lists the many centers of excellence, several of which produce annual reports of their own, such as the Center for Emergent Materials – CEM – an NSF-funded MRSEC (Materials Research Science and Engineering Center), which was IMR's first developed center of excellence. The section also lists core research facilities that either IMR operates fully, that IMR supports directly through our network of IMR Members of Technical Staff, or that IMR is engaged through our seed grant program and other promotional means. These core facilities are distributed throughout campus, housed in different colleges and are also on Ohio State's West Campus. IMR works to establish a coordinated network of such facilities that are available to our community.

CENTER FOR AUTOMOTIVE RESEARCH (CAR)

The Center for Automotive Research (CAR) is an interdisciplinary research center focusing on energy, safety and the environment to improve sustainable mobility. IMR and CAR have multiple joint activities, including M&MS faculty hiring, support of IMR's new Energy Storage Hub, and collaborative faculty research projects in areas such as materials for energy and sustainability.

CENTER FOR DESIGN AND MANUFACTURING EXCELLENCE (CDME)

The Center for Design and Manufacturing Excellence (CDME) is the manufacturing port of entry into Ohio State for innovative, applied research for product design, technology commercialization, and manufacturing for industry. Through the translational interface of the IMR Innovation Lab, IMR and CDME staff collaborate frequently to develop business and joint projects in manufacturing science and innovation. Further, the leadership of IMR and CDME work together strategically to advance Ohio State's presence and leadership in manufacturing R&D and deployment, identifying and leading major block-funding efforts, and enabling the expansion of manufacturing-relevant national and global partnerships.

CENTER FOR EMERGENT MATERIALS (CEM)

The Center for Emergent Materials (CEM) is an NSF MRSEC at Ohio State that engages researchers from multiple disciplines to work in teams on scientific problems too complex for a single researcher to solve. Established in 2008, CEM has three Interdisciplinary Research Groups (IRGs), and focuses on magnetoelectronics at the physics to nanodevice level. IMR is deeply engaged with CEM: first, by driving the process that led to its successful proposal and establishment and, over the years, by sharing in many strategic programs and activities, including the multi-tiered seed grant program, the student poster sessions annually at materials week, the joint support of the Nanosystems Laboratory (NSL), the hiring of M&MS faculty into strategic positions within CEM, and many more interaction points too numerous to list. CEM is perhaps the center we have interacted with the most through the years, as winning and maintaining a MRSEC was IMR's first primary goal. We are deeply symbiotic, even operationally, through our support of CEM staff and its international collaboration programs. One of IMR's current associate directors, Fengyuan Yang, is an IRG leader.

CENTER FOR ELECTRON MICROSCOPY AND ANALYSIS (CEMAS)

The Center for Electron Microscopy and Analysis (CEMAS) is a core materials research facility and one of the largest concentrations of electron and ion beam analytical microscopy instruments for materials characterization. IMR is very deeply engaged with all aspects of CEMAS, similar to our relationship with CEM. CEMAS was partly funded by IMR's ORSP award – Technology Enabling and Emergent Materials (TEEM), which also provided the position filled by David McComb, who is the CEMAS director and an IMR associate director. IMR provides direct support to CEMAS in the form of an IMR member of technical staff, numerous seed grants to faculty who use CEMAS, and we jointly developed the remote microscopy nodes across the state and routinely share in major proposal development (e.g. NSF NNCI and MRI programs, etc). Several of the IMR's M&MS faculty work directly toward CEMAS objectives.

RESEARCH CENTERS & CORE LABORATORIES

CENTER FOR HIGH PERFORMANCE POWER ELECTRONICS (CHPPE)

The Center for High Performance Power Electronics (CHPPE) is a power electronics laboratory in which researchers exploit the high temperature, high frequency operation and efficiency advantages of silicon carbide (SiC)-based power electronics. IMR identified CHPPE as an area of strategic growth during our M&MS process and, as such, have provided some faculty slots around future power electronics. Therefore, we are deeply engaged, but at the lower TRL levels leading to CHPPE, which is more of a systems-level center. IMR works with CHPPE on industry engagement and several large, external funding opportunities, including from ARPA-E and DARPA.

CENTER FOR INNOVATION STRATEGIES (CIS)

The Center for Innovation Strategies (CIS) is housed in the Fisher College of Business. CIS collaborates across campus and in the community, as a facilitator and connector promoting innovation at Ohio State and beyond. IMR works closely with CIS in the area of innovation that leads to new products for industry partners and new research centers for the university. CIS is a co-developer of the IMR INNOVATE-O-thon model, and IMR and CIS collaborate thoughtfully and deliberately on innovation models applied across the entire university enterprise and external innovation ecosystem.

ELECTROSCIENCE LAB (ESL)

The ElectroScience Lab (ESL) is a major center of excellence in Ohio State's College of Engineering and one of the largest radio frequency and optics research laboratories in the world. Since 1942, ESL has consistently maintained a national and international pre-eminence in electromagnetics. IMR leverages ESL faculty, research scientists and students to support innovation events and sponsored projects with our strategic partners in all aspects of electromagnetic and RF technologies.

ENERGY STORAGE HUB

Innovations in energy storage systems requires integrating diverse knowledge from multidisciplinary teams. Through the Energy Storage Hub, faculty, staff and students who share this vision are dedicated to defining current issues on electrochemical energy storage/conversion devices, as well as innovating the materials and systems to develop future energy technologies. The Hub is part of the Nanotech West user facility, and a member of IMR's technical staff coordinates its lab activities. It also serves as the primary lab for two M&MS faculty members.

FONTANA CORROSION CENTER (FCC)

The Fontana Corrosion Center (FCC) focuses on the study of aqueous corrosion in our effort to develop better methods to protect materials from the adverse impacts of the environment. IMR indirectly works with FCC not at an institute-center level, but more at the faculty support level via our seed and other programs.

INFECTIOUS DISEASES INSTITUTE (IDI)

The Infectious Diseases Institute (IDI) generates solutions to the detrimental effects of microbes on the health of humans, animals, plants, and the environment for the benefit of society. IMR and IDI collaborate in developing materials and manufacturing solutions to achieve a world free from the threat of infectious diseases.

IIT BOMBAY-OHIO STATE FRONTIER SCIENCE AND ENGINEERING RESEARCH CENTER

The Frontier Center, a collaboration between IMR and the Indian Institute of Technology Bombay (IIT Bombay), is believed to be Ohio State's first academic research center shared outside the U.S. It's mission is to create a global community of researchers, students and industry to build on the strengths of the universities in materials, devices, components and systems to advance the creation and translation of knowledge, and educate students for the global economy to improve the well-being of our world. IMR is providing physical space, operations support and center leadership.

IMR INNOVATION LAB

This interface connects IMR strategic partners to our faculty, staff and students to create value and deliver impact to meet the needs in the market. The vision of this lab is for innovation to inform research opportunities while serving as a hub for a vibrant, interdisciplinary innovation community. The Innovation Lab is located at Nanotech West, and it is fully operated by IMR.

LIGHTWEIGHT INNOVATIONS FOR TOMORROW (LIFT)

Lightweight Innovations for Tomorrow (LIFT) is a National Network for Manufacturing Innovation (NNMI) institute awarded to Ohio State, EWI and the University of Michigan, as a public-private partnership that works on advanced lightweight materials manufacturing technologies, workforce education and training programs in this area. Glenn Daehn, IMR Director of Manufacturing Initiatives, has been the spearhead for LIFT at Ohio State. Through their member companies and CDME, IMR is engaged by seeking testing and services agreements, as well as other arrangements suitable for partner companies.

MID INFRARED CHARACTERIZATION AND APPLICATION (MICA) LAB

The Mid Infrared Characterization and Application (MICA) Lab houses electro-optical systems to characterize fabricated infrared detectors and imagers. Research in this lab explores advances in both the array and readout integrated circuit (ROIC). MICA is part of the Nanotech West user facility, and a member of IMR's technical staff coordinates its lab activities.

METALORGANIC CHEMICAL VAPOR DEPOSITION (MOCVD) LAB

The Metalorganic Chemical Vapor Deposition (MOCVD) Lab is home to three MOCVD epitaxial deposition systems: a 4" Aixtron system for deposition of As, P, Sb based III-V compounds (2009), a 2" Agnitron custom dual-chamber growth system for III-nitride materials and novel II-IV-nitride materials (2018), and an Agnitron vertical, quartz cold-wall design for the ultra-wide bandgap oxide alloys and heterostructures (2019). Part of IMR's Nanotech West user facility, the MOCVD lab is the primary growth facility for and is advised by M&MS faculty member and associate professor Hongping Zhao.

RESEARCH CENTERS & CORE LABORATORIES

NANOSYSTEMS LABORATORY (NSL)

The NanoSystems Laboratory (NSL) is the primary facility for emergent materials. It provides academic and industrial users with access to advanced material characterization and fabrication tools for research and development applications. Research capabilities available at NSL include focused ion beam/scanning electron microscopy, e-beam lithography, nanomanipulation, EDS X-ray microanalysis, X-ray diffractometry, SQUID magnetometry, atomic force/magnetic force microscopy, low temperature magnetotransport measurements and Langmuir-Blodgett trough monolayer deposition. NSL is also a member of the IMR network of laboratories, and directed by a member of the IMR technical staff.

NANOTECH WEST LAB (NTW)

Nanotech West Lab (NTW) is IMR's core materials research facility and the largest nanofabrication user facility in the state of Ohio. It is a shared user facility supporting both academic and industrial users. NTW provides its users access to a range of material synthesis, fabrication, characterization, and metrology equipment to support a diverse range of materials related research. With 24,000 square feet of lab space, NTW is home to the class 100 nanofabrication clean room, the Metalorganic Chemical Vapor Deposition (MOCVD) lab, the Mid Infrared Characterization and Application (MICA) Lab, the Energy Storage Hub, and IMR's Innovation Lab. As a university unit under IMR, NTW is directed by a member of IMR technical staff and its operation is supported by nine additional NTW administrative and engineering staff who provide training, process support and project support to Nanotech's user base. Three M&MS faculty members are located there. Through a large amount of IMR's seed programs, the institute directly supports faculty who use NTW, as an essential facility that enables their funded research. It is also home to the IMR Innovation Lab.

OHIO MANUFACTURING INSTITUTE (OMI)

The Ohio Manufacturing Institute (OMI) develops industry-vetted policy recommendations to help the state and nation establish a best-practice competitive ecosystem for small- and mid-sized manufacturing enterprises (SMMEs). IMR works with OMI in a number of areas, including participation and support of workshops that shape the future of SMMEs. IMR faculty and staff also serve as co-PIs with OMI staff on federal and state grants that enable diverse, community-engaged learning to collaborate on solving advanced manufacturing issues to help address real-world skill gaps and occupational shortfalls in SMMEs industry sectors.

REDUCING EMBODIED-ENERGY AND DECREASING EMISSIONS (REMADE) INSTITUTE

The Reducing EMbodied-Energy And Decreasing Emissions (REMADE) Institute is a National Network for Manufacturing Innovation (NNMI) Institute public-private partnership. The goal of the REMADE Institute is to reduce the cost of technology essential to reusing, recycling and remanufacturing materials such as metals, fibers, polymers and electronic waste, as well as improve overall energy efficiency 50 percent by 2027, saving billions in energy costs. IMR and the M&MS Discovery Theme have shared in Ohio State's contribution, based on expected participation in consortium projects — two of which have been awarded.

SEMICONDUCTOR EPITAXY AND ANALYSIS LAB (SEAL)

The Semiconductor Epitaxy and Analysis Lab (SEAL) is Ohio State's primary facility for molecular beam epitaxy (MBE) and is located within the 4,000-square-foot Dreese Lab Cleanroom (DLC). SEAL can provide epitaxial growth of crystalline layers, heterostructures, nanostructures and device structures in a variety of material domains. It is a staffed user-based cost center within the College of Engineering and Department of Electrical and Computer Engineering. SEAL is also a member of the IMR network of laboratories and operated by a member of the IMR technical staff.

SIMULATION INNOVATION AND MODELING CENTER (SIMCENTER)

The Simulation Innovation and Modeling Center (SIMCenter) is an interdisciplinary research center for the virtual simulation and modeling of product performance and manufacturing processes. IMR leadership is working closely with the SIMCenter to develop joint research projects in which materials and computer-aided engineering techniques intersect at the design and manufacturing of advanced product and production concepts.

SUSTAINABILITY INSTITUTE (SI)

The Sustainability Institute (SI) integrates, supports and leads sustainability across the university. IMR and SI collaborate at the intersections of materials, manufacturing and sustainability to enhance our interdisciplinary community, research and innovation. This includes working together to develop new public- and private-sector partnerships and unique experiential learning programs.

TRANSLATIONAL DATA ANALYTICS INSTITUTE (TDAI)

The Translational Data Analytics Institute (TDAI) creates and applies data analytics solutions to issues of global importance in partnership with the external community, while advancing foundational data science theories and methods. IMR and TDAI collaborate on the hiring of joint faculty possessing data science expertise that expand our interdisciplinary materials research community.

OHIO AGRICULTURAL RESEARCH AND DEVELOPMENT CENTER (OARDC)

The mission of The Ohio Agricultural Research and Development Center is to enhance the well-being of the people of Ohio, the nation and world through research on foods, agriculture, family and the environment. The interaction between IMR and OARDC stems from IMR's Ohio Research Scholar Program (ORSP) – Technology-Enabling and Emergent Materials (TEEM). IMR supported the position for the hiring of Katrina Cornish into the Department of Horticulture and Crop Science (adjunct in Chemistry and Biochemistry). We continue to work with OARDC indirectly through Dr. Cornish and have supported multiple proposals and seed programs benefiting OARDC in the area of agriculture-based biomaterials and bioproducts.

Gunjan Agarwal, Biomedical Engineering

Anant Agarwal, Electrical and Computer Engineering

Sudha Agarwal, Oral Biology

Sheikh Akbar, Materials Science and Engineering

Boian Alexandrov, Materials Science and Engineering

Heather Allen, Chemistry and Biochemistry

Douglas Alsdorf, Earth Sciences

Betty Lise Anderson, Electrical and Computer Engineering

Peter Anderson, Materials Science and Engineering

Shamsul Arafin, Electrical and Computer Engineering

Aaron Arehart, Electrical and Computer Engineering

Aravind Asthagiri, Chemical and Biomolecular Engineering

Jovica Badjic, Chemistry and Biochemistry

Robert Bailey, Mechanical and Aerospace Engineering

Robert Baker, Chemistry and Biochemistry

Jim Beatty, Physics

Avraham Benatar, Materials Science and Engineering

Alison Bennett, Evolution, Ecology & Organismal Biology

Paul Berger, Electrical and Computer Engineering

Bharat Bhushan, Mechanical and Aerospace Engineering

Ashley Bigham, Architecture

Christian Blanco, Management Sciences

Thomas Blue, Mechanical and Aerospace Engineering

Marc Bockrath, Physics

Dennis Bong, Chemistry and Biochemistry

Janet Box-Steffensmeier, Political Science

Leonard Brillson, Electrical and Computer Engineering

Jonathan Brown, Chemical and Biomolecular Engineering

Nicholas Brunelli, Chemical and Biomolecular Engineering

Rafael Bruschweiler, Chemistry and Biochemistry

Rudy Buchheit, Materials Science and Engineering; Fontana Corrosion Center

Ralf Bundschuh, Physics

Lisa Burris, Civil, Environmental and Geodite Engineering

Richard Busick, COE Administration & Planning; Engineering Education Innovation Center

Lei (Raymond) Cao, Mechanical and Aerospace Engineering

William Carson, Surgery Oncology

Luis Casian, Mathematics

Carlos Castro, Mechanical and Aerospace Engineering

Jose Castro, Mechanical and Aerospace Engineering

Jeffrey Chalmers, Chemical and Biomolecular Engineering

Heather Chandler, Optometry

Hanna Cho, Mechanical and Aerospace Engineering

William Clark, Materials Science and Engineering

John Clay, Chemical and Biomolecular Engineering

Anne Co, Chemistry and Biochemistry

James Coe, Chemistry and Biochemistry

Edward Collings, Materials Science and Engineering

Terry Conlisk, Mechanical and Aerospace Engineering

Ardeshir Contractor, Mechanical and Aerospace Engineering

Stuart Cooper, Chemical and Biomolecular Engineering

Katrina Cornish, Horticulture and Crop Science

Glenn Daehn, Materials Science and Engineering

Karen Dannemiller, Civil, Environmental and Geodite Engineering

Marcelo Dapino, Mechanical and Aerospace Engineering

Lakshmi Dasi, Surgery; Biomedical Engineering

Frank De Lucia, Physics

David Dean, Plastic Surgery

Justin Diles, Materials Science and Engineering

Dennis Dimiduk, Materials Science and Engineering

Vicky Doan-Nguyen, Materials Science and Engineering

Suliman Dregia, Materials Science and Engineering

Charles Drummond, Materials Science and Engineering

Rebecca Dupaix, Mechanical and Aerospace Engineering

Prabir Dutta Fox, Chemistry and Biochemistry

Thaddeus Ezeji, Animal Sciences

Liang-Shih Fan, Chemical and Biomolecular Engineering

Dave Farson, Materials Science and Engineering

Ayman Fayed, Electrical and Computer Engineering

Carolin Fink, Materials Science and Engineering

Gerald Frankel, Materials Science and Engineering

Hamish Fraser, Materials Science and Engineering

Dan Gauthier, Physics

Samir Ghadiali, Biomedical Engineering

Nima Ghalichechian, Electrical and Computer Engineering

Maryam Ghazisaeidi, Materials Science and Engineering; Physics

Josh Goldberger, Chemistry and Biochemistry

Keith Gooch, Biomedical Engineering

Pelagia-Iren Gouma, Materials Science and Engineering

Thomas Gramila, Physics

Tyler Grassman, Electrical and Computer Engineering

Dorota Grejner-Brzezinska, College of Engineering

Michael Groeber, Mechanical and Aerospace Engineering; Integrated Systems Engineering

Jianjun Guan, Materials Science and Engineering

Yann Guezennec, Mechanical and Aerospace Engineering

Liang Guo, Electrical and Computer Engineering

Prabhat Gupta, Materials Science and Engineering

Jay Gupta, Physics

Terry Gustafson, Chemistry and Biochemistry

Denis Guttridge, Cancer Biology and Genetics

Christopher Hadad, Chemistry and Biochemistry

Lisa Hall, Chemical and Biomolecular Engineering

Nathan Hall, Radiology

P. Chris Hammel, Center for Emergent Materials; Physics

Derek Hansford, Biomedical Engineering

Ryan Harne, Mechanical and Aerospace Engineering

Richard Hart, Biomedical Engineering

Andrew Heckler, Physics

Carin Helfer, Food, Agricultural and Biological Engineering

Joseph Heremans, Mechanical and Aerospace Engineering

Anton Heyns, Chemistry and Biochemistry

Richard Higgins, Professional and Distance Education Programs

Ned Hill, Public Affairs

George Hinkle, Pharmacy

W.S. Winston Ho, Chemical and Biomolecular Engineering

John Horack, Mechanical and Aerospace Engineering

Nan Hu, Civil, Environmental and Geodite Engineering

Jinwoo Hwang, Materials Science and Engineering

Joerg Jinschek, Materials Science and Engineering

Joel Johnson, Electrical and Computer Engineering

Ezekiel Johnston-Halperin, Physics

Roland Kawakami, Physics

Marat Khafizov, Mechanical and Aerospace Engineering

Waleed Khalil, Electrical and Computer Engineering

Jung-Hyun Kim, Mechanical and Aerospace Engineering

Matt Kleinhenz, Horticulture and Crop Science

Rachel Kleit, College of Engineering

Kurt Koelling, Chemical and Biomolecular Engineering

Sanjay Krishna, Electrical and Computer Engineering

Ashok Krishnamurthy, Electrical and Computer Engineering

Gregory Lafyatis, Physics

John Lannutti, Materials Science and Engineering

Gil Latz, Office of International Affairs

Jeanie (ChunNing) Lau, Physics

Stephen Lee, Biomedical Engineering

L. James Lee, Chemical and Biomolecular Engineering

Robert Lee, Electrical and Computer Engineering

Robert J. Lee, Pharmacy

Jennifer Leight, Biomedical Engineering

John Lenhart, Civil, Environmental and Geodite Engineering

Blaine Lilly, Mechanical and Aerospace Engineering

Li-Chiang Lin, Chemical and Biomolecular Engineering

John Lippold, Materials Science and Engineering

Jun Liu, Biomedical Engineering

Xun Liu, Materials Science and Engineering

Jenifer Locke, Materials Science and Engineering

Wu Lu, Electrical and Computer Engineering

Alan Luo, Materials Science and Engineering

Anthony Luscher, Mechanical and Aerospace Engineering

Raghu Machiraju, Computer Science and Engineering

Edward Martin Jr., Surgery Oncology

Randall Mathison, Mechanical and Aerospace Engineering

Sandip Mazumder, Mechanical and Aerospace Engineering

David McComb, Materials Science and Engineering

Psaras McGrier, Chemistry and Biochemistry

Erin McKie, Management Sciences

Jack McNamara, Mechanical and Aerospace Engineering

Jeffery McNeal, Mathematics

Bruce McPheron, Academic Affairs Administration

Chia-Hsiang Menq, Mechanical and Aerospace Engineering

Fred Michel Jr., Food, Agricultural and Biological Engineering

Terry Miller, Chemistry and Biochemistry

Michael Mills, Materials Science and Engineering

Prasad Mokashi, Mechanical and Aerospace Engineering

John Morral, Materials Science and Engineering

Patricia Morris, Materials Science and Engineering

Randy Moses, Electrical and Computer Engineering

Karin Musier-Forsyth, Chemistry and Biochemistry

Stephen Myers, Horticulture and Crop Science

Roberto Myers, Materials Science and Engineering

David Nagib, Chemistry and Biochemistry

Pitchi Raju Nandyala, Physics

Ali Nassiri, Integrated Systems Engineering; Simulation Innovation and Modeling Center

Stephen Niezgoda, Materials Science and Engineering

Susan Olesik, Chemistry and Biochemistry

Michael Ostrowski, Molecular and Cellular Biochemistry

Umit Ozkan, Chemical and Biomolecular Engineering

Andre Palmer, Chemical and Biomolecular Engineering

Wendy Panero, Earth Sciences

Jon Parquette, Chemistry and Biochemistry

Srinivasan Parthasarathy, Computer Science and Engineering

Michael Paulaitis, Chemical and Biomolecular Engineering

Jonathan Pelz, Physics

David Phillips, Materials Science and Engineering

Matthew Platz, Chemistry and Biochemistry

Michael Poirier, Physics

Alison Polasik, Materials Science and Engineering

Farhang Pourboghrat, Mechanical and Aerospace Engineering

Stephen Povoski, Surgery Oncology

Heather Powell, Materials Science and Engineering

Shaurya Prakash, Mechanical and Aerospace Engineering

Judit Puskas, Food, Agricultural and Biological Engineering

Siddharth Rajan, Electrical and Computer Engineering

Thaliyil Rajanbabu, Chemistry and Biochemistry

Antonio Ramirez, Materials Science and Engineering

Mohit Randeria, Physics

Robert Rapp, Materials Science and Engineering

William Ravlin, Evolution, Ecology & Organismal Biology

Ronald Reano, Electrical and Computer Engineering

Matthew Reilly, Biomedical Engineering; Opthalmology

David Rigney, Materials Science and Engineering

Matthew Ringel, Endo, Diabetes, and Metabolism

Steven Ringel, Institute for Materials Research; Electrical and Computer Engineering

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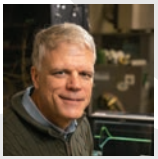

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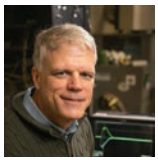

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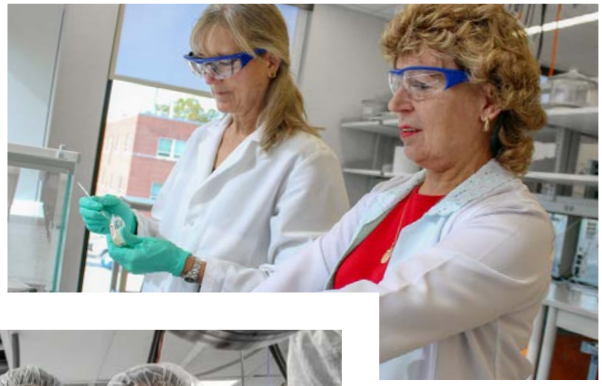

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