INSTITUTE FOR MATERIALS AND MANUFACTURING RESEARCH

FISCAL YEAR 2023

THE OHIO STATE UNIVERSITY
INSTITUTE FOR MATERIALS AND MANUFACTURING RESEARCH

Letter from Executive Director Steven A. Ringel

Every year I struggle to write this column due to the constantly growing list of amazing and visionary accomplishments made by our faculty, students and staff and the constraint of word count. While this year is no different, it is easy to lead with the first re-branding of the Institute since its inception in 2006, with our renaming as the Institute for Materials and Manufacturing Research. Our leadership and advisory board spent 4 years debating its effect on our brand and on ensuring this is perceived as intended, a recognition that prototyping is fast becoming a requisite extension of research, and not an erosion of our commitment to basic research. Translational research is here to stay, as our nation's scientific research centers are being asked to consider translation to prototypes in a finite time period. While this is usually a struggle for academic institutions, Ohio State and the IMR are in a nationally unique position to be a leader in this translation where we can seamlessly connect science to technology to prototypes by virtue of our existing breadth and proven depth in both materials and manufacturing. Our Signature Areas have been prophetic in this regard.

Indeed, at this time last year, we had just learned of the winning an NSF-funded Engineering Research Center for $26M– Hybrid Autonomous Manufacturing from Evolution to Revolution (HAMMER), which complements the existing $18M NSF-funded MRSEC – Center for Emergent Materials. At the same time, our $3M Intel-funded Center for Advanced Semiconductor Fabrication Research and Education was awarded in FY23, with a focus on research to prototypes. The newly funded $7.5M Army-funded Center for Ultrawide Bandgap Semiconductors is expected to explore fundamental materials aspects while producing transformational prototype devices; the newly announced $25M Battery Research and Innovation Center includes emphases on prototype development that is connected to the basic research ongoing in the IMR Energy Innovation Lab. These are just a few examples that exemplify breadth, depth and ability to seamlessly integrate from research to prototyping through the translation of materials to manufacturing.

Our goal is to position the Institute for Materials and Manufacturing Research to lead the nation in this vertically-integrated research-development-prototype ecosystem that aligns with commercial and government needs across a spectrum of technology domains. With that, I hope you enjoy reading highlights from the past year, and please visit our website for more up-to-date information at imr.osu.edu.

Sincerely, Steven A. Ringel, Ph.D.

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

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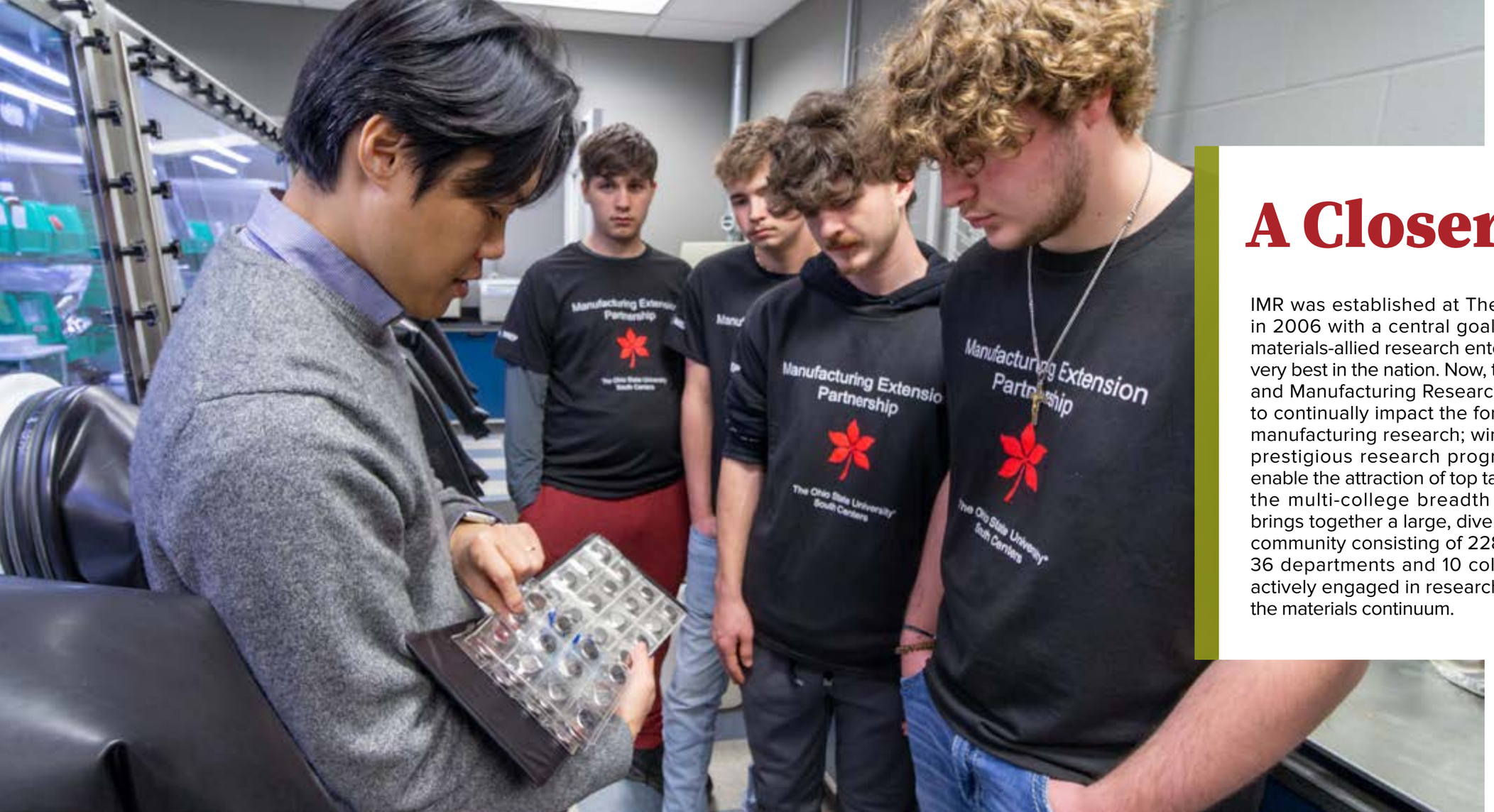


A Closer Look

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. Now, the Institute for Materials and Manufacturing Research steers this enterprise to continually impact the forefront of materials and manufacturing 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. IMR brings together a large, diverse and interdisciplinary community consisting of 228 faculty members from 36 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 and Manufacturing Research (IMR) is a multi-college, university-level institute that leads materials and manufacturing-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 and manufacturing 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 internal partnerships with colleges and departments to co-lead faculty hiring programs, including the Targeted Investment in Excellence program, the Ohio Research Scholars program, and our Materials & Manufacturing for Sustainability (M&MS) Discovery Theme program.

IMR has also enabled critical external partnerships, including Ohio State's first global research center, the IIT Bombay-Ohio State Frontier Science and Engineering Research Center, and numerous industry partnerships in areas of strategic importance, from semiconductors and batteries to aerospace, transportation and medical devices.

IMR supports Ohio State's materials and manufacturing community through:

- Strategic leadership
- Intercollege coordination
- Research infrastructure support, development and operations
- Development and administration of major research proposals, programs and centers
- Development and management of strategic industry partnerships
- Support of innovation ecosystems
- Multi-tiered seed funding program
- Global research partnerships
- Outreach and engagement
- 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 focused Strategic Themes within them, represent areas of IMR's existing national and international prominence, unique capabilities and emerging strategic directions.

As such, the Signature Areas help 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.

Semiconductor Materials and Devices
Compound and wide band-gap semiconductors; Epitaxy, hetero-integration, device processing and nanofabrication; Defects and reliability; Optoelectronics, photovoltaics and photonics; RF and power devices

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 and materials

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; Photovoltaics, thermoelectrics and energy conversion; High-voltage electronics, low-energy devices, and integrated systems

IMR Strategy

The Institute for Materials and Manufacturing 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 and manufacturing research, technology advancement, and innovation.

MISSION

- Lead an interconnected, interdisciplinary materials and manufacturing 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:

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*
$99.1M

TOTAL PROJECT VALUE*
$ 665.6M

NEW AWARDS*
$ 105.5M

* Sponsored projects only

228 FACULTY MEMBERS

36 DEPARTMENTS

10 COLLEGES

8 PUBLICATIONS PER MEMBER [1]

629 CITATIONS PER MEMBER [1]

217 PATENTS FILED [2]

59 PATENTS ISSUED [2]

128 INVENTION DISCLOSURES [2]

[1] Average of researchers found on Google Scholar in CY22

[2] Office of Innovation and Economic Development, FY23

Research & Innovation

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, lists projects that received seed grant awards from IMR, and showcases programs that provided experiential learning for students in FY23.

Highlights

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 and manufacturing community. Here, we provide a summary of some of those spotlights on IMR staff, faculty members and students from the past year.

Highlights

INTEL-FUNDED CAFE SERVES UP 3 NEW RESEARCH THEMES AND EXPERIENTIAL LEARNING OPPORTUNITIES TO STUDENTS ON THE CUTTING EDGE OF SEMICONDUCTOR FABRICATION

After marking its inaugural year, the IMR-led, multi-institutional Center for Advanced Semiconductor Fabrication Research and Education (CAFE) is continuing work in semiconductor fabrication, development and research, while fostering a skilled workforce ready to step into an industry expected to grow considerably across the U.S. and, in particular, in Ohio.

Intel broke ground in FY23 on a new, $20 billion semiconductor manufacturing site to produce leading-edge chips in New Albany, which sits just 25 minutes northeast of the university's main campus in Columbus, Ohio.

Funded by a $3 million Intel grant through the company's Semiconductor Education and Research Program for Ohio, CAFE kicked off with three research themes in FY23. These themes connected students in varying semiconductor-related disciplines to expert researchers, access to state-of-the-art nanofabrication labs, and other hands-on opportunities and experiences.

The IMR-operated center brings together 10 institutions of higher education throughout the state. IMR executive director Steven Ringel, professor of Electrical and Computer Engineering and associate VP for research at Ohio State, is the lead principal investigator.

Researchers at the Nanofabrication Lab at Ohio State's Nanotech West Lab.

Student Experiential Opportunities and New Semiconductor Curriculum

Through the CAFE Student Experiential Opportunities program, 21 students, from Ohio State, the University of Cincinnati and Ohio University began working in Ohio State labs on a myriad of cutting-edge projects related to semiconductor fabrication and manufacturing.

"It's been really exciting to do this project because it's kind of been a combination of everything I've gotten to learn up to this point," said Rachel Adams, a CAFE grad student in Theme 3. "I started in wide bandgap semiconductors doing the electrical characterization, then I moved to solar cells, which is very similar to the photodetector material we're working with. And then, getting to actually combine those compound semiconductors with silicon on my project has been fantastic."

Additionally, the College of Engineering announced the launch of two undergraduate minors, two undergrad certificates and six graduate certificates for the Autumn 2023 semester, as a direct response to the demand for talent in semiconductor manufacturing fields.

Highlights

Graduate students who work within CAFE research themes take a break from participating in a Student Poster Session at IMR's 2023 Ohio State Materials & Manufacturing Conference.

Theme 1: Fabrication Technology for 2D Semiconductor Devices

Projects within the first CAFE theme are undertaking the synthesis of 2D semiconductors for integration with field effect transistors. The application of atomically thin-structured semiconductors in these metal-oxide field effect transistors could offer researchers the ability to further shrink the size of devices. A primary focus is on materials, with researchers developing p-type doping for PMOS transistors to complement the existing NMOS transistors and minimize defects that limit the devices' electronic efficiency. Semiconductor synthesis is being done by chemical vapor deposition and molecular beam epitaxy, while other theme members are focused on characterization and theoretical calculations and modeling.

Theme 2: Fabrication of III-Nitride Devices for Silicon IC Platform

In the second CAFE theme, researchers are investigating the integration of high-permittivity dielectrics on GaN-based transistors to push the boundaries of current density, breakdown voltage, and high-frequency performance beyond today's state-of-art technology, and grow epitaxial ferroelectric films on a III-Nitride platform.

Currently, radio-frequency devices utilizing III-Nitride semiconductors show impressive performance, in terms of high breakdown fields and saturation velocity. However, improving power density proves difficult as a rise in sheet charge density can lead to low breakdown voltage due to the premature breakdown of the gate-drain junction. Researchers are investigating the integration of a high-permittivity dielectric material, both beneath the gate and in the gate-drain region of III-Nitride semiconductors in an effort to create a more even electric field profile. This is expected to allow higher current densities without compromising the breakdown voltage.

Theme 3: Fabrication Technology for Photonic Devices and Integration

Teams within the third CAFE theme are working in alignment with Intel's systems and technology roadmap of Silicon photonics and heterogeneous integration to meet the current challenges inherent in the communications and connectivity of advanced sensing technologies. In this effort, researchers are working to demonstrate next-generation silicon-compatible devices, such as quantum dot-based semiconductor optical amplifiers, with high gain and high saturation output power in the O-band, waveguide optical modulators, and high gain-bandwidth product photodetectors. Researchers will heterogeneously integrate these devices using micro-transfer printing. Quantum dots within amplifier devices as a gain medium are not just noteworthy for their high-gain bandwidth and low-noise operation, but may benefit the implementation of other vital photonic devices.

CAFE in the News

In FY23, CAFE captured significant media attention for its efforts to address the anticipated labor needs in the U.S. semiconductor sector. Fox Business news highlighted the university's proactive measures in an article and video featuring Nanotech West Lab. The story was syndicated and seen across the U.S. IEEE Spectrum also wrote about Ohio State's West Campus and covered IMR's state-of-the-art infrastructure in preparing for the industry's growth. Local outlets WOSU 89.7 NPR News and The Lantern, Ohio State's student newspaper, also reported on the launch of the CAFE program.

CAFE team members gather at Nanotech West Lab for the center kick-off meeting.

CAFE graduate student Rachel Adams being interviewed by Fox Business reporter at the IMR Innovation Lab.

Highlights

NSF AWARDS OHIO STATE RESEARCHERS FUTURE OF SEMICONDUCTORS TEAMING GRANT WITH IMR DEVELOPMENT SUPPORT

A group of researchers at Ohio State in FY23 received funding from the National Science Foundation (NSF) to study new ways conventional Si microelectronics can be combined with new "wide bandgap" semiconductors. The project led by principal investigator Siddharth Rajan, a professor in Electrical and Computer Engineering, brings together multiple experts in areas related to semiconductor devices, circuits, and heterogeneous integration, including Harish Krishnaswamy of Columbia University, Subramanian Iyer of UCLA, Steven Ringel of Ohio State, and Jay Sayre of Ohio State.


Lead PI Siddharth Rajan, Ohio State.

Wide bandgap semiconductors are materials, such as Gallium Nitride and Silicon Carbide, that are used extensively in communications, power electronics, and lighting. In this project, the researchers are focusing on a relatively unexplored area: combining chips made from wide bandgap semiconductors with those made from Silicon. Rajan said combining the low cost and dense functionality of Si microchips with the unique capabilities of wide bandgap semiconductors could enable many new possibilities, but the underlying tools for design, fabrication, and packaging are still relatively unexplored.


Steven Ringel, Ohio State.


Jay Sayre, Ohio State.


Subramanian Iyer, UCLA.


Harish Krishnaswamy, Columbia University.

The project funded by NSF is a teaming grant, and will enable the researchers not only to do path-breaking research in this area, but also to seed new collaborations and partnerships beyond this team as they with industry and academic partners to develop the engineering techniques to create such heterogeneously integrated semiconductor ships.

The research will enable innovations in many areas including mixed-signal radio frequency design, power management, extreme environment applications, and optoelectronic circuits.

The project was awarded $300k and up to two years of support by NSF, through its Future of Semiconductors - Teaming for Co-Design Research Capacity program.

IMR assisted in the pre-award process through its proposal development specialist Joanna Gardner and continues to provide project admin support.

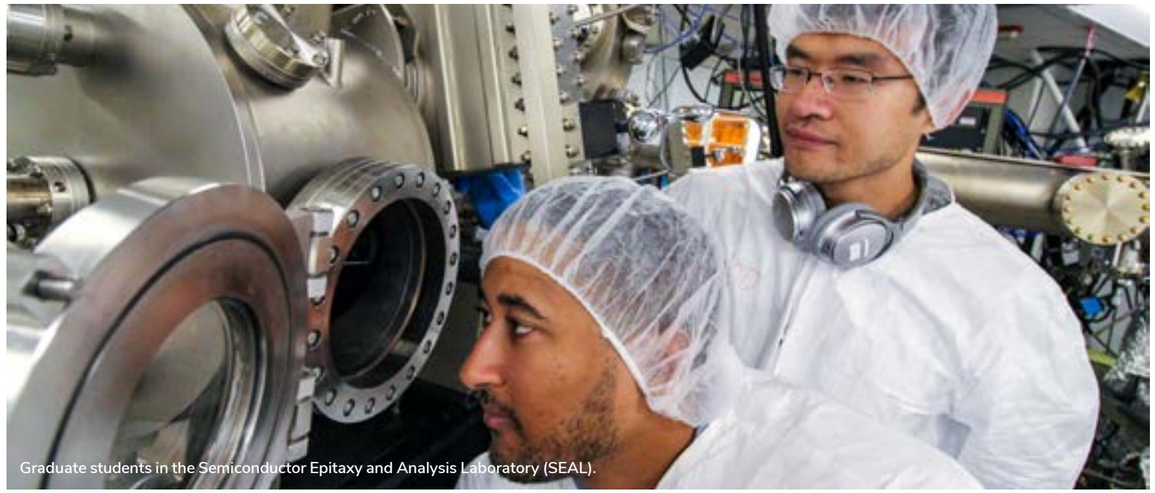
OHIO STATE'S ERIK CREATES MICROELECTRONICS STRATEGY COUNCIL, TAPS PROF. SIDDHARTH RAJAN TO LEAD

Following Intel's arrival in Ohio, IMR faculty member Siddharth Rajan joined the Enterprise for Research, Innovation and Knowledge as a Faculty Fellow and chair of the recently created Microelectronics Strategy Council to the Office of Knowledge Enterprise for a new University Microelectronics Research Initiative. Professor Rajan is assisting the university to harness its expertise and scale in semiconductor-related research and workforce training.

The council includes Guzin Bayraksan, Integrated Systems Engineering; Tyler Grassman, Materials Science and Engineering (MSE) and Electrical and Computer Engineering (ECE); Ezekiel Johnston-Halperin, Physics; Sandip Mazumder, Mechanical and Aerospace Engineering; Tawfiq Musah, ECE; Rajan, ECE and MSE; and Patrick Woodward, Chemistry and Biochemistry.

Highlights

IMR PROPOSAL DEVELOPMENT ENABLES NEW OHIO STATE-LED DEPARTMENT OF DEFENSE RESEARCH PROGRAM FOR NEXT-GENERATION SEMICONDUCTOR DEVICES



Graduate students in the Semiconductor Epitaxy and Analysis Laboratory (SEAL).

Ohio State will lead a multi-institutional, multidisciplinary research team developing next-generation semiconductor devices for wireless communication and radar applications.

The team was awarded a $7.5 million, five-year grant for its role in the newly established Department of Army Ultra-wide Bandgap RF Electronics Center. The Army Research Office (ARO), a directorate of the U.S. Army Combat Capabilities Development Command's Army Research Laboratory (ARL) instituted the center with the goal of increasing the power density of current, state-of-the-art electronic devices that utilize wide bandgap semiconductors.

"The Ultra-wide Bandgap RF Electronics Center will facilitate collaboration between extramural academic researchers and the Army in pursuit of a mutual goal: generating the foundational knowledge needed to enable the next generation of RF electronics with unprecedented power, bandwidth, frequency agility, and size-weight-and-power (SWaP) requirements," said Dr. Joe Qiu at DEVCOM ARL ARO, the lead program manager for this center.

The project will partner Ohio State researchers led by lead principal investigator Siddharth Rajan, a professor in the departments of Electrical and Computer Engineering and Materials Science and Engineering, with experts from the Georgia Institute of Technology, Massachusetts Institute of Technology, Sandia National Laboratories, the State University of New York at Buffalo, the University of Arkansas, and the University of California, Santa Barbara.

IMR provided proposal development support through the expertise of its proposal development specialist, Joanna Gardner.

High frequency transistors are a critical component of the communication systems used in data networks and for military applications such as radar. The highest performance high frequency transistors today are built using wide bandgap semiconductors such as gallium nitride. The key parameter that makes gallium nitride a good material for such high frequency transistors is the electric field strength it can sustain, known as the breakdown electric field.

However, in the pursuit of improved performance at the higher frequencies needed for next-generation communication and radar systems, researchers are now interested in materials called ultra-wide bandgap semiconductors

Graduate students in SEAL.

with even larger breakdown electric field than gallium nitride. In the proposed work, the Ohio State-led team will investigate transistors built using aluminum gallium nitride and will perform interdisciplinary research that spans materials science, electrical engineering, semiconductor fabrication, and semiconductor physics. The center will provide the Army with a new ability to create advanced RF technologies across its modernization priorities for robust multi-domain operations in highly contested electromagnetic environments.

"We are so excited for this opportunity to work on next-generation high-frequency electronics based on ultra-wide bandgap semiconductors that have the potential to surpass the state-of-art," Rajan said.

"But as in any new technology, there are critical challenges that will need innovation, hard work, and skill across many disciplines. This center-level grant has enabled us to bring together a team of outstanding researchers with the experience and skills to address these challenges."

Highlights

DEFENSE MURI PROGRAM FOR QUANTUM MATERIALS RESEARCH LAUNCHES WITH IMR PROPOSAL DEVELOPMENT SUPPORT

Maryam Ghazisaeidi (left), associate professor in Materials Science and Engineering, in Smith Laboratory with doctoral students in her research group.

Supporting the development of major research proposals, projects and infrastructure at Ohio State are among IMR's most important efforts in its mission to continually strengthen the university's materials research community. IMR pursues this goal, in part, through its proposal development program by supporting faculty in the development of competitive proposals, from pre-solicitation to submission.

In FY23, IMR's support helped lead to the U.S. Department of Defense awarding funds to Maryam Ghazisaeidi, associate professor in Materials Science and Engineering, for her work connecting dislocations of mechanical metallurgy to condensed matter physics for quantum applications.

The Department of Defense announced in Spring 2023 the allocation of $220 million to fund basic research through its Multidisciplinary University Research Initiative (MURI) Program.

Among the awarded programs, Ghazisaeidi's multidisciplinary project, titled Dislocations as One Dimensional Quantum Matters, was allocated an estimated $7.5 million over five years.

The MURI project will leverage concepts from mechanical metallurgy, introducing a novel approach to tackle significant hurdles in the realm of quantum computing.

The team includes Materials Science and Engineering professor Roberto Myers and associate professor Tyler Grassman, as well as University of Chicago professors of Molecular Engineering David Awschalom and Giulia Galli.

The team at Ohio State will be assisted by multiple students and postdoctoral researchers.

RESEARCH OUTLINES DATA-DRIVEN SAFETY TESTS FOR LEGGED ROBOTS IN REAL-WORLD ENVIRONMENTS

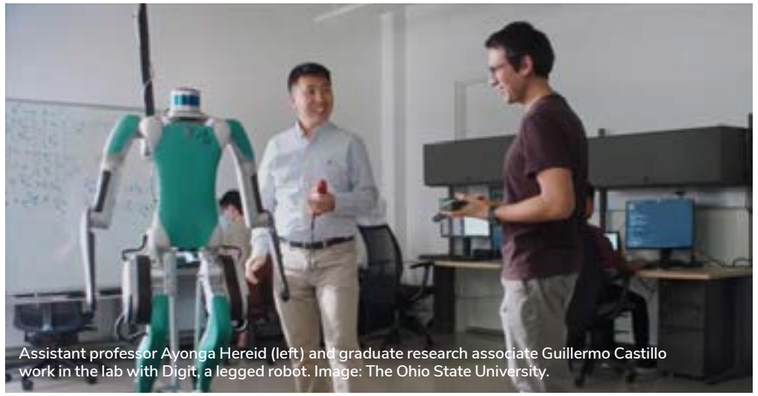
The recent surge in demand for autonomous mobile robots in a myriad of sectors and settings is expected to only increase in the coming years.

Not so fast, say researchers at Ohio State in a 2022 study published in the IEEE/RSJ International Conference on Intelligent Robots and Systems.

"Our work reveals that these robotic systems are complex and, more importantly, anti-intuitive," said Bowen Weng, a doctoral student in Electrical and Computer Engineering. "It means you can't rely on the robot's ability to know how to react in certain situations, so the completeness of the testing becomes even more important."

The study focuses specifically on legged robots and presents a first-of-its-kind, scenario-based framework for testing and characterizing the safety of those types of mobile robots.

The study was co-authored by Ayonga Hereid, an assistant professor in Mechanical and Aerospace Engineering who joined Ohio State in 2019 through the IMR-operated Materials and Manufacturing for Sustainability Discovery Theme. He worked with co-author and doctoral candidate Guillermo Castillo and Wei Zhang of the Southern University of Science and Technology in Shenzhen, China.



Assistant professor Ayonga Hereid (left) and graduate research associate Guillermo Castillo work in the lab with Digit, a legged robot. Image: The Ohio State University.

The team designed multiple scenarios for simulations to better understand the conditions in which the robot would stay upright while navigating a new environment. "We believe this data-driven approach will help create an unbiased, more efficient way to make observations of robots in the conditions of a test environment," he said.

"What we're working towards isn't immediate, but for researchers down the line."

Highlights

ONE YEAR IN, NSF ENGINEERING RESEARCH CENTER HAMMERS HOME COMMITMENT TO REVOLUTIONIZE US MANUFACTURING


Left to right: Professor Glenn Daehn, CDME executive director Nate Ames, College of Engineering dean Ayanna Howard, and associate professor Michael Groeber.

A multi-institutional engineering research center led by Ohio State to develop and deploy revolutionary, intelligent autonomous manufacturing systems, as well as educate and strengthen the future manufacturing workforce of the U.S., completed its successful first year of operations.

The National Science Foundation awarded funding last year for the Hybrid Autonomous Manufacturing, Moving from Evolution to Revolution (HAMMER) Engineering Research Center, for five years at $26 million with the ability to renew for another $26 million for an additional five years. If fully realized, it will be one of the largest research investments in the last decade for Ohio State, which is partnering on the project with Case Western Reserve University, North Carolina Agricultural and Technical State University, Northwestern University and the University of Tennessee, Knoxville, along with dozens of industry, educational and technical organization collaborators.

HAMMER is working with IMR, which was instrumental in developing the proposal development plan through the pre-award process, while working with investigators, the Research Development Office, and Office of Sponsored Programs.

HAMMER has hit the ground running, reaching multiple first-year milestones. The center has already successfully kick-started 10 projects, each maintained with regular meetings and reports. Additionally, several research papers and provisional patents have been accepted or published, underscoring the center's substantial contribution to U.S. manufacturing.

The center has also worked hard to foster a community of innovators, researchers, and industry members through a run of 13 HAMMER-Time meetings and other events. Advisory councils of students, industry experts, and scientists are actively participating, providing valuable guidance for the center's strategic initiatives. Additionally, intellectual property from all five participating universities will be consolidated into an independent non-profit corporation. This will expedite the development and licensing of intellectual property, accelerating the deployment of hybrid autonomous manufacturing technology.

In June, HAMMER furthered its commitment to manufacturing education with its first-ever Materials Camp for Teachers. This innovative program aims to equip educators with the expertise and fresh teaching tactics to inspire tomorrow's trailblazers in advanced manufacturing.

With a full year and their first visit with NSF in Columbus, Ohio, behind them, the HAMMER team is eager and optimistic, as leaders anticipate continued growth, success, and a decade dedicated to revolutionizing manufacturing in the U.S. Visit hammer.osu.edu.

AIM YOUR SMARTPHONE CAMERA AT THE QR CODE TO WATCH THE VIDEO

Highlights

OHIO STATE RECEIVES $3.8M GRANT FROM U.S. DEPARTMENT OF ENERGY TO IMPROVE ELECTRIC VEHICLE BATTERIES

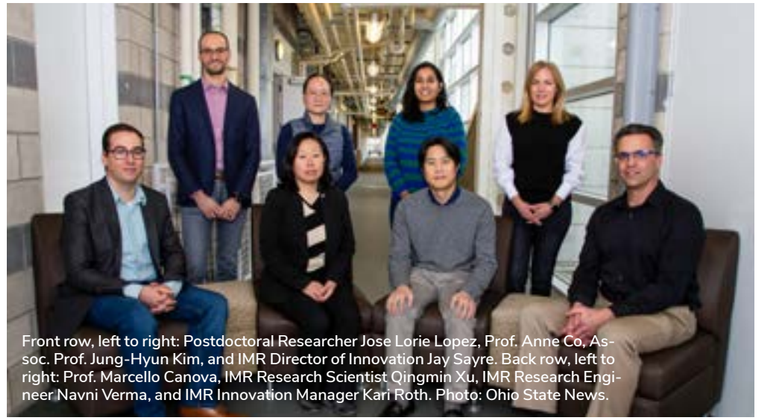
With a long-held focus on enhancing Ohio State's research strengths in electrochemical energy storage, IMR was eager to extend resources and researchers to the new university program Electric Vehicles for American Low-Carbon Living (EVs4ALL).

The team led by Anne Co, professor in Chemistry and Biochemistry, was awarded a $3.8M grant from the Department of Energy's Advanced Research Projects Agency-Energy (ARPA-E) to address barriers to EV adoption by developing next-gen battery technologies.

IMR director of innovation Jay Sayre leads the tech-to-market arm of the team that collaborates with Argonne National Laboratory, Honda, Mechanical and Aerospace Engineering professor Marcello Canova, MAE assistant professor Jung-Hyun Kim, and the Center for Automotive Research.

The goal is to boost EV usage by developing batteries with extended lifespan, shorter charging times, and better cold-weather performance. The team will scale a prototype high-power battery technology by overcoming manufacturing challenges, ensuring compatibility with current battery components, and optimizing battery performance in freezing temperatures.

"The U.S. Department of Energy's grant is an exciting investment in the future of clean energy and a testament to the dedicated Ohio State researchers who are working at the forefront of more affordable, sustainable and accessible transportation," said Melissa Gilliam, the university's executive vice president and provost. "I am delighted to see those efforts recognized with this funding that will accelerate electric vehicle adoption."



Front row, left to right: Postdoctoral Researcher Jose Lorie Lopez, Prof. Anne Co, Assoc. Prof. Jung-Hyun Kim, and IMR Director of Innovation Jay Sayre. Back row, left to right: Prof. Marcello Canova, IMR Research Scientist Qingmin Xu, IMR Research Engineer Navni Verma, and IMR Innovation Manager Kari Roth. Photo: Ohio State News.

DONATED EQUIPMENT FROM NANOBIO SYSTEMS ALLOWS FOR MORE RESEARCH, TRAINING AND EDUCATION IN IMR LABS

Nanotech West Lab's capabilities recently expanded with a donation of equipment from Nanobio Systems, formerly based in northeast Ohio.

In summer 2023, a literal truckload of newly acquired equipment arrived at the West Campus facility. The donation included a wide range of instruments and lab supplies, like microscopes, cameras, sonicators and centrifuges.

The equipment primarily benefits Nanotech West Lab's growing energy-related and medical spaces, with a portion of the supplies being utilized within the Medical Modeling, Materials and Manufacturing Lab's space in Beavis Hall, operated by the College of Medicine and the College of Engineering's Center for Design and Manufacturing Excellence.

The bulk of the equipment that arrived at Nanotech West Lab is being utilized by faculty, staff and students in the Energy Innovation Lab (EIL). This lab focuses on translating electrochemical energy storage and conversion research to meet the needs in the market through strategic, industrial partnerships. The lab also focuses on innovating the materials and systems to develop future energy technologies.

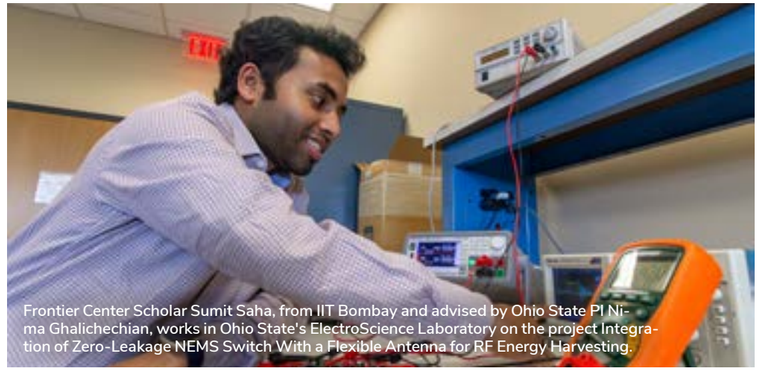
One new piece of equipment now installed in the EIL allows rapid printing of circuit boards and other electronics through screen printing. This equipment introduces new additive manufacturing capabilities to the lab that will produce new electrode designs. These deigns will achieve electrodes with higher densities while requiring less solvent solution which will, in turn, allow for a cleaner, more environmentally friendly printing process.

The widening range of state-of-the-art capabilities in IMR-operated labs increases user accessibility, experiential learning opportunities, and training for students, staff and faculty conducting high-impact research at Ohio State.

Highlights

IIT BOMBAY-OHIO STATE FRONTIER CENTER AWARDS 20TH GLOBAL PROJECT IN ITS THIRD ROUND OF SEED FUNDING

In FY23, the IIT Bombay-Ohio State Frontier Center awarded its 20th collaborative research team through its third round of awards under the Frontier Center Scholars Program.



Frontier Center Scholar Sumit Saha, from IIT Bombay and advised by Ohio State PI Nima Ghalichechian, works in Ohio State's ElectroScience Laboratory on the project Integration of Zero-Leakage NEMS Switch With a Flexible Antenna for RF Energy Harvesting.

The IIT Bombay-Ohio State Frontier Science and Engineering Research Center most recently supported six collaborative research teams.

The Frontier Center is a joint research center operated by IMR at Ohio State and the Indian Institute of Technology Bombay. It builds on both institutions' research strengths in renewable energy, electronics, photonics, semiconductors, materials, and quantum information technology. Teams receiving funding join investigators with complementary expertise from India and the U.S. to enable projects that push the frontier of science and engineering research beyond what could be accomplished by a single institution. Costs are shared by Ohio State and the Indian Institute of Technology Bombay.

Standard projects supported by the Frontier Center Scholars Program are led by a pair of principal investigators, one from Ohio State and another from IIT Bombay, as well as a graduate student who receives support for a semester of research at their partner university. This year, the Frontier Center expanded the scope and impact of this program by supporting four additional projects that included a doctoral students from both institutions.

In FY22, eight research teams were supported through the second round of Frontier Center Scholar Grants. Those teams are now conducting research across a wide range of areas related to AI, infrared detectors, photovoltaics and more.

FRONTIER SCHOLAR RESEARCHES NEW NANOSTRUCTURED STEEL THAT MAY LAY TRACK FOR THE NEXT RAIL REVOLUTION

Through the IIT Bombay-Ohio State Frontier Center, an international, collaborative research team is investigating the efficacy of impact welding of a newly developed, advanced class of steels. This nanostructured bainitic steel could hold the key to increased strength of steels used in U.S. railways.

The Frontier Center, operated by IMR and IIT Bombay, builds on both institutions' research strengths through collaborative research. Frontier Center Scholars are doctoral students who spent about one semester researching at their partnering institutions. Frontier Scholar Bhawesh Chhajed, a doctoral student from the Indian Institute of Technology Bombay (advised by Prof. Aparna Singh), and Ohio State PI Dr. Anupam Vivek and and Prof. Glenn Daehn in Ohio State's Materials Science and Engineering, are performing efficacy and microstructural studies on the steel, while at the Center for Design and Manufacturing Excellence. The researchers are utilizing a solid-state welding technique called impact welding. This approach to welding the high-carbon steel allows it to retain strength and ductility by avoiding large field heating and melting in conventional welding techniques. The process forces metal sheets together at very high velocity. Chhajed said, after a full semester of work, this employment to nanostructured bainitic steels is already showing some promising results. Chhajed's introduction to Ohio State's campus fell on a football Saturday. He knew getting accustomed to life at Ohio State, especially the hype of American football, would not be instantaneous, but it didn't take him long.

"As soon as I got to learn about the culture, as soon as I got to learn about Brutus Buckeye, I started feeling more of a belonging here," he said. "And then Professor Anupam, he introduced me to the Cricket Club as well at OSU. And now I've got the jersey of OSU that says I'm a Buckeye."

Highlights

Professor Glenn Daehn (second from left) and CDME executive director Nate Ames (right) with students in the Center for Design and Manufacturing Excellence.

IMR DIRECTOR OF MANUFACTURING MICHAEL GROEBER ON THE FUTURE OF MANUFACTURING AT OHIO STATE

As manufacturing evolves, Ohio State is at the forefront, pioneering new techniques that combine traditional and advanced manufacturing that can connect domains like robotics, AI, data analytics and more with a ready, well-trained workforce to build more flexible, robust and sustainable manufacturing techniques and solutions that meet the changing demands of today and tomorrow. For Michael Groeber, an associate professor in Integrated Systems Engineering, and Mechanical and Aerospace Engineering, the challenges posed in transforming advanced manufacturing demand collaborations among manufacturing experts and those specializing in a wide range of disciplines that are not immediately correlated with manufacturing. These areas span electrical and computer engineering to computer science to even social sciences, like psychology.

This is where IMR comes in, said Groeber, who also serves as the Faculty Director of the Artificially Intelligent Manufacturing Systems Lab at the College of Engineering's Center for Design and Manufacturing Excellence (CDME), as well as IMR Director of Manufacturing. Manufacturing's future lies in its ability to foster interdisciplinary collaboration and a coordinated vision.

"IMR helps bundle all that together," Groeber said. "There are things happening at a lot of centers and labs across Ohio State, including CDME, Nanotech West Lab, the ElectroScience Laboratory, the Center for Automotive Research and beyond, that can be leveraged across each other. We can continue to increase efficiency and grow new collaborations, and IMR has the ability and reach to do that, unifying these strengths under a single umbrella."

In FY20, IMR created and counseled a task force to unify Ohio State's vision and efforts in manufacturing-related research and development. This undertaking led by Groeber included differentiating the various manufacturing efforts already advancing innovation and education at the university.

With a strong legacy in traditional structural materials manufacturing, within areas related to aerospace and automotive research, and a rapidly expanding leadership in electronic materials and energy storage, all coupled with advanced approaches being developed at CDME, Ohio State is now poised to be at the vanguard of a revolution in manufacturing that leverages interdisciplinary collaboration to redefine the sector's future.

IMR Director of Manufacturing Michael Groeber.

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Highlights

IMR FACULTY MEMBER JOHN HORACK LEADS LAUNCH OF FIRST-EVER SCIENCE PARK DEVOTED TO SPACE RESEARCH

With the final frontier already a targeted investment area for education and discovery, Ohio State now pioneers as host of the first-ever science park devoted to space research.

The George Washington Carver Science Park at Ohio State will be a terrestrial analogue site, housing a replica laboratory of the Starlab space station developed by Nanoracks and associated facilities. There, researchers will be able to test missions and conduct parallel experiments back on Earth.

The park is a collaboration between Voyager Space, Ohio State, the State of Ohio, JobsOhio and One Columbus.

John Horack, Neil Armstrong Chair in Aerospace Policy, is lead researcher for the Starlab collaboration. Horack, who joined the university through the IMR-operated Materials and Manufacturing Discovery Theme and the Sustainability Institute, is also a professor in the Center for Aviation, Mechanical and Aerospace Engineering, and the John Glenn College of Public Affairs.

Cathann Kress, dean of the College of Food, Agricultural, and Environmental Sciences, addresses the grand opening audience. Photo: The Ohio State University.

"By collaborating with Team Ohio, Voyager Space will launch one of the most creative public-private partnerships in one of the most sought-after space destinations on this planet," said John Horack, Neil Armstrong Chair in Aerospace Policy at Ohio State. "We know this facility will transform into a broader commercial space research magnet that serves as the primary North American site for the George Washington Carver Science Park."

And research and learning at the facility will touch far beyond just areas more commonly associated with aviation and aerospace activities. Work at the space park will involve the colleges of Engineering; Food, Agricultural, and Environmental Sciences; Medicine; and Arts and Sciences, along with various university research centers, faculty, staff and students. Along with generating a wide range of positive societal, economic, and educational impact, lab research is anticipated to benefit the Ohio agriculture sector in particular, with research benefits to the community expected to include the preservation of Ohio water quality, improvements to crop genetics, increased production efficiency, and enhanced animal health.

"Agriculture and aerospace continue to be huge growth industries, and the past decade has seen unprecedented investment and accelerated investment in aerospace into the market of commercial space flight," Horack said. "This has opened, and I think it's opened in a figurative and literal sense, an entirely new frontier for exploration, research, education and fulfillment of key national objectives."

The facility's temporary home is currently the Agricultural Engineering Building, with construction planned for a stand-alone facility on the Aerospace and Air Transportation Campus.

Starlab, the Voyager Space commercial space station. Image: Nanoracks.

Seed Grant Awards

IMR PROVIDES SEED FUNDING FOR 25 NEW PROJECTS IN FY23

Twenty-five new projects led or co-led by researchers at Ohio State received seed funding support in FY23 through IMR grant programs and the OSU Materials Research Seed Grant Program (MRSGP), which is co-funded and co-managed by IMR. IMR's Global Partnership Grants supported six international research teams through the IIT Bombay-Ohio State Frontier Center Scholars Program and Catalyst Program shared with Tyndall National Institute. Additionally, IMR awarded nine teams through its Kickstart Facility Grant Program. Lastly, eight MRSGP awards were supported by IMR, the Center for Emergent Materials, and the Center for Exploration of Novel Complex Materials.

GLOBAL PARTNERSHIP GRANTS

Global Partnership Grants (GPGs) establish global impact in research and development, technology innovation and shared multinational education. Eight Global Partnership Grants were awarded in FY23.

Frontier Center Scholars Program

Developing Structure-Property Linkages for Electron Beam Melted Ti-6Al-4V – PIs: Alankar Alankar (Mechanical Engineering, IIT Bombay) and Stephen Niezgoda (Materials Science and Engineering, Ohio State) Frontier Center Scholar: Aayush Trivedi (IIT Bombay)

Development of a Compact Magnetocardiography Sensor – PIs: Rajesh Zele (Electrical Engineering, IIT Bombay) and Asimina Kiourti (Electrical and Computer Engineering, Ohio State) Frontier Center Scholar: Shubham Jain (IIT Bombay)

Fundamental Transport Studies of Impact Ionization Process in Antimonide Avalanche Photodiodes – PIs: Bhaskaran Muralidharan (Electrical Engineering, IIT Bombay) and Sanjay Krishna (Electrical and Computer Engineering, Ohio State) Frontier Center Scholar: Anuja Singh (IIT Bombay) and Nathan Gajowski (Ohio State)

Micro and Macro Characterization of Nano-composite Materials for Biomedical Applications – PIs: Sunita Srivastava (Physics, IIT Bombay) and Gunjan Agarwal (Mechanical and Aerospace Engineering, Ohio State) Frontier Center Scholar: TBA (IIT Bombay) and Aratrika Pan (Ohio State)

Rapid 3D Printing of Geometric Features for EV Battery Enclosures – Principal investigators (PIs): Amitava De (Mechanical Engineering, IIT Bombay) and Wei Zhang (Materials Science and Engineering, Ohio State) Frontier Center Scholar: Diljith P K (IIT Bombay) and Aryan (Ohio State)

SiC-based On-board Charger with Smart Gate Driver for Electric Vehicle Application – PIs: Sandeep Anand (Electrical Engineering, IIT Bombay) and Anant Agarwal (Electrical and Computer Engineering, Ohio State) Frontier Center Scholar: Aditya Aman (IIT Bombay) and TBA (Ohio State)

Tyndall-OSU/IMR Catalyst Program

Heterogeneous integration of micro-LEDs and GaN HEMTs for highspeed visible light communications
PIs: Siddharth Rajan (Electrical and Computer Engineering, Ohio State) and Muhammet Genc (Tyndall National Institute)

Metal-chalcogenide Surface Passivation For AlGaInP Optoelectronic Devices
PIs: Tyler Grassman (Materials Science and Engineering, and Electrical and Computer Engineering, Ohio State) and Paul Hurley (Tyndall National Institute)

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. Nine Kickstart Facility Grants were awarded in FY23.

Engineered extracellular vesicles for targeted therapeutic applications in chronic lung diseases
PI: Ana Isabel Salazar-Puerta, Department of Biomedical Engineering

Robotic Painting for Environmental Performance
PI: Ashley Bigham, Department of Architecture

Effect of the Additive Manufacturing Process on the Phase Content and Precipitation of Nitrides in Duplex Stainless Steels
PI: Boian Alexandrov, Department of Materials Science and Engineering

Seed Grant Awards

Tissue-embedded microfluidic device for studies of glomerular filtration barrier
PI: Dan Wang, Departments of Internal Medicine and Nephrology

Characterizing majority and minority carrier emission in N and Mg ion implanted β-Ga2O3 using double beam DLOS spectroscopy
PI: Hemant Ghadi, Department of Electrical and Computer Engineering

Metal Contact Interface Interactions for Organic Metal Halide Gamma Ray Detectors for High Electric Potential Applications
PI: Praneeth Kandlakunta, Department of Mechanical and Aerospace Engineering

Cathodoluminescence studies of N-Polar InGaN/GaN Nanowires
PI: Shamsul Arafin, Department of Electrical and Computer Engineering

Functional study of the leaf surface features modified by beneficial bacteria in priming plant drought tolerance
PI: Wenshan Liu, Department of Plant Pathology

Partial polymerase chainless reaction (P2CR)
PI: Wolfgang Pfeifer, Department of Mechanical and Aerospace Engineering

OSU MATERIALS RESEARCH SEED GRANT PROGRAM

Exploratory Materials Research Grants

Exploratory Materials Research Grants enable nascent and innovative materials research to advance to the point of being competitive for external funding. Four Exploratory Materials Research Grants were awarded in FY23.

Site-Controlled InGaN/GaN Quantum Dots in GaN Nanowires for Single Photo Emission
PI: Shamsul Arafin, Department of Electrical and Computer Engineering

Epitaxial Strain Control of Ferroelectricity for Advanced Microelectronics
PI: Kaveh Ahad, Department of Materials Science and Engineering and Electric and Computer Engineering

Polar Instabilities in Locally Polar Superconductors
PI: Salva Salmani-Rezaie, Department of Materials Science and Engineering

Design & Synthesis of FunctionalCovalent Organic Frameworks for the Photocatalytic Reduction of Carbon Dioxide to Chemical Fuels & Feedstocks
PI: Psaras McGrier, Department of Chemistry and Biochemistry

Multidisciplinary Team Building Grants

Exploratory Materials Research Grants fund multidisciplinary materials research teams that can later compete effectively for federal block-funding opportunities. Two Multidisciplinary Team Building Grants were awarded in FY23.

Polymer-Based Enzymatic Nanomaterials
PI: David Wood, Department of Chemical and Biomolecular Engineering
Co-PI: Davita Watkins, Department of Chemistry and Biochemistry

Signal Transducing Nanodevice Assemblies for Triggered Materials Self-assembly
PI: Carlos Castro, Department of Mechanical and Aerospace Engineering
Co-PI: Michael Poirier, Department of Physics

Proto-IRG Grants

Proto-IRG Grants fund multidisciplinary materials research teams that can compete effectively for federal block-funding opportunities, such as the NSF MRSEC program. Two Proto-IRG Grants were awarded in FY23.

Topological States Beyond Crystaline Materials
PI: Jinwoo Hwang, Department of Material Science and Engineering
Co-PI: Yuan-Ming, Department of Physics
Co-PI: Jyoti Katoch, Department of Physics

Department of Physics In situ Control of Band Gaps & Intersubband Transition of 2D Semiconductors
PI: Jeanie Lau, Department of Physics
Co-PI: Roberto Myers, Department of Material Sciences and Engineering
Co-PI: Wolfgang Windl, Department of Material Sciences and Engineering

Experiential Learning for Students

IMR INTERNSHIP PROGRAM EXTENDS HANDS-ON LEARNING OPPORTUNITIES TO STUDENTS OUTSIDE OHIO STATE

Eleven undergraduate students in FY23 took advantage of experiential learning opportunities through the IMR Internship Program. The program offers paid, learning-by-doing positions in a range of spaces at Ohio State's Nanotech West Lab

Three students from Columbus State Community College joined the team at Nanotech West Lab at Ohio State this semester through an internship program run by IMR.

IMR's internship program creates multiple avenues to experiential learning opportunities for students, including research experience for undergraduate students, graduate research associateships, and externships.

Each paid position engages students enrolled and external to Ohio State with hands-on experience and education related to their fields of study or career goals. Undergraduate student interns at Nanotech West Lab, located on West Campus, generally come from a range of studies spanning engineering to business and the arts.

Columbus State Electro-mechanical Engineering majors Zachary Reese and Christopher Staudt are spending their Spring 2023 internship supporting laboratory operations related to semiconductor device fabrication in Nanotech West's Nanofabrication Lab.

Under the direction of Aimee Price, the facility's manager of nanofabrication, the two students are learning through hands-on experiences in process development for semiconductor and microelectronic device fabrication, equipment process qualifications, and basic equipment and facility maintenance — all while working shoulder to shoulder with experienced engineers in a 6,000-square-foot, class 100 cleanroom.

Students from Columbus State Community College interested in internship opportunities attend an open house at the IMR Innovation Lab.

Undergraduate students in the Nanofabrication Lab at Nanotech West Lab during a tour and info session, as part of the Ohio 5-OSU SURE program through CAFE.

But the experiential learning opportunities at Nanotech West don't end in the labs. IMR also offers business- and administrative-focused experience in the fast-paced offices that keep the largest nanotechnology user facility in the state running smoothly.

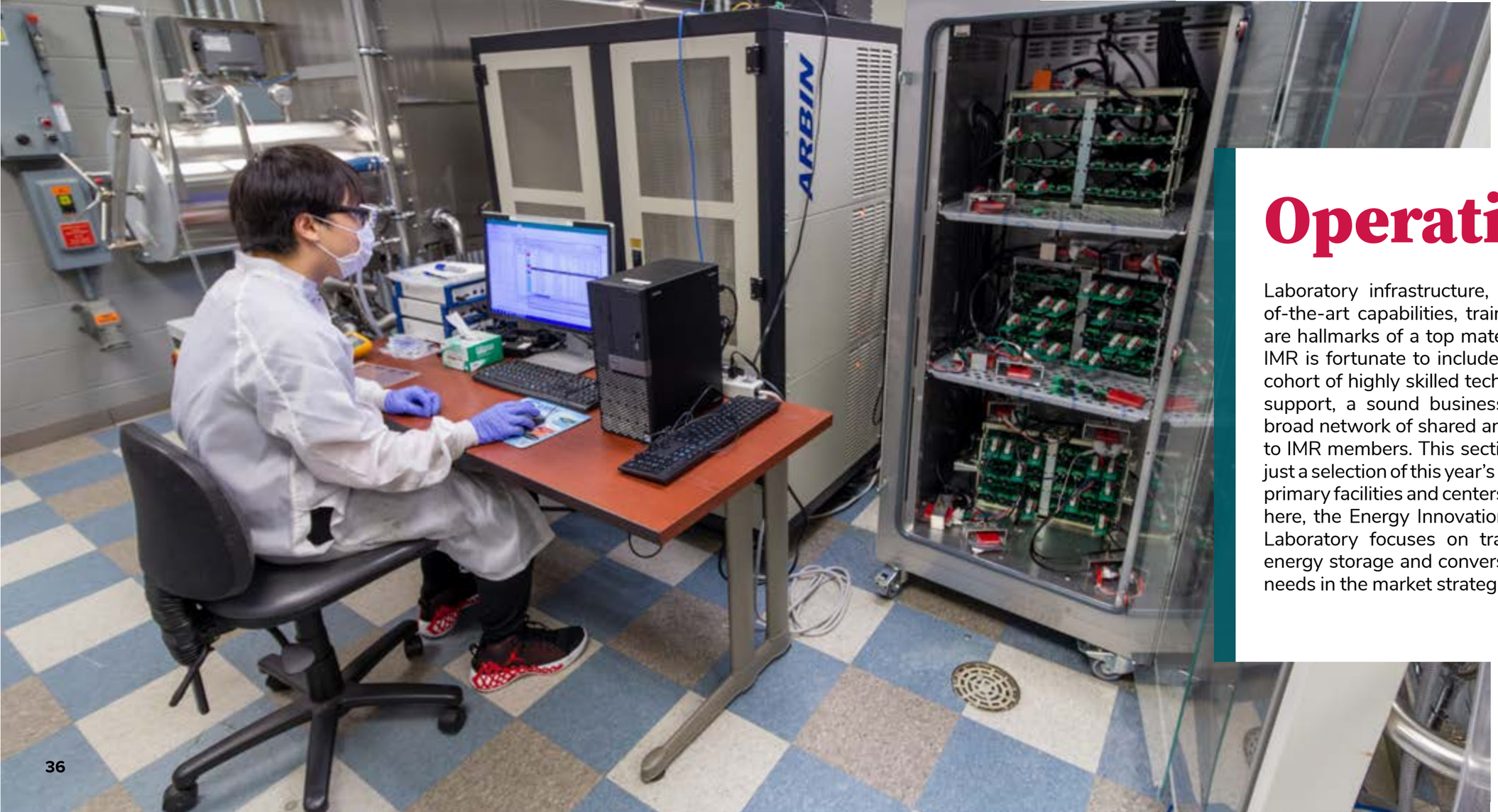
In one such office, Columbus State student Alison Falcon Reyes, a Business Administration major, sits front and center. As IMR's new front desk administrative intern, Reyes is responsible for customer service, purchasing and financial requests, and data entry.

IMR's most recent search for talented Columbus State students interested in these real-world, learning-by-doing opportunities at Ohio State kicked off late last year with information sessions and tours of Nanotech West Lab.

More than 40 Columbus State students, including the three soon-to-be hired interns, registered to visit Nanotech West Lab, met experienced business professionals and engineering experts, and toured facilities focusing on materials synthesis and semiconductor device fabrication, medical-related modeling and manufacturing, and energy storage and conversion research.

IMR program assistant Laurie Coyne managed the student info sessions, as well as the onboarding process for those joining the team.

"Some of the most innovative ideas come from our student interns; they offer a fresh perspective and enthusiasm," Coyne said. "As a Columbus State alumna, I'm aware of the great instructional programs the college offers, and it has been a pleasure collaborating with them to provide opportunities for students through experiential learning and the IMR internship program."



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 and centers. One such facility, shown here, the Energy Innovation Lab at Nanotech West Laboratory focuses on translating electrochemical energy storage and conversion research to meet the needs in the market strategic, industrial partnerships.

Nanotech West Laboratory

Nanotech West Laboratory is a 36,000-square-foot shared user facility servicing the Ohio State materials community and is open to both academic and industrial researchers. Managed by the Institute for Materials and Manufacturing Research (IMR), Nanotech West Lab is an extensively equipped and fully staffed facility where researchers can access laboratories and equipment, as well as take advantage of in-house training, process and project support. Nanotech West Lab's user-accessible facility resources include a 6,000-square-foot Class 100 cleanroom, major shared facilities for semiconductor and oxide epitaxy, materials and device characterization, 3D printing for clinical applications and shared labs for research in energy storage materials and devices. With more than 320 active users and 75 new users trained in FY23, research activities at Nanotech West Lab span a range of cutting-edge materials research that is rather extraordinary for a single facility – including GaN/AlGaN and β-Ga_2O_3 materials and devices, solar cells and infrared focal plane arrays to microfluidics, biotechnology, 3D printing of anatomic models, material synthesis and testing for energy storage and the fabrication of structures for use in the study of basic physics and chemistry. As IMR's primary laboratory facility, Nanotech West Lab is located on Ohio State's West Campus and provides substantial impact and continues to be a centerpiece of collaborative research to the university's materials research community. Driven by the IMR-operated Materials and Manufacturing for Sustainability Discovery Theme, starting in 2015, and its strategic faculty recruitment, Nanotech West Lab continues to expand its impact by continually installing new equipment and lab enhancements to support cutting-edge capabilities and additional research thrusts. Developing labs that continue to expand capabilities offered within the user facility include the IMR Innovation Lab (dedicated to collaborative industry interactions and outreach), the Opto-electronic Metrology Lab (providing metrology and enabling infrared pixel and array characterization), the Energy Innovation Lab (dedicated to battery related materials synthesis and test) and the Metal Organic Chemical Vapor Deposition Lab (providing semiconductor and oxide epitaxy). Learn more by visiting nanotech.osu.edu.

ENERGY INNOVATION LAB

The Energy Innovation Lab (EIL) is focused on translating electrochemical energy storage and conversion research to meet the needs in the market through strategic, industrial partnerships. The extent of the lab's technology development spans from materials to systems and advanced manufacturing. Innovations in energy storage and conversion systems require integrating diverse knowledge from multidisciplinary teams. Through EIL, faculty, staff and students who share this vision are dedicated to defining current issues on electrochemical energy storage and conversion devices, as well as innovating the materials and systems to develop future energy technologies. In electrochemical energy storage and conversion, we synthesize and characterize materials for batteries and fuel cells, study interfaces, conduct postmortem analysis, develop advanced processing and manufacturing techniques, and create new structures. This laboratory ecosystem serves as IMR's core energy multi-user facility and R&D center that are open to internal and external users on a fee basis to support research, development, and education. It is also supported by the IMR Innovation Lab, which manages strategic, industrial relationships to advance technology development, demonstration and deployment. EIL is equipped with multiple systems enabling battery testing and analysis, as well as mixers for electrode materials preparation and a lab scale roll-to-roll coater for electrode fabrication. EIL is enabling multiple projects that resulted from a jointly held research strategy recently established by IMR and Honda. The space is also home to faculty member Jung-Hyun Kim, an assistant professor in Mechanical and Aerospace Engineering who was hired through the IMR-operated Materials and Manufacturing for Sustainability Discovery Theme. EIL also hosted multiple workforce training activities for industry users.

MEDICAL MODELING, MATERIALS AND MANUFACTURING (M4) LAB

The Medical Modeling, Materials and Manufacturing (M4) Division is where medicine, advanced manufacturing, and materials-related development converge to pursue innovative approaches to advance the health and well-being in our society, while being an experiential education platform for undergraduate research assistants, postdoctoral researchers, medical students, and residents. The M4 Division supports the life-saving efforts of medical professionals and faculty at Ohio State by stimulating and centralizing research innovation around biomedical engineering, medical device development, and clinical 3D printing. The M4 Division expanded its interdisciplinary team of clinicians, engineers, and a quality system manager, all working across campus in four facilities: Pelotonia Research Center (PRC), Nanotech West Lab (NTW), the James Cancer Center, and the Manufacturing Innovation Learning Laboratory (MILL) within the Center for Design and Manufacturing Excellence. The PRC and NTW sites host printers for patient-specific clinical products and device prototyping, while the James location is a consultation and demonstration space for clinicians to discuss their clinical printing and medical device needs with the M4 Division team. The MILL houses polymer and metal 3D printers, along with traditional machine shop fabrication equipment to support medical device prototyping. In the past year, M4 moved into the Pelotonia Research Center to a brand-new lab for a centralized location for printers and engineers to work together. The M4 continues to grow its collaborations across the medical, dental, nursing and engineering disciplines to create innovative health care solutions with clinicians and faculty in a myriad of medical and engineering fields.

METAL-ORGANIC CHEMICAL VAPOR DEPOSITION (MOCVD) LAB

The Metal-organic Chemical Vapor Deposition (MOCVD) Lab houses three MOCVD tools for epitaxial growth of compound semiconductors, one for III-V materials like GaAs, one for nitride-based materials like GaN, and another for oxide-based materials like Ga_2O_3. Novel materials, structures and devices developed from the state-of-the-art MOCVD growth techniques cover a wide range of key applications in photovoltaics, photodetectors, light emitters and high power/high frequency electronics. The unique dual chamber nitride MOCVD system is featured with two chambers that allow the growth of (i) III-nitrides (Al-, Ga-, In-, N), their alloys and heterostructures; and (ii) novel materials/structures based on II-IV-nitrides [e.g., $Zn(Mg)Ge(Si, Sn)N_2$]. The system is also coupled with a high-power CO_2 laser source. Funded by DOE ARPA-E and ONR projects, Prof. Hongping Zhao has successfully developed high-quality GaN thick drift layer epitaxy and high-power GaN PN diodes with record breakdown voltage of 7.8 kV. The newest oxide MOCVD tool has successfully developed the state-of-the-art Ga_2O_3, an emerging ultrawide bandgap semiconductor for next-generation power electronics. This tool supports research projects funded by the Department of Defense Multidisciplinary University Research Initiative (MURI) program, National Science Foundation, Semiconductor Research Corporation, among others.

NANOFABRICATION LAB

The Nanofabrication Lab (Nanofab) within Nanotech West is Ohio's premier, and largest state-of-the-art and openly accessible class 100 cleanroom, which houses full process flow capabilities supporting micro-and nano-fabrication of semiconductor devices. With 10 staff members, plus graduate student super-users and undergraduates, the Nanofab supports researchers from Ohio State and many external organizations. In Spring Semester 2023, and under the leadership of Laurie Coyne, IMR/NTW Program Assistant, Nanofab partnered with the Experiential Learning Team within Career Services at Columbus State Community College. The Nanofab welcomed two engineering interns, Chris Staudt and Zach Reese both majoring in Electro-Mechanical Engineering. Chris and Zach have become valuable members of the Nanofab technical staff performing routine maintenance, tool monitoring, process baseline measurements and process monitoring in the lithography (Chris) and plasma etch/deposition (Zach) areas. Substantial investment in FY22, '23, and '24 in plasma etch capabilities in the Nanofab will enhance material flexibility, improve ease of use, and add reliability/serviceability to the NTW ICP-RIE etchers. A Cortex software/hardware upgrade to the existing III-V Plasmatherm ICP-RIE 770 was completed in July '23, and installation of a new PlasmaTherm Takachi ICP-RIE is scheduled for later that year. Together, these enhancements to the plasma etch suite will benefit researchers working on novel and hard to etch materials, many of which could not previously be fully processed at NTW. In addition to the etch tool improvements, a new state-of-the-art Raith/Leica EBPG 5150 electron beam lithography system will be installed in September '23, funded by Major Research Instrumentation (MRI) award by the National Science Foundation. Additionally, installation of a new Unitemp RTP-100 rapid thermal anneal system in late '23 will add thermal processing capacity and extended high temperature steady state anneal capability. These additions, along with the Heidelberg MLA150 in FY20/21, significantly improve the fabrication capabilities and broaden the impact of the NTW Nanofab for researchers both within Ohio State and regionally.

OPTO-ELECTRONIC METROLOGY (OEM) LAB

The Opto-electronic Metrology (OEM) Lab at Nanotech West (NTW) continues to provide critical test and packaging capabilities that cover the full semiconductor device fabrication and test cycle. Material growth experts and battery researchers utilize the Bruker D8 XRD, Bruker Icon 3 AFM, and Hitachi S-3000H SEM for material growth analysis. A suite of optical and electrical test equipment including a Lakeshore Cryogenic Probe Station and an 8D Photoluminescence and Lifetime Mapping System offer flexible device characterization covering the optical and infrared spectrums. Researchers producing prototype electronics utilize the K&S and West-Bond Wire Bonders to perform device packaging for testing exposure in real-world environments. Recently, students from Sanjay Krishna's research group expanded the infrared (IR) test capabilities in the lab to perform targeted quantum efficiency measurements on high voltage IR avalanche photodiodes (APDs). This previously missing piece of information provided important insight into the behavior of these novel devices. The flexible optical test setup available in the OEM lab was also leveraged by a group from the ElectroScience Lab to test a new class of liquid crystal on silicon (LCoS) device promising efficient light modulation for communication and display applications.

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 more than 70 faculty, research staff and grad students, and 336 undergraduates, from 43 departments and six colleges, to companies that range from start-ups to Fortune 500s. This has led to the creation of more than 200 externships and internships, and more than a dozen sponsored projects. The lab is also enabling the transition of technologies to commercialization with our faculty, staff and students. Thanks to the Innovation Lab, there are now more than 75 companies engaged in multiple ways that will enable long-term, mutually beneficial relationships with students, faculty and external partners. IMR operates the Innovation Lab as the place where Ohio State guests and industry visitors can engage each other, as well as students and faculty. It is home to a number of IMR events, including INNOVATE-O-thon and other collaborative programs involving faculty, staff and industry partners. It is where students wanting real-world, experiential learning connect with companies wanting better access to the university and undergraduates through externship opportunities. Learn more at imr.osu.edu/innovation-lab.

Center for Advanced Semiconductor Fabrication Research and Education

The Center for Advanced Semiconductor Fabrication Research and Education (CAFE) is a multi-institutional, interdisciplinary education and research center to advance the fabrication and development of semiconductors and next-generation device technologies. CAFE is supported by the Intel Corporation via its Semiconductor Education and Research Program for Ohio. The new center will lay the foundation for a sustained, highly skilled and diverse semiconductor manufacturing workforce by developing comprehensive experiential learning frameworks for both graduate and undergraduate students, all while paving the way for leading-edge device technologies through state-of-the-art research. CAFE is operated at Ohio State IMR, with IMR executive director Steven Ringel, professor in Ohio State's Department of Electrical and Computer Engineering and associate vice president for research, as lead principal investigator. CAFE partners Ohio State with nine other institutions in the state, including Ohio University, the University of Cincinnati, Central State University and Wilberforce University, as well as the education consortium Five Colleges of Ohio, Inc., composed of Denison University, Kenyon College, Oberlin College, Ohio Wesleyan University and the College of Wooster.

IN FY23, CAFE ENABLED EXPERIENTIAL LEARNING OPPORTUNITIES TO 21 STUDENTS AT NANOTECH WEST LAB

Through CAFE, undergraduate and graduate students, from Ohio State, the University of Cincinnati and Ohio University work in Ohio State labs on a myriad of cutting-edge projects related to semiconductor fabrication and manufacturing. Learn more on page 10.

Center for Design and Manufacturing Excellence

Ohio State's Center for Design and Manufacturing Excellence works with companies and researchers to translate new technologies into market-ready products. These industry-driven projects give student employees real, hands-on experience integrating new technology while providing customers the workforce advantage necessary to compete in the global marketplace. CDME boasts partnerships with more than 150 companies, has completed over 700 projects, and has been awarded over $135 million in applied research. CDME operates manufacturing research facilities in five buildings across Ohio State's campus, which is home to more than $15 million in industrial-scale equipment. CDME's areas of emphasis cover a wide range of manufacturing sectors, including robotics, machine learning, additive manufacturing, metal casting, biomedical devices, medical modeling, cybersecurity and defense systems. The center employs over 2 dozen full-time technical staff members and supports over 120 affiliated faculty members. These professionals execute projects while mentoring and advising CDME student employees. More than 300 undergraduate students across academic disciplines have been impacted by CDME to date, with 134 students employed by the center in FY23. CDME strives to execute its innovative approach to technology translation and workforce development while shaping the national conversation on advanced manufacturing innovation.

RESEARCH REVIEW: ADVANCED CASTING RESEARCH FINDS HOME AT CDME

The first affiliated site of the Advanced Casting Research Center (ACRC) was established at Ohio State in FY23, with IMR-affiliated faculty Alan Luo serving as Site Director. ACRC, headquartered at UC Irvine, is a large industry-university consortium dedicated to collaborative research in metal casting and digital manufacturing. Of note, ACRC sponsors research on metal casting process development, alloys design, material recovery and recycling, and digitization. ACRC helps bring a fundamental understanding to existing processes, while also developing new methods, alloys, and computational tools. Jason Walker, PhD, CDME's Materials and Process Director, is an ACRC-affiliated faculty and an expert in metal casting and advanced manufacturing. CDME has a world-class academic foundry for metal casting, where ACRC's research takes place at Ohio State. The Ohio State foundry program was recertified by the Foundry Educational Foundation in 2022.

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. With one of the largest concentrations of electron and ion beam analytical microscopy instruments in any North American institution, CEMAS brings together multidisciplinary expertise to drive synergy, amplify characterization capabilities and challenge what is possible in analytical electron microscopy. The center provides a world-class environment for the teaching and practice of advanced microscopy across all scientific disciplines, from biomaterials to nanoelectronics, energy materials, advanced structural materials and medicine. CEMAS' facility offers a full-service, expertly designed environment for researchers executing entire microscopy and analysis programs.

CEMAS was partly funded by IMR's ORSP award – Technology Enabling and Emergent Materials, which also provided the position of center director, filled by IMR associate director David McComb. Capabilities include scanning electron microscopy (SEM), focused ion beam microscopy, transmission electron microscopy (TEM), X-ray diffraction, micro-computed tomography and cryo-electron microscopy (cryo-EM). Highlights of CEMAS' $40M equipment portfolio include the Thermo Scientific Themis Z S/ TEM and Thermo Scientific Glacios Cryo-TEM. The center enabled $185M+ in research during FY22 and has supported 1.106 users, including 205 principal investigators, since opening its doors in 2013. Learn more at cemas.osu.edu.

RESEARCH REVIEW: CEMAS PARTNERS WITH NASA TO DEVELOP REVOLUTIONARY ALLOY

Researchers at CEMAS collaborated with NASA Glenn Research Center to develop a new 3D printable alloy that can result in stronger, more durable parts for airplanes and spacecraft. The revolutionary work introduces a 3D printable alloy, called GRX-810, that can withstand harsher conditions and higher temperatures than earlier alloys. The breakthrough was detailed in the journal Nature. GRX-810 is a multi-principal element alloy, meaning that multiple elements have been combined in similar amounts to form the base of the alloy. Current state-of-art 3D-printed alloys can withstand temperatures up to 2,000 degrees Fahrenheit, but GRX-810 is twice as strong, twice as resistant to oxidation and over 1,000 times more durable at that temperature. GRX-810 can be used to build aerospace parts for high-temperature environments, like those inside aircraft and rocket engines. GRX-810's higher temperature resistance and increased durability can also translate into reduced fuel burn and lower operating and maintenance costs.

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 Semiconductors & Microelectronics, Power & Energy Technologies, and Advanced Energy Materials & Devices. The center is also a catalyst to develop and advance collaborative industry- and government-funded projects. The center facilitates faculty collaborations, hosts workshops and webinars, and provides seed funding to new research endeavors. The leadership team includes Ohio State professors Ardeshir Contractor and Anant Agarwal, and IIT Bombay professors Saurabh Lodha and Raghavan Sunoj. Learn more at imr.osu.edu/frontier-center.

RESEARCH REVIEW: FRONTIER CENTER TEAM STUDIES IMPACT WELDING OF NEW NANOSTRUCTURED STEEL

Through the IIT Bombay-Ohio State Frontier Center, an international, collaborative research team is investigating the efficacy of impact welding of a newly developed, advanced class of steels. This nanostructured bainitic steel could hold the key to increased strength of steels used in U.S. railways. Learn more on page 25.

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 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. SEAL is proficient in providing quick solutions to cutting edge research ideas. Recently, SEAL provided scandium epitaxy capabilities to our N_2MBE reactor for ferroelectric device research. SEAL also added antimony material to arsenide – phosphide MBE allowing future exploration into low bandgap infrared materials combinations. SEAL is managed by IMR and operates under the guidance of the Department of Electrical and Computer Engineering and College of Engineering.
Learn more at seal.osu.edu.

RESEARCH REVIEW: GROWTH OF β-GA_2O_3 BY MOLECULAR BEAM EPITAXY FOR HIGH-POWER ELECTRONICS

Leading research by students in Prof. Siddharth Rajan's and Prof. Steven Ringel's groups are using SEAL's Oxide MBE system to engineer beta-phase Ga_2O_3 epitaxial structures for high power electronics applications. Recent work focuses on the developing Mg delta-doping to create insulating epitaxial buffers for lateral devices that successfully mitigated problematic buffer leakage currents that have plagued β-Ga_2O_3 metal-semiconductor field effect transistors to date (A.V. Dheenan et al., Appl. Phys. Lett. 121, 113503 (2022)). Prof. Rajan's students have used the same MBE system to integrate high quality Al_2O_3 dielectric layers within β-Ga_2O_3 devices (S. Dhara, A. Dheenan et. al., Appl. Phys. Lett. 123, 083504 (2023)). Oxygen plasma-assisted deposition of Al_2O_3 layers on (001) β-Ga_2O_3 drift layers revealed outstanding properties in terms of oxide breakdown field, breakdown field in the Ga_2O_3 at reverse bias, and trap concentrations. The optimized Al_2O_3 layers were integrated into trench diodes formed using the atomic Ga flux etching method developed at Ohio State and show breakdown voltage greater than 1.4 kV and a breakdown field of 5.1 MV/cm in the Ga_2O_3 (S. Dhara, N.K. Kalarickal, A. Dheenan et al., Appl. Phys. Lett. 123, 023503 (2023)).

Nanosystems Laboratory

NanoSystems Laboratory (NSL) provides a broad base of academic and industrial users with access to advanced material characterization and fabrication tools for research and development applications. NSL operates a diverse set of research instrumentation, such as (1) fabrication tools: FIB/SEM/e-beam lithography, Physical Vapor Deposition, Ar ion milling and ICP/RIE etching, maskless photolithography, and diamond CVD growth; and (2) characterization tools: X-ray diffractometry, SQUID magnetometry, PPMS, AFM/MFM, EPR/FMR spectroscopy, and Kerr microscopy. NSL operates two 1,100-square-foot clean rooms, housing deposition, lithography, etching, and gloveboxes. Visit nsl.osu.edu.

RESEARCH REVIEW: EVIDENCE FOR DIRAC FLAT BAND SUPERCONDUCTIVITY ENABLED BY QUANTUM GEOMETRY

The research groups of ChunNing Jeanie Lau (Physics, Ohio State) and Marc Bockrath (Physics, Ohio State) in collaboration with the groups of Mohit Randeria (Physics, Ohio State), Fan Zhang (University of Texas at Dallas) and the scientists from the National Institute for Materials Science, Tsukuba, Japan conducted electrical transport measurements on twisted bilayer graphene devices. The results demonstrated an extremely slow normal state charge carrier drift velocity of about 1,000 m/s for filling fraction between -1/2 and -3/4 of the moiré superlattice. In the superconducting state, the same velocity limit constitutes a new limiting mechanism for the critical current, analogous to a relativistic superfluid. Importantly, the conducted measurement of superfluid stiffness, which controls the superconductor's electrodynamic response, showed that it is not dominated by the kinetic energy but instead by the interaction-driven superconducting gap, consistent with recent theories on a quantum geometric contribution. The authors found evidence for small Cooper pairs, characteristic of the Bardeen-Cooper-Schrieffer to Bose-Einstein condensation crossover, with an unprecedented ratio of the superconducting transition temperature to the Fermi temperature exceeding unity. In the following publication the authors discuss how this arises for ultra-strong coupling superconductivity in ultra-flat Dirac bands. The research was supported in part by the US Department of Energy, the US National Science Foundation, and the US Army Research Office. The results and discussions are presented in the publication: H. Tian, X. Gao, Y. Zhang, S. Che, T. Xu, P. Cheung, K. Watanabe, T. Taniguchi, M. Randeria, F. Zhang, C.-N. Lau & M. W. Bockrath, "Evidence for Dirac flat band superconductivity enabled by quantum geometry." Nature, 614, (2023).

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 and supports several outreach and engagement events each year that promote Ohio State's presence in strategic areas of interest. FY23 saw the post-pandemic return of IMR's annual event, now called the Ohio State Materials & Manufacturing Conference, and two events in the Distinguished Leacture Series, as well as several other events suported by IMR. Also in this section, several new staff members are introduced. You will also find the rest of the IMR team, a rundown of affiliated centers and core laboratories, and a roster of IMR's 228 faculty members.

New Staff

IMR WELCOMES THREE RESEARCHERS TO NANOTECH WEST LAB

Navni Verma steps into new position as IMR research associate focusing on electrochemical energy storage and conversion materials, components and devices in batteries and fuel cells

IMR welcomed Navni Verma as its new research associate at Nanotech West Lab. In the position, she conducts externally sponsored research, developing computational modeling capabilities that support design and manufacturing processes of energy storage systems.

Verma, who earned her doctoral degree in mechanical engineering from Ohio State in 2019, brings to IMR more than a decade of research experience. Prior to joining IMR, she worked as a research associate in the Computational Lab for Energy Applied Research within Ohio State's Department of Mechanical and Aerospace Engineering. Before that, Verma was a graduate research associate at Ohio State's SIMCenter.

At IMR, Verma conducts externally sponsored research to develop computational modeling capabilities that support the design and manufacturing processes of energy storage systems. Her efforts focus on electrochemical energy storage and conversion materials, components, and devices in batteries and fuel cells. Among a myriad of other duties at Nanotech West Lab, Verma also assists residential principal investigators in the Energy Innovation Lab with the development of proposals and preparation of research results for publication.

Before earning her doctoral degree, Verma earned her master's degree in mechanical engineering and bachelor's degree from Ohio State and a Bachelor of Engineering in Mechanical Engineering from the University of Mumbai. Outside of work, she enjoys gardening, painting, reading, knitting, traveling, and spending time with her family and friends.

New research scientist Joe McGlone concentrates work on semiconductor device fabrication and technology, while supporting Intel-funded CAFE

Joe McGlone has joined IMR as its new research scientist. In the position, he will carry out and enable collaborative research and training in semiconductor research and education, with a focus on wide bandgap semiconductors.

McGlone, who earned his doctoral degree in electrical and computer engineering from Ohio State in 2022, brings to IMR experience from both industry and academia. Before IMR, he worked on wide bandgap semiconductor devices and ultra-wide bandgap materials as an Ohio State postdoctoral researcher. Before that, McGlone twice co-opped at IBM.

At IMR, McGlone's work focuses on carrying out, guiding, and enabling collaborative research and training in semiconductor research and education, specializing in semiconductor device fabrication and in wide and ultrawide bandgap semiconductor technologies. He also supports the Center for Wide Bandgap Semiconductors, as well as IMR's efforts in industry-facing semiconductor research and training, including the Center for Advanced Semiconductor Fabrication and Education and activities at IMR-operated facilities, like Nanotech West Laboratory, the Semiconductor Epitaxy and Analysis Lab, and the Electronic Materials and Devices Lab.

"I'm looking forward to collaborating with my new and old colleagues in IMR, ECE, and Nanotech West to continue advancing the very strong semiconductor research at Ohio State, especially in the wide bandgap technology area," he said. "I am also excited to help a wide range of students by providing guidance on semiconductor tools and techniques that have steep learning curves, to help them more quickly reach their research goals."

McGlone loves being a dad, and spending his free time with his family at local events around Columbus, and also trains his stubborn border collie in dog agility.

Punam Murkute joins Ohio State as a postdoctoral researcher focusing on semiconductor fabrication and characterization at Nanotech West Lab, KIND Lab

Punam Murkute came on board two teams at Ohio State last year, as a postdoctoral researcher at professor Sanjay Krishna's Infrared Detector (KIND) research group, in the Department of Electrical and Computer Engineering, and IMR-operated Nanotech West Lab. Among multiple duties within the KIND Laboratory team, Murkute performs research on semiconductor materials and devices for infrared detection and imaging, and leads the fabrication and characterization of semiconductor devices being investigated as potential infrared detectors or imagers. As a member of the Nanotech West Lab staff, Murkute fabricates and characterizes research materials and devices, while training and supporting researchers at the West Campus user facility.

Murkute earned a Ph.D. in Microelectronics at the Indian Institute of Technology Bombay, after earning a master's degree in Physical Science at the University of Pune, India.

Conferences & Workshops

2023 OHIO STATE MATERIALS & MANUFACTURING CONFERENCE: COMMUNITY CELEBRATES IN-PERSON, POST-PANDEMIC REVIVAL

Hundreds of researchers from academia, industry and government labs recently came together from around the world to discuss the latest advances in materials and manufacturing research and innovation at the 2023 Ohio State Materials & Manufacturing Conference (MMC).

The annual event at Ohio State featured 39 cross-cutting and focus sessions over the course of the three-day conference, as well as two evenings of poster sessions with more than 90 graduate students. The conference also hosted the popular Three Minute Thesis competition with seven finalists competing for top prize. Dr. Carolyn Duran, formerly of Intel and now senior director of product integrity at Apple, helped welcome attendees and delivered the keynote address.

Session topics spanned a wide range of areas. Presentation and discussion topics included advanced semiconductor materials and devices, manufacturing of future battery technologies, emergent materials and quantum phenomena, manufacturing in space, among other cutting-edge areas that are defining the next generation of materials and manufacturing.

MMC is hosted by IMR as an opportunity to connect Ohio State's materials and manufacturing communities and celebrate their innovative research and accomplishments. This year's 13th annual event was held May 9-11 at the Fawcett Center, marking the conference's first return to an in-person format since the start of the pandemic.

Attendees this year represented 13 Ohio State departments from five colleges, as well as nearly a dozen universities from around the globe and various federal labs and companies.

Attendee Rachel Adams, a graduate student working with Ohio State Prof. Steven Ringel, joined nearly a dozen fellow students presenting their work within the Center for Advanced Semiconductor Fabrication Research and Education (CAFE), a multi-institutional research and education center funded by Intel Corporation. With her current research on fabrication technology for photonic devices being the culmination of her academic career, she was eager for the chance to share her work with a new, wider audience.

"Coming today, to the conference, it was fun to actually get to show people outside of the discipline what we are doing, and having them interested in what we're doing was fantastic," she said. "And getting to see the other students who are in the two other themes that Intel is sponsoring and getting to see their work and talk to them about it has been great — it's just cool science."

Conferences & Workshops

Ninety-one students from Ohio State presented their research over the course of two evenings during MMC '23's student poster sessions.

Under the scarlet glow of the numerous Block O lights spanning the ceiling of the Fawcett Center ballroom, curious students and judges from academia and industry roamed row after row of research summaries spanning a wide array of disciplines from more than a dozen university departments.

The poster sessions are a chance for students to not only meet and mingle with peers conducting research outside their own areas, but serves as a unique opportunity to get real-time feedback on their work and presentations from a broad range of experts and professional researchers.

Ohio State doctoral student Fariha Musharrat Haque, a graduate research associate in Mechanical and Aerospace Engineering, said MMC '23 was her first time presenting a poster at a conference. Although she has some experience giving technical talks, after presenting her poster Wednesday evening, she said the two opportunities are quite different.

"I think this is a really good experience," she said. "There are so many other people showing off their work, and then you get to engage with them even more because it's not just you standing over there, talking about your research. Now, you can actually engage with other people and see what others are doing."

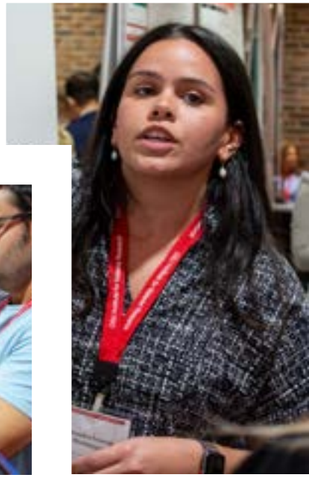
Graduate students also participated in the Three Minute Thesis (3MT). The competition allows each presenter just one static slide and no more than three minutes to communicate a distilled, compelling thesis and its significance. Of the seven finalists who took the stage, top prize went to Michael Lee, a doctoral student in Mechanical and Aerospace Engineering (MAE), for his presentation of his thesis on composite electrodes for Li-ion batteries.

3MT emcee Jay Sayre, IMR director of innovation, said being able to explain one's research thesis to an audience can be crucial when pursuing a job in academia, industry or government. "It is really great seeing students who are comfortable being uncomfortable," he said. "Being able to have your elevator pitch down is really critical."

On the final evening, students back in the Fawcett Center ballroom began folding up their posters, wrapping up their conversations with new connections, and heading for the doors. But not Haque, who works in the Multi-functional Materials and Intelligent Design Lab with asst. prof. Alok Sutradhar. She was still buzzing about the conference and her first poster session.

"Earlier, I was taking pictures, and I was trying to make a straight face. But I couldn't, because I couldn't stop smiling," she said. "The whole ambiance is so exciting, and I'm really glad to be here."

MMC '23 was sponsored by Tokyo-based innovation group Taiyo Nippon Sanso and Entrotech, inc., a Columbus-based provider of advanced materials solutions.



Conferences & Workshops

DISTINGUISHED LECTURE SERIES, FALL '22: SEMICONDUCTOR MANUFACTURING AND DESIGN – HOW DO WE EXCITE TODAY'S STUDENTS?, WITH MARK LAW OF THE UNIVERSITY OF FLORIDA

A career in semiconductor fabrication is not just potentially lucrative and stable, but also exciting and impactful. However, is the opportunity to work in a field brimming with cutting-edge technology, complex problem-solving, creativity, and global significance enough to engage and inspire the next generation of students?

Mark Law, a distinguished professor at the University of Florida, told attendees at IMR's fall Distinguished Lecture Series he believes it certainly could, but only if the students learn about it. And the responsibility falls on educators to reinvigorate student interest in technology enabling chips and other devices by making semiconductors exciting and relevant again.

Law emphasized the critical importance that educators adapt and modernize current teaching methods, some of which have gone largely unchanged in at least 40 years, for a younger generation who have unique learning styles and access to ever-evolving, innovative educational tools.

Law focuses on semiconductor devices and materials research and has headed UF's honors program for eight years.

DISTINGUISHED LECTURE SERIES, SPRING '23: DESIGNER NUCLEIC ACID ARCHITECTURES FOR PROGRAMMABLE SELF-ASSEMBLY, WITH HAO YAN OF ARIZONA STATE UNIVERSITY

Taking inspiration from nature's intricate design principles, Hao Yan is leveraging self-assembling molecules to pioneer advancements in biomedical and energy-related innovation, and beyond.

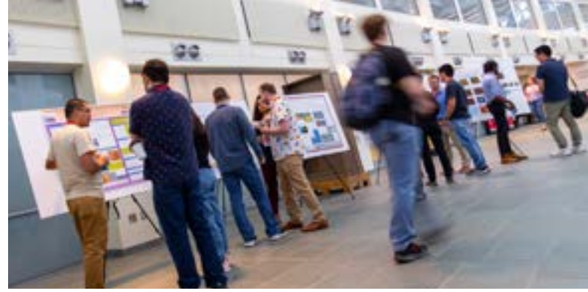
Yan is the Milton D. Glick Distinguished Professor in Chemistry and Biochemistry and director of the Center for Molecular Design and Biomimetics in the Biodesign Institute at Arizona State University. He spoke at Ohio State in Spring 2023, as the latest invited speaker at IMR's Distinguished Leacture Series. Yan's talk explored the emergence of DNA and RNA as unique molecular tools for nano-construction, utilizing their predictable conformations and programmable base pairing interactions. He discussed the development of design rules, such as repetition and spatial control, and assembly methods to create increasingly intricate DNA nanostructures that can allow novel applications in material assembly, DNA computing, biocatalysis, and healthcare.

Yan also reviewed some of his own work in structural nucleic acid nanotechnology and highlighted the challenges and potential in DNA and RNA-based molecular design and programming. With decades of experience, he has published more than 200 papers and has received a myriad of honors, from the NSF Career Award to AFOSR's Young Investigator Award. He is an elected fellow in multiple organizations and an associate editor for Science Advances and ACS Applied Bio Materials.

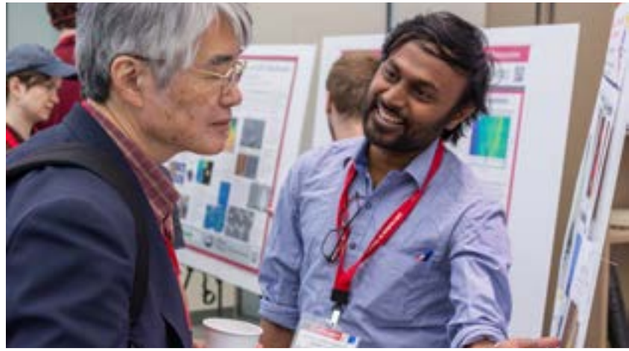
Conferences & Workshops

WOMEN IN NANO CELEBRATES INTERNATIONAL WOMEN'S DAY WITH INAUGURAL EVENT FEATURING COLLEGE OF ENGINEERING DEAN AYANNA HOWARD AND BIOMEDICAL ENGINEERING ASSISTANT PROFESSOR NATALIA HIGUITA-CASTRO

In celebration of International Women's Day on March 8, 2023, IMR hosted the inaugural Ohio State Women in Nano (WIN) networking and career conversation with Dr. Ayanna Howard, dean of the College of Engineering and Professor Natalia Higuita-Castro, Associate Professor of Biomedical Engineering. Dean Howard led the discussion covering a broad range of topics including research, career choices, mentoring, overcoming obstacles, and defining success. More than 30 attendees joined the event and reception that followed including graduate, undergraduate students, post-doctoral scholars, professional staff, faculty, and external guests from industry. The goal of WIN is to create a supportive community of women, network, and grow interest in the micro- and nanotechnology-related fields.



8TH CONFERENCE ON SPIN POLARIZED STM AND NANOSCALE MAGNETIC IMAGING



The 8th, international Conference on Spin Polarized STM and Nanoscale Magnetic Imaging reconnected the community in June 2023 with a program highliting recent SPSTM work. The event, organized by Physics professor Jay Gupta, featured student posters and research by experts in other imaging techniques, such as Lorentz TEM, diamond NV-center magnetometry, X-ray holography and MFM/MExFM. These methods offer distinct, supplementary perspectives areas that include quantum information systems, quantum matter, spintronics and biological systems. IMR was among multiple organizations offering event sponsor support.

IIT BOMBAY-OHIO STATE FRONTIER CENTER 2022 FALL SEMINAR

The IIT Bombay-Ohio State Frontier Science and Engineering Research Center hosted leaders in academia, industry partners, campus centers from around the world, including Nanyang Technological University (NTU), in Singapore, at the center's 2022 Fall Seminar. The event offered an opportunity for leaders from Ohio State, the Indian Institute of Technology Bombay, other universities, and industry to discuss opportunities to collaborate in a range of fields that included advanced materials and technologies for energy and mobility, artificial intelligence, electronic materials and semiconductors, quantum information science and technology, as well as an overview of the NTU Energy Research Institute.

In addition to faculty from IIT Bombay and Ohio State, the event's featured speakers included representatives from A*STAR, Tagor Technologies, Toyota, Eni Next and NTU Singapore. Several panel discussions were also featured, as well as a memoriam by Frontier Center co-leader Anant Agarwal for Tulsi Tanti, a pioneer of wind power in India.

Affiliated 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.

Bio-AFM Core Facility

Located in Scott Laboratory, the Bio-AFM Core Facility joined IMR's network this past year, enabling capabilities that include electron microscopy and atomic force microscopy. This facility specializes in high-resolution characterization of biological materials. IMR is set to provide the lab support through its first five years of operation.

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 like materials for energy and sustainability.

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 two 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 the Ohio State Materials & Manufacturing Conference, 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 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.

Affiliated Centers & Core Laboratories

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 preeminence 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.

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.

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.

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.

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 — several of which have been awarded.

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.

Sudha Agarwal, Oral Biolgy

Anant Agarwal, Electrical and Computer Engineering

Gunjan Agarwal, Mechanical and Aerospace Engineering

Kaveh Ahadi, Materials Science and Engineering

Sheikh Akbar, Materials Science Engineering

Boian Alexandrov, Materials Science and Engineering

Heather Allen, Chemistry and Biochemistry

Douglas (D & DE) Alsdorf, Earth Science

Peter Anderson, Materials Science and Engineering

Betty Lise (B. L.) Anderson, Electrical and Computer 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 Baker, Chemistry and Biochemistry

James Beatty, Physics

Avraham Benatar, Materials Science and Engineering

Alison Bennett, Evolution, Ecology, and Organismal Biology

Paul Berger, Electrical and Computer Engineering

Christian Blanco, Fisher College of Business

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, Materials Science and Engineering

Nicholas Brunelli, Chemical and Biomolecular Engineering

Rafael Bruschweiler, Chemistry and Biochemistry

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