INSTITUTE FOR MATERIALS AND MANUFACTURING RESEARCH

FISCAL YEAR 2024

THE OHIO STATE UNIVERSITY
INSTITUTE FOR MATERIALS AND MANUFACTURING RESEARCH

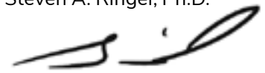
Letter from Executive Director Steven A. Ringel

Dear Colleagues,

I am delighted to share with you the FY24 annual report of Ohio State's Institute for Materials and Manufacturing Research – IMR. As I write every year, it is always difficult to keep up with the incredible accomplishments and innovations our students, staff and faculty members are making every day, and provide a succinct and fully inclusive summary. This year is no different. Highlights abound, from our role as the primary infrastructure partner for the Midwest Microelectronics Consortium (MMEC) in winning one of the eight regional innovation hubs awarded by the Department of Defense through its Microelectronics Commons program, establishing a $20M Microelectronics Technology Innovation Cluster to work with industry and government partners; to breaking ground on the IMR Battery Cell R&D Center, which in the coming year will see the installation and ramp-up of close to $30M of state-of-the-art infrastructure for dual-use training and next-generation battery R&D; to solving the challenges of materials systems in the harsh environment of space through a wide range of programs. While last year we reported on completing the first year of our National Science Foundation (NSF) Engineering Research Center (ERC) – HAMMER (Hybrid Autonomous Manufacturing, Moving from Evolution to Revolution) led by Prof. Glenn Daehn, which is Ohio State's first ERC award since 1986, this year we have just learned of Ohio State being awarded its second NSF ERC – TARDISS (Transformation of American Rubber through Domestic Innovation for Supply Security), jointly led by Profs. Judit Puskas and Katrina Cornish that was enabled by a leadership coalition between IMR and other Ohio State centers, especially its Sustainability Institute. This sort of uniquely seamless, interdisciplinary collaboration has made Ohio State the only university with two active ERC programs, and both are focused on materials! While we engage in these large, strategic efforts that are built upon years of deliberate strategy and research development, our research core growth has never been stronger. For example, as shown in our cover photo, we saw a first-of-its-kind laser installed at Ohio State's NSF National Extreme Ultrafast Science Facility (NeXUS). This custom laser produces femtosecond, infrared light pulses at rapid repetition rates, allowing for measurements currently possible only in a few global labs and producing extreme ultraviolet light with attosecond resolution. Further, early-stage seed grants leading to team science and high-impact research results in areas from quantum materials to photonics to metals are already reaping results and accolades to our researchers. Inside, you will also read about the continued growth of our international partnerships, which are critical in positioning IMR and Ohio State as a global center for innovation, training and research.

With all of this, our goal has never wavered. It is to position IMR, and Ohio State, as the nation's leader in providing a sustained, vertically-integrated, interdisciplinary ecosystem where students, staff and faculty are engaged in a flourishing and impactful iterative innovation process that spans from basic materials research to translation via advanced manufacturing, impacting key areas of science and technology for our world. 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 250 faculty members from 43 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 and solid state batteries; 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*
$117.6M

TOTAL PROJECT VALUE*
$794.2M

NEW AWARDS*
$138.9M

* Sponsored projects only

250 FACULTY MEMBERS

43 DEPARTMENTS

10 COLLEGES

7.2 PUBLICATIONS PER MEMBER [1]

591 CITATIONS PER MEMBER [1]

210 PATENTS FILED [2]

65 PATENTS ISSUED [2]

107 INVENTION DISCLOSURES [2]

[1] Average of researchers found on Google Scholar in CY23

[2] Office of Innovation and Economic Development, FY24

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 FY24.

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

NEW OHIO STATE BATTERY CENTER OPERATED BY IMR WILL ENABLE MANUFACTURING OF ADVANCED EV BATTERY CELLS


Rendering of Ohio State's Battery Cell R&D Center.

The Ohio State University was joined by Ohio Lt. Gov. Jon Husted, congressional leaders, Honda, Schaeffler Americas and JobsOhio officials Monday to announce the creation of a new battery cell research and demonstration center.

Slated to open in July 2025, the lab will accelerate the domestic development of battery cell materials and manufacturing technologies while providing an experiential learning setting for advanced battery technology workforce development.

With over $22 million in commitments to date, this project will include the renovation of a 22,000-square-foot facility in Ohio State's innovation district into a dedicated battery cell research, production and education support space. The center will be managed and operated at Ohio State by IMR.

"Ohio State's commitment to research, innovation and bringing solutions to the world is at the heart of our land-grant mission," said Peter Mohler, executive vice president for research, innovation and knowledge at Ohio State. "We have more reach and impact when we work with our partners at the local, state and federal levels and we join industry-leading partners like Honda and Schaeffler."

Honda will serve as lead foundational partner for the project and has committed $15 million for the research and development center. The project was also endorsed by the State of Ohio and JobsOhio.

"Honda is committed to an electrified future for our automobiles, motorcycles and power products worldwide," said Bob Nelson, executive vice president of American Honda Motor Co., Inc. "We have had a long-standing relationship with Ohio State that goes back more than 30 years, and this new facility is an extension of that great partnership. This facility will be a great resource to train the next-generation workforce in advanced manufacturing technologies."

The completed project will also create a hub for academic and industry connections across chemical and physical sciences, engineering, business and policy. Once completed, the project will create a strong pipeline of industry talent while also attracting electric vehicle battery manufacturing and supply chain businesses to help support the evolving vision for the industry.

"Schaeffler is developing the next generation of all solid-state battery technology to support the automotive industry's transition to electric mobility. Our strategic partnership with The Ohio State University provides a hands-on and collaborative approach with the goal of providing industry-leading and scalable solutions that will position Ohio at the center of battery technology," said Jeff Hemphill, chief technology officer of Schaeffler Americas.


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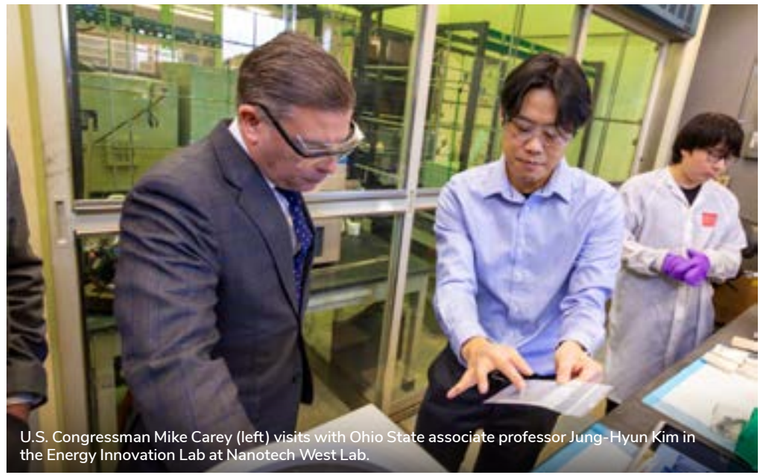
Highlights



U.S. Congressman Mike Carey (left) visits with Ohio State associate professor Jung-Hyun Kim in the Energy Innovation Lab at Nanotech West Lab.

"When presented with an opportunity to take the lead in battery innovation, particularly with reputable Ohio employers such as Honda and Schaeffler, it is wise to capitalize on that potential," said Husted. "Establishing this battery technologies innovation center on Ohio State's campus will play a key role in ensuring that we continue to be pioneers in automotive and sustainability advancements."

"The EV industry, aerospace and aviation, health care and more will benefit directly from this innovative center by gaining a competitive advantage in battery technology," said JobsOhio President and CEO J.P. Nauseef. "This collaborative effort between Honda, one of the world's most successful manufacturers, and Ohio State, a global leader in academic and industry research, establishes one more extraordinary asset for Ohio as industries across sector lines move toward more electrification."

Congressional champions for this project include U.S. Sen. Sherrod Brown and U.S. Reps. Joyce Beatty and Mike Carey, who all participated in today's event. Through their work, $4.5 million in federal funding was secured through the National Institute of Standards and Technology's (NIST) Extramural Construction program.

"We know how to make cars in Ohio. The auto industry is our past, and our future. The next generation of vehicles that families will drive all over the country and all over the world will be made in Ohio, by Ohio workers," Brown said. "Ohio State, One Columbus and Honda came to us with this project, and we worked together to secure the investment to make it happen. This is how we are burying the term 'Rust Belt.'"

"The announcement of Ohio State's new battery research center is yet another step in the right direction of academic excellence," Beatty said. "I'm proud to have helped secure federal funding to see this project into fruition and look forward to seeing this investment grow and flourish. This also continues to mark central Ohio as a pivotal workforce hub in America from the key technologies, economic impact, products, training and infrastructure this center will offer."

"I was proud to help secure federal funding for this new battery cell and research center at my alma mater," said Carey. "This investment will help ensure this new research center has a state-of-the-art facility to develop and assemble electric vehicle batteries right here in Ohio."

The federal funding will support a 4,000-square-foot dry room, which is necessary for the assembly of battery cells due to the extreme moisture sensitivity of cell components. The dry room and new battery cell assembly equipment will facilitate the accelerated development and translation of batteries from the lab to practical scales, including the electric vehicle market.

Additionally, Coatema Coating Machinery GmbH and their U.S. distributor, next Machinery Group, will sponsor the acquisition of a cutting-edge equipment line for battery cell coating, which will enable users to experiment with different materials, processes and configurations at varying scales of production. Coatema's Click&Coat machine line will serve as an integral set of tools in the development of high-quality, consistent battery cells for the market. University researchers, students and industry users will be able to customize the coating configurations of the new machine line to scale to the scope of their specific project, from the lab to pilot production line. The partnership also brings a new opportunity to connect around state-of-the-art equipment, bringing Coatema R&D teams and other industry users from Germany to train and demonstrate system capabilities alongside Ohio State faculty and students.

Ohio State's Battery Center acting director Jay Sayre, with U.S. Congresswoman Joyce Beatty, U.S. Congressman Mike Carey, Coatema's VP Thomas Kolbusch and the next Machinery Group team led by Tomi Belosevic at the announcement ceremony in Columbus, Ohio. Photo credit Emma Parker.

Highlights

Manager of nanofabrication Aimee Price operates an electron beam lithography system at Nanotech West Lab.

NANOTECH WEST LAB EXPANDS CAPABILITIES FOR SEMICONDUCTOR FABRICATION, ETCHING AND ASSEMBLY

Nanotech West Lab expanded their lithography capabilities in the Nanofabrication Lab with the addition of a new state-of-the-art Raith EBPG 5150 Plus electron beam lithography (EBL) system, which replaced the existing Raith/Leica EBPG 5000. The EBPG 5150 Plus was installed in November 2023 and open to users for training in February 2024. With resolution below 8nm and stitching and overlay (alignment) specs of better than 10nm, the new EBL far exceeds the capabilities of any other lithography tool at Nanotech West. In addition, the EBPG 5150 Plus has a dramatically higher maximum clock frequency of 125MHz as compared to the previous tool's 10MHz. This in combination with the higher maximum available beam current, large 1mm field size, and improved universal pattern generator allow for 2-10x faster write times with improved pattern resolution and fidelity.

Access to Genisys' Beamer and Tracer software was included with the EBL purchase, enabling users to fully optimize the EBPG 5150 Plus. Beamer enhances devices requiring low pattern line edge roughness, such as photonic waveguides and gratings, while 3D proximity effect correction optimizes structures like gamma and t-gates. The Raith universal pattern generator allows true curves and arbitrary angles, significantly improving pattern fidelity for designs involving curved features, dots, and ellipses, moving beyond the limitations of Manhattan geometries.

The EBPG 5150 Plus utilizes a graphical user interface operating on a Linux platform which significantly improves the user experience as compared to the previous tool's command line interface. Training time is improved, and more users can operate the tool independently. Further improvements are planned to the pre-alignment microscope and training tools, which will facilitate larger group training, education, and outreach opportunities. The EBL is available to Nanotech West Nanofab users for training and operation. The EBPG 5150 Plus was funded by a Major Research Instrumentation (MRI) Award from the National Science Foundation, led by principal investigator Siddharth Rajan, professor in Electrical & Computer Engineering and Materials Science & Engineering.

Additionally, the installation of a new Plasma Therm Takachi ICP-RIE expanded etching capabilities with enhanced gas options and sample temperature control, ranging from -20°C to 250°C. The inclusion of the X-Celeprint Micro-Transfer Printer allows researchers to assemble diverse semiconductor devices on various substrates, complementing IMR's heterogeneous epitaxy portfolio. This allows multiple approaches for creating advanced materials and devices through direct epitaxy and micro-transfer printing.

Kavya Dathathreya, Nanotech West Lab research assistant.

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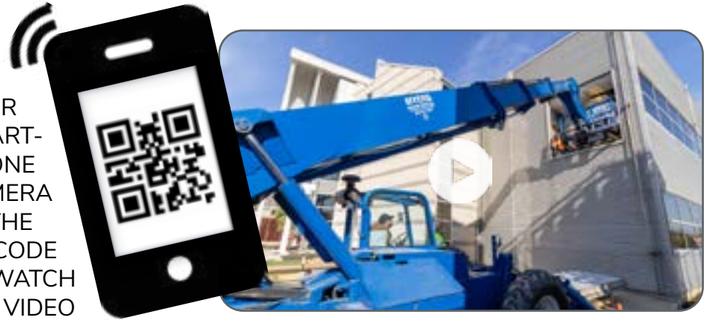
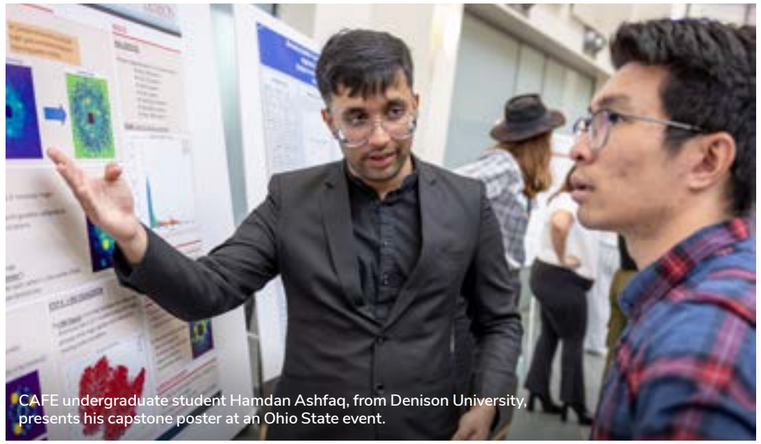


Highlights

IMR-LED, INTEL-FUNDED CENTER FOR SEMICONDUCTOR FABRICATION RESEARCH, EDUCATION MARKS MIDPOINT

After completing its second year of a three-year funding cycle in FY24, the IMR-led, multi-institutional Center for Advanced Semiconductor Fabrication Research and Education (CAFE) continues its efforts in semiconductor fabrication, development, and research. The center is also playing a key role in preparing a skilled workforce to meet the demands of an industry poised for significant growth, both across the U.S. and particularly in 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. Themes focus on fabrication technology for 2D semiconductor devices, fabrication of III-nitride devices for silicon IC platform, and fabrication technology for photonic devices and integration. Through multiple projects within these themes, 21 undergraduate students and 21 graduate students and postdoctoral researchers in varying semiconductor-related disciplines have connected with expert researchers, accessed state-of-the-art nanofabrication labs, and gained hands-on experiences and opportunities.



CAFE undergraduate student Hamdan Ashfaq, from Denison University, presents his capstone poster at an Ohio State event.

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

Since FY23, research teams have produced a growing list of published research, conference presentations, student honors and faculty recognitions.

Additionally, the center is preparing to extend its research and experiential learning programs beyond its initial funding. By leveraging $2M from Intel, CAFE has generated more than $30M in related or follow-on funding programs.

Intel broke ground in FY23 on a new 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.

VETERANS TRAINING FOR SEMICONDUCTOR JOBS BEGINS AT NANOTECH WEST LAB

Ohio State has joined the Microelectronics and Nanomanufacturing Veterans Partnership (MNVP), a project aimed at integrating military veterans into the growing nanotechnology workforce. In collaboration with Columbus State Community College, Ohio State began offering MNVP training in Autumn 2024 through Nanotech West Lab. Nanotech West Lab, which is operated by IMR, is a 36,000-square-foot shared user facility servicing the Ohio State materials community and is open to both academic and industrial researchers.

The program builds on the success of similar initiatives across the country by pairing community colleges with research universities, allowing veterans access to cutting-edge facilities and training. The initiative is funded by the National Science Foundation and focuses on providing veterans with the skills needed for semiconductor fabrication and nanotech-related careers.

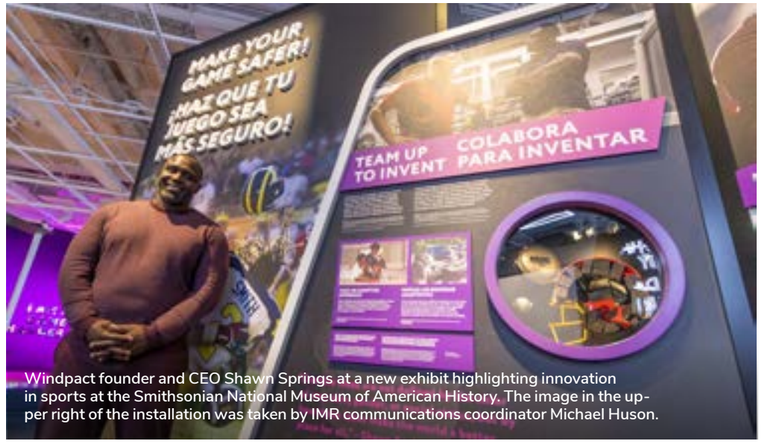
Other universities involved in the partnership include Arizona State University, the University of California San Diego, Georgia Institute of Technology, Cornell University, and the University of Texas at Arlington. The program's expansion to Ohio reflects the state's growing investment in semiconductor manufacturing, positioning veterans to take advantage of emerging job opportunities in the region.

Highlights

ALL-AMERICAN, IMR COLLABORATOR SHAWN SPRINGS FEATURED IN SMITHSONIAN AMONG SPORTS INNOVATORS

Ohio State Buckeye and NFL veteran Shawn Springs is no stranger to making history on the football field. He was a standout athlete for the Buckeyes, earning All-American honors and being named All-Big Ten twice. Following his college success, he enjoyed a 13-season NFL career as a cornerback, playing for three teams, recording 33 interceptions, and making the Pro Bowl.

But he never dreamed he, his company Windpact, and his passion for finding solutions to protect against concussions and everyday impacts would be recognized in the Smithsonian National Museum of American History. When he realized his work as an entrepreneur was to be featured as one of the main installations at a Smithsonian exhibition highlighting invention and technology in sports, he was "blown away."



Windpact founder and CEO Shawn Springs at a new exhibit highlighting innovation in sports at the Smithsonian National Museum of American History. The image in the upper right of the installation was taken by IMR communications coordinator Michael Huson.

"That's an incredible accomplishment. I always dreamed about being a professional athlete," he said. "I never thought that the title "inventor" or "innovator" would be associated with my name, but, you know, that's where we are today, right?"

Springs' work to revolutionize safety through his company, Windpact, is highlighted in the Smithsonian exhibit "Change Your Game"/"Cambia tu juego." Windpact designs and implements impact protection technologies and maintains a database of foam materials to improve protective gear. Ohio State researchers collaborated with Windpact at the Dynamic Mechanics of Materials Laboratory, led by Prof. Amos Gilat, to study materials for potentially life-saving applications. The lab specializes in measuring mechanical properties under various conditions, with contributions from research associate professor Jeremy Seidt, of the Department of Mechanical and Aerospace Engineering.

"When I first started Windpact, I had no idea of the important role The Ohio State University would play in our growth and success," Springs said. "Discovering the immense talent and resources that the school has to offer has allowed us to put together one of my all-time favorite teams."

Springs was also invited by the museum's Lemelson Center to discuss his work, life and the importance of education at an "Innovative Lives" event.

IMR PHOTOGRAPH INSTALLED IN NEW EXHIBITION AT THE SMITHSONIAN MUSEUM OF AMERICAN HISTORY

A new exhibition at the Smithsonian National Museum of American History is connecting the legacies and art of the past with forward-thinking innovations shaping tomorrow.

Thanks to a connection facilitated by IMR, Ohio State labs played a key role in testing one of these innovations. IMR was there to capture the collaboration between Shawn Springs, his company Windpact, and his alma mater.

In March of 2024, a photograph of Springs and Ohio State Prof. Amos Gilat taken by IMR communications coordinator Michael Huson was installed as part of the exhibit "Change Your Game"/"Cambia tu juego." The photo features the two at Ohio State's Dynamic Mechanics of Materials Laboratory, where materials used for Windpact's potentially life-saving technology were studied and characterized.

The photograph by Huson is now on display at the Smithsonian, where it shares a special familial connection to his great-great-great-grandfather, Emanuel Leutze. Leutze, renowned for his painting "Washington Crossing the Delaware," has work in the Smithsonian American Art Museum's collection.

IMR photography focuses on capturing the breadth and wide-ranging efforts and discoveries of Ohio State's materials and manufacturing community, with images featured from across the university to The Washington Post.

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Highlights

IMR LEADS MICROELECTRONICS INNOVATION AND TECHNOLOGY CLUSTER TO ADVANCE US SEMICONDUCTOR MANUFACTURING

Researchers in the Nanofab Lab cleanroom at Nanotech West Lab.

In FY24, Ohio State was awarded a significant new project to establish and operate a shared facility cluster that will enhance transitions from research to commercial manufacturing in advanced semiconductor technologies. As the primary infrastructure partner of the Midwest Microelectronics Consortium (MMEC), a Department of Defense-designated regional hub funded through the Microelectronics Commons Initiative, the Ohio State Microelectronics Innovation and Technology Cluster (MITEC) will form a state-of-the-art network of user facilities at the university that is expected to boost the Midwest region's position as a major innovation hub in microelectronics.

This collaboration between IMR and the consortium will be instrumental in accelerating microelectronics research and development in the region. The project is led by IMR executive director Steven Ringel, a Distinguished University Professor in Electrical & Computer Engineering and Associate Vice President for Research.

"The new MITEC capabilities will have a significant impact on Ohio State's semiconductor ecosystem and infrastructure, with the goal to support device development and prototyping for Department of Defense technology transitions working with the MMEC," Ringel said. "We are excited about our partnership with the MMEC as the midwest's leading innovation hub for compound semiconductor technologies."

MITEC will integrate new capabilities funded by the Department of Defense Microelectronics Commons program into Ohio State's existing facilities, including the Semiconductor Epitaxy and Analysis Laboratory and several facilities within the Nanotech West Lab. These laboratories will undergo renovations and add equipment to enhance materials growth capabilities, such as 100mm wafer-process-compatible metal-organic chemical vapor deposition and hydride vapor-phase epitaxy systems, for AlGaN and Ga2O3 technologies, respectively, and additional semiconductor cleanroom device processing capabilities necessary to accelerate device prototyping for DoD applications. Additionally, a new, 100mm wafer compatible molecular beam epitaxy system will be installed to support infrared compound semiconductor technologies. These upgrades will expand Ohio State's capacity for cutting-edge research and enable state of the art prototype fabrication. The project's impact will be transformative, supporting the MMEC in advancing "lab to fab" transition projects in key technology areas of microelectronics, as identified by the Department of Defense. The MITEC team includes co-PIs Siddharth Rajan, a Distinguished Professor of Engineering, Nanotech West Lab director John Carlin, and IMR research scientist Joe McGlone. In addition to supporting research, MITEC will enable workforce training in semiconductor device testing and fabrication, helping to build the next generation of experts in this field. Projects utilizing MITEC will also have access to the network of existing IMR and Ohio State facilities, including the Center for Electron Microscopy and Analysis and the NanoSystems Laboratory.

Nanotech West Lab, Carmenton, West Campus.

Highlights

IMR LAUNCHES NEW NSF-FUNDED PROGRAM FOR CLEAN-TECH BATTERY MANUFACTURING CAREERS

BATTERI team members, from left to right: IMR innovation manager Kari Roth; IMR proposal development specialist Joanna Gardner; IMR program assistant Laurie Coyne; Co-PI Matthew Mayhew, William Ray and Marie Adamson Flesher Professor of Educational Administration; Jung-Hyun Kim, associate professor in Mechanical and Aerospace Engineering; PI Jay Sayre, IMR director of innovation; Qingmin Xu, Energy Innovation Laboratory manager at Nanotech West Lab; Co-PI Lenroy Jones, director of Career Services at Columbus State Community College; Co-PI Caroline Crisafulli, director of Entrepreneurial Education at the Keenan Center for Entrepreneurship; and Co-PI Jeff Bielicki, program director of the Ohio State EmPOWERment Program, not pictured.

IMR introduced a new program to create pathways for individuals with various levels of experience in STEM fields to enter the rapidly growing workforce in clean-tech battery manufacturing for the automotive industry.

This program will provide unique career training and hands-on learning opportunities, equipping participants with the skills to develop and deploy advanced battery technologies that meet industry standards.

The program was recently funded by the U.S. National Science Foundation (NSF) through its Experiential Learning for Emerging and Novel Technologies (ExLENT) program. Through ExLENT, NSF has announced more than $30 million in investments to nearly 40 institutions of higher education and nonprofits throughout the U.S.

The resulting program at Ohio State, named BATTERI (Bridging Academic Training Through Experiential Research and Innovation), is led by IMR. The institute also operates the university's Energy Innovation Lab and the upcoming $22-million Battery Cell R&D Center. BATTERI is the first funded program for the Battery Center, which is scheduled to open in Carmenton district in 2025. “We're excited and grateful to have this new program. It’s more than a vehicle to explore new technologies; it will serve as a catalyst that will shape advanced manufacturing by lighting pathways for a diverse STEM workforce,” said IMR Director of Innovation Jay Sayre, BATTERI lead PI and research associate professor in Materials Science and Engineering.

IMR FACULTY MEMBER SHAMSUL ARAFIN EARNS INTEL RISING STAR AWARD FOR TECHNOLOGY ADVANCEMENT

Each year, the Intel Rising Star Faculty Award program recognizes early-career academic researchers who are driving technology advancements with the potential to disrupt the industry.

In FY24, Intel selected Shamsul Arafin, an assistant professor in Electrical and Computer Engineering, for his significant contributions in multiple areas. Arafin was recruited to Ohio State through the university's IMR-operated Materials and Manufacturing for Sustainability Discovery Theme.

Arafin has made notable contributions in electrical engineering and materials science in his time at Ohio State, focusing on III-V compound semiconductors, 2D materials, optoelectronic devices, semiconductor lasers and photonic integrated circuits. His research aims to advance semiconductor technologies and the future of computing. Since founding the Optics and Photonics Research Lab four years ago, his team has conducted pioneering work on quantum dot-based tunable lasers, mid-wave infrared photonic integrated circuits, and quantum materials. Arafin’s experimental research also delves into topological photonics, a field that promises devices with properties such as scatter-free edge-state transport and immunity to perturbations and disorder.

Arafin currently leads the Intel-funded Center for Advanced Semiconductor Fabrication Research and Education (CAFE) project "Heterogeneous Integration of Novel Materials via Micro-Transfer Printing for Silicon Photonics." CAFE is a multi-institutional research and education center advancing the state of semiconductor fabrication for next-generation device technologies, leveraging world-leading research expertise and capabilities available within our team.

Previously, Arafin won am NSF Early CAREER Research Award, with the goal of creating the first non-telecom photonic integrated circuits (PICs) platform above 2 µm dedicated to advance biomedical sensing applications. Before that, he was awarded an NSF EAGER, or Early-concept Grants for Exploratory Research, award to fund exploratory research that could advance future quantum technologies.

ECE assistant professor Shamsul Arafin.

Highlights

NEXUS LASER BRINGS NEW CAPABILITIES IN ULTRAFAST SCIENCE

Dina Eissa (left),a graduate student in Chemical Physics, and NeXUS research staff member Tim Scarborough.

Following the Nobel committee's recognition of attosecond science with the 2023 Nobel Prize in Physics, Ohio State's NeXUS Facility acquired the NeXUS Laser – the first kilowatt-class laser of its kind in the U.S. This state-of-the-art technology, producing attosecond to femtosecond light pulses, is available to researchers around the world and across multiple disciplines.

The NeXUS (National eXtreme Ultrafast Science) facility aims to advance ultrafast measurements in the U.S., enabling the study of matter at the scale of electrons and atoms. It was established in 2019 with support from the National Science Foundation (NSF) and Ohio State. In 2019, IMR launched a proposal-building campaign to promote Ohio State responses to NSF's new Mid-scale Research Infrastructure program, and Ohio State secured funding for two facilities, including NEXUS.

The custom NeXUS laser produces femtosecond, infrared light pulses at rapid repetition rates, allowing for measurements currently possible only in a few global labs. These pulses ultimately produce extreme ultraviolet light (10 to 200 eV or 6 to 125 nm) with attosecond resolution, building on the advancements that earned Anne L'Huillier, Ferenc Krausz, and Ohio State Professor Emeritus Pierre Agostini the 2023 Nobel Prize in Physics.

NeXUS construction was led by Robert Baker, professor in Chemistry and Biochemistry, and Louis DiMauro, professor in Physics, who led a team of faculty, staff, postdocs, and graduate students to acquire, design, and assemble about one dozen subsystems that comprise the NeXUS system. The facility has three beamlines off the laser, each with tailored extreme ultraviolet light. End stations use the light to measure the dynamics of atoms, molecules, and materials. A scanning tunneling microscopy end station enables surface studies with time, element, and atomic spatial resolution. An angle-resolved photoelectron spectroscopy end station measures a material's evolving electronic band structures with femtosecond time resolution. An X-ray absorption end station allows studies of ultrafast electron dynamics in photocatalysts and quantum materials.

NeXUS is an open-access user facility and will make biannual calls for user proposals. Fundamental research is proposed and evaluated for scientific merit, and teams are granted facility time at no charge, with the cost covered by NSF. NeXUS is open to collaborations with companies interested in commercial research studies. The research center enables ongoing collaborations with IMR, the Center for Emergent Materials, the Institute for Optical Science, and other university researchers interested in its capabilities.

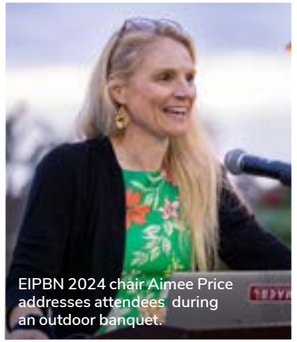
"It is really exciting to be a part of this effort that will take the unique ability to characterize molecules and materials on the fastest scales of time and make them available to the entire scientific community through this new open-access, national user facility," Baker said. "As a partnership between Ohio State and the NSF, NeXUS is poised to have a significant impact on the future of ultrafast science in the U.S. and abroad."

Lily Nichols (left),a graduate student in Chemistry, and NeXUS research staff member Seth Shields.

Highlights

AIMEE PRICE CHAIRS 67TH EIPBN INTERNATIONAL CONFERENCE

EIPBN 2024 attendees at the Hilton La Jolla Torrey Pines, San Diego, California.



EIPBN 2024 chair Aimee Price addresses attendees during an outdoor banquet.

Natalya Kublik, a doctoral candidate at Arizona State University, during a poster session.

Aimee Price, nanofabrication manager at Nanotech West Lab, chaired the 67th International Conference on Electron Ion Photon Beam and Nanofabrication (EIPBN), which brought together more than 400 leading researchers from academia, government labs and industry from around the world to share and explore the latest trends and future directions in cutting-edge technologies related to electron, ion and photon lithography, imaging and analysis; atomically precise fabrication; nanofabrication process and related emerging technologies. EIPBN 2024 was held in May at the Hilton La Jolla Torrey Pines, San Diego, California, with the theme "Nanofabrication/nanomanufacturing in the AI Era." Abstract submissions increased by 10 percent over 2023, with 14 countries and regions represented. Events included a theme panel, Women in Nano and student-mentor lunches, commercial session, and banquet. EIPBN 2025 will be in Savannah, GA, May 27-30, 2025.

CENTER FOR WIDE BANDGAP SEMICONDUCTORS POWERS NEW RESEARCH AND DISCOVERIES AT OHIO STATE

Ohio State's Center for Wide Bandgap Semiconductors, which is supported by IMR, is driving groundbreaking research and education in wide and ultra-wide bandgap semiconductor materials and devices. With more than 50 faculty and researchers spanning various disciplines, the center is helping push the university further into the forefront of this critical technology field.

In FY24, the WBG Center produced more than 60 journal publications and secured five patents, underscoring its leadership in semiconductor advancements. The center's researchers have also earned multiple research awards, fueling further exploration in wide bandgap semiconductors, allowing for technological breakthroughs in electronics, power devices, and beyond.

WBG Center researcher Hongping Zhao, a professor in Electrical & Computer Engineering and Materials Science & Engineering, is a co-PI on a new MURI project funded by the Army Research Office. The project, Nanoscale and Transduction-Optimized Pristine Ferroelectric Nitrides (NanoTOP), aims to advance understanding of newly discovered III-V and II-IV ferroelectric nitrides. Zhao's team will focus on investigating the MOCVD growth technique to identify high-performance ferroelectric nitride semiconductors.

WBG Center director Siddharth Rajan, a Distinguished Professor of Engineering in Electrical and Computer Engineering, received funding from the NSF Future of Semiconductors 2 (FUSE2) program. The project, funded jointly by NSF, Intel, Ericsson, Samsung, and Micron Technology, brings together researchers from UT-Austin, UT-Dallas, and the University of Michigan. The team will explore the integration of gallium nitride transistors with Boron Arsenide, enhancing semiconductor performance and functionality.

Additionally, IMR director and WBG Center researcher Steven Ringel is leading Ohio State's efforts in a newly awarded $8 million, five-year AFOSR MURI grant led by NC State University. The project, Extreme Bandgap Electronics, joins five universities to explore doping and conductivity control in aluminum nitride and aluminum gallium nitride semiconductors. These materials have applications for next-generation high-voltage and high-frequency electronics. Ohio State's team will focus on investigating atomic defects and enabling doping control across various epitaxial growth platforms.

WBG Center students are also making strides. Sushovan Dhara, a graduate student in Electrical & Computer Engineering, was awarded the Graduate School's highest honor, a Presidential Fellowship, for his work on vertical gallium oxide power devices. Other students are securing internships with leading semiconductor companies, further highlighting the center's impact in research and career development.

Highlights

NEW EPITAXIAL GROWTH SYSTEM FOR COMPLEX OXIDES INSTALLED AT SEAL

The Semiconductor Epitaxy and Analysis Laboratory (SEAL) at Ohio State significantly increased its research capacity in this past year with the installation of a new Veeco GEN930 molecular beam epitaxy (MBE) system dedicated to growth of complex oxide materials. The arrival of this new system brings SEAL's total MBE systems to seven, marking a milestone as its first MBE that is focused solely on complex oxide materials. Operated by IMR, SEAL facilitates fundamental and applied research into the epitaxial growth of a wide range of materials and device structures based on materials like narrow and wide bandgap III-V compound semiconductors, gallium oxide and 2D materials. This new complex oxide MBE system extends SEAL's reach into new dimensions where the novel properties of complex oxide materials and heterostructures can be explored, and developed, for next generation electronics and quantum computing.

The purchase, move and installation of this system were led by Kaveh Ahadi, an assistant professor in Electrical & Computer Engineering and Materials Science & Engineering, as part of his start up at Ohio State.

Among its key features, the Veeco GEN930 system includes a UNI-Block transfer system that handles wafers up to three inches, and a dual-filament high-temperature substrate heater reaching up to 1200°C. Its automatic controller facilitates substrate movement between growth, loading, and monitoring positions, while nine source ports with solenoid-actuated shutters ensure precise deposition.

The system is equipped with advanced cryo shrouds, turbo pumps, and a load-lock chamber for optimal growth conditions. It also features Veeco Molly growth software for streamlined process control, as well as essential components such as the Staib electron source for reflection high energy electron diffraction, Veeco Oxygen RF plasma source, and a custom precursor system to support a variety of materials systems and research applications.

Kaveh Ahadi, an assistant professor in Electrical & Computer Engineering and Materials Science & Engineering, with the Veeco GEN930 MBE system in SEAL.

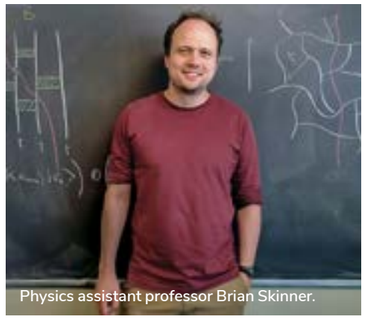
"This system brings new capabilities in synthesis and exploration of novel materials systems which are critical for microelectronics and quantum materials to SEAL and broader Ohio State research community," Ahadi said.

IMR FACULTY MEMBER BRIAN SKINNER EARNS YOUNG CAREER AWARD

Brian Skinner, an assistant professor of Physics, was honored in FY24 with the 2024 Early Career Distinguished Scholar Award, one of the highest honors at Ohio State. The recognition was presented to him during a surprise department meeting by senior leaders from the Enterprise for Research, Innovation and Knowledge.

"It feels very touching that so many people put so much effort into something like this that is extraneous to the rest of their work," he said. "A lot of people worked very hard on this nomination package and I'm very grateful to those who helped make this happen."

Skinner's research focuses on the theoretical aspects of quantum entanglement and the behavior of materials at the quantum level. He also holds a patent for a new form of thermoelectric energy conversion, which turns waste heat into usable electric power.



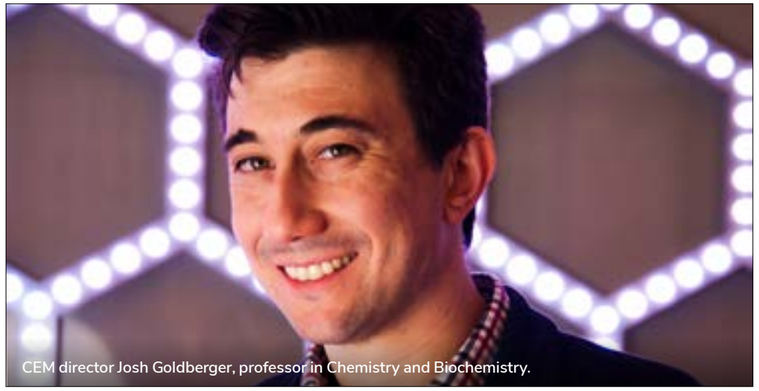
Physics assistant professor Brian Skinner.

Joining Ohio State through the IMR-operated Materials and Manufacturing for Sustainability Discovery Theme, Skinner has continually made significant contributions with his work.

"While Dr. Skinner is early in his career, he's known internationally as an emerging leader in the fields of quantum dynamics, quantum materials and sustainable energy research," said Cynthia Carnes, senior vice president for research operations. "His ability to clearly communicate complex ideas and subjects has won him praise from colleagues and students alike."

Highlights

PROF. JOSHUA GOLDBERGER SUCCEEDS PROF. CHRIS HAMMEL AS DIRECTOR OF THE CENTER FOR EMERGENT MATERIALS



CEM director Josh Goldberger, professor in Chemistry and Biochemistry.

Joshua Goldberger, the Charles H. Kimberly Professor in Chemistry and Biochemistry, was named director of Ohio State's Center for Emergent Materials, an NSF Materials Research Science and Engineering Center (MRSEC), in Autumn 2023. He stepped into the role previously held by P. Chris Hammel for the past 12 years. Goldberger recognized the impactful leadership and vision implemented by Hammel, an Ohio Eminent Scholar and professor of Physics.

In 2008, IMR and then-Ohio State professor Nitin Padture, now at Brown University, secured a $10.8 million NSF award to establish the Center for Emergent Materials (CEM), Ohio State's first MRSEC, which is seen as an indicator of an elite materials research program. Since this initial award, CEM has been awarded subsequent NSF MRSEC funding for the 2014 and 2020 cycles.

Goldberger said CEM is dedicated to fostering the next generation of materials discoveries and researchers through initiatives, like the OSU Materials Research Seed Grant Program, co-funded by IMR. CEM also engages in education and outreach from elementary to graduate levels, while building strong industrial and international collaborations. The center plays a key role in supporting research and course facilities and regularly hosts workshops on emerging scientific topics. Goldberger has already implemented several new initiatives at CEM, including monthly peer networking sessions for young faculty, research team-building events, and student-led workshops. CEM recently partnered with California State University, Long Beach on a new NSF program that connects funded centers to minority-serving institutions to expand access to materials science facilities, education, training and careers.

NSF ERC HAMMER FORGES NEW NON-PROFIT HAIMCo

Hybrid Autonomous Manufacturing Innovations, Inc. (HAMICo) launched in FY24 to develop novel intellectual property from a National Science Foundation-funded Engineering Research Center (ERC) led by Ohio State. The HAMMER ERC includes five universities and more than 70 industry, educational and technical collaborators.

As a 501(c)(3) nonprofit entity, HAMICo aligns the interests of industry, academia, federal agencies, and community stakeholders on projects, incubates intellectual property, develops minimum viable products, and produces prototypes.

HAMICo will commercialize intellectual property through direct licensing, launching and incubating startups, and prototyping and low-volume manufacturing using HAMMER technologies. It is also a new alliance partner of the National Center for Defense Manufacturing and Machining and is establishing cooperative research and development agreements with federal labs.

HAMMER will benefit from significant collaboration with IMR, which was instrumental in developing the proposal development plan and initial external communications work.

Mars G. Fontana Professor of Metallurgical Engineering Glenn Daehn is HAMMER's lead principal investigator and HAMICo's chief scientific officer.

"HAMMER promises to usher in a new era in industrial manufacturing in the United States," he said. "Through basic, applied and translational research, HAMMER is uniquely situated in the innovation ecosystem to develop and deploy intelligent autonomous manufacturing systems. In launching HAMICo, we are embarking on the critical step to connect new discoveries with real-world applications."

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

Highlights

CEMAS CELEBRATES 10 YEARS OF EXCELLENCE AT OHIO STATE

Researcher operating the Titan³™ G2 60-300 S/TEM system at CEMAS.

Students, researchers, and industry leaders celebrated the 10th anniversary of the Center for Electron Microscopy and Analysis (CEMAS) in FY24.

In January 2024, guests gathered at CEMAS to reflect on its impact across various fields, from materials development to cancer research. The reception included researchers, industry partners, and distinguished guests.

The event highlighted CEMAS' achievements over the past decade and its potential in leading innovations in electron microscopy in the future.

"It's important to celebrate and see how far we have come and all the research we have impacted," said Director David McComb, a professor of Materials Science and Engineering who was recruited to Ohio State by IMR from Imperial College London in 2011 to design and lead CEMAS. "We also are looking forward to what CEMAS is poised to do in the next decade."

Speakers from Ohio State and industry partners discussed their collaborations over the past 10 years. Steve Ringel, Executive Director of the Institute of Materials and Manufacturing Research, emphasized CEMAS' significant role in securing large research programs at the university. Michael Mills, Chair of the Department of Materials Science and Engineering (MSE), spoke about how CEMAS has advanced MSE research.

Industry representatives, including Marc Peters from Thermo Fisher Scientific and Narayan Vishwanathan from Ametek, shared how their partnerships with CEMAS have driven innovations in electron microscopy. Keynote speakers included experts in electron microscopy.

Since opening its doors, CEMAS capabilities have been cited more than 600 times in peer-reviewed research and in formal intellectual property filings by industrial partners. Throughout its first decade, CEMAS has enabled innovative research for some of the world's largest companies, including Procter & Gamble (P&G). The relationship with Procter & Gamble began in 2013, focusing on seven leading brands, including Pampers, Pantene, and Gillette. In March, P&G senior scientists visited CEMAS to present the Making the Invisible Visible Award, celebrating a decade of collaboration.

A DECADE OF DISCOVERY: OHIO RESEARCH SCHOLAR BRÜSCHWEILER'S INNOVATIVE IMPACT AT OHIO STATE

In his 11 years since joining Ohio State as a professor and Ohio Research Scholar, Rafael Brüschweiler has dedicated his career to research at the interface of physical chemistry, biochemistry, and analytical chemistry with application to biomedicine.

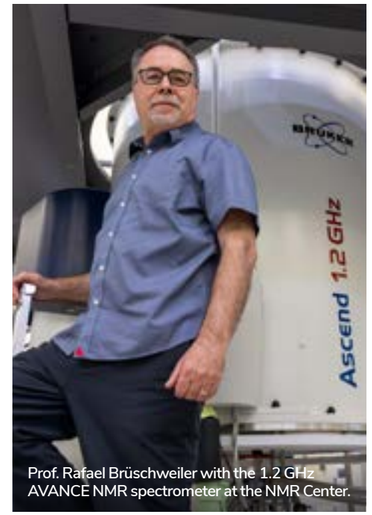
In his lab, Brüschweiler, a professor in Chemistry and Biochemistry, focuses on two main areas. First, he studies protein dynamics, using experimental data and molecular dynamics simulations to observe protein motions across various timescales. His work in metabolomics analysis of cells, organisms and biofluids, contribute to a better understanding of biochemical processes.

IMR led the $18 million, state-funded Ohio Research Scholars Program, forming a coalition of universities and creating five endowed chair positions, including one held by Brüschweiler.

Brüschweiler served as principal investigator on a multimillion-dollar National Science Foundation grant in 2019 that brought North America's most advanced nuclear magnetic resonance instrument yet to Ohio State's National Gateway Ultrahigh Field NMR Center. The instrument enables new liquid and solid-state experiments to study complex chemical systems, from batteries to the dynamics of biological molecules underlying the mechanisms of diseases like cancer and Alzheimer's.

"Technology wise, it's a significant leap," he said. "With these advanced capabilities, we can look at larger and more complex biological, chemical and biochemical systems than ever."

In a study published last year in Nature Structural & Molecular Biology, his team's work uncovered previously hidden regions of the K-Ras protein, linked to 25 percent of human cancers. The findings shed light on dynamic features that drive uncontrolled cell division, a hallmark of many cancers.



Prof. Rafael Brüschweiler with the 1.2 GHz AVANCE NMR spectrometer at the NMR Center.

Brüschweiler is an elected fellow of the American Physical Society and Association for the Advancement of Science. He is also a recipient of the Günther Laukien Prize.

Global Partnerships

OHIO STATE, IIT BOMBAY BUILD ON HALF DECADE OF SUCCESS WITH AGREEMENT TO CONTINUE SHARED RESEARCH CENTER

The Ohio State University and the Indian Institute of Technology Bombay are continuing to advance pioneering research on cutting-edge technologies through a unique global partnership.

Over the last five years, Ohio State and IIT Bombay have fostered a collaborative environment, leveraging each other's strengths and expertise to drive forward innovative research initiatives. This collaboration is facilitated through the IIT Bombay-Ohio State Frontier Science and Engineering Research Center. Since its establishment, the Frontier Center has enabled funding and development for 24 projects delving into diverse realms of applied and fundamental research in the U.S. and India. These projects span across renewable energy, electronics, photonics, semiconductors, materials sciences, and quantum information technology.

The center serves as a nexus for principal investigators and students from both institutions, pooling together their universities' expertise and infrastructure to expand the boundaries of science and engineering beyond the capabilities of individual entities.

In FY24, the two institutions solidified their commitment to ongoing collaboration by signing a memorandum of understanding, with a mutual agreement to not only sustain existing partnerships but also to broaden and diversify the spectrum of research areas explored by these two esteemed institutions. The governments of the United States and India have continued to encourage economic and research collaboration between the two countries, and the Frontier Center will support both institutions to take advantage of these opportunities.

Ohio State's Nathan Gajowski (right) with IIT Bombay grad student Karthik Raitani atop Sameer Hill in Mumbai.

Nathan Gajowski (right) with fellow Frontier Center Scholar Bhupesh Bhardwaj (second to the right) and friends at the India Gate in New Delhi.

IMR executive director Steven Ringel, one of the Frontier Center founders, noted that "the timing of the expanding partnerships between the United States and India though both academic and industrial channels couldn't be better for the Frontier Center as it continues its expansion into strategic areas for both countries such as next generation semiconductors, advanced energy technologies, quantum and AI."

Graduate students also benefit from the collaboration, immersing themselves in diverse research opportunities, educational experiences, and cultural exchanges during their semester-long stay at the partner university. Nathan Gajowski left Ohio State in FY24 to work with IIT Bombay Prof. Bhaskaran Muralidharan. For him, the benefits of his time in India expanded far past his work in the lab.

"I believe this exchange experience has made me a more well-rounded person, more grateful, and happier in life overall. I was even able to visit the Ohio State India Gateway and share my Buckeye experience with admitted undergraduate students and their parents. It felt great to share my story, answer their questions, and give back to the university in a small way," he said.

IIT BOMBAY PROF. DINESH KABRA JOINS FRONTIER CENTER LEADERSHIP TEAM

IIT Bombay Prof. Dinesh Kabra.

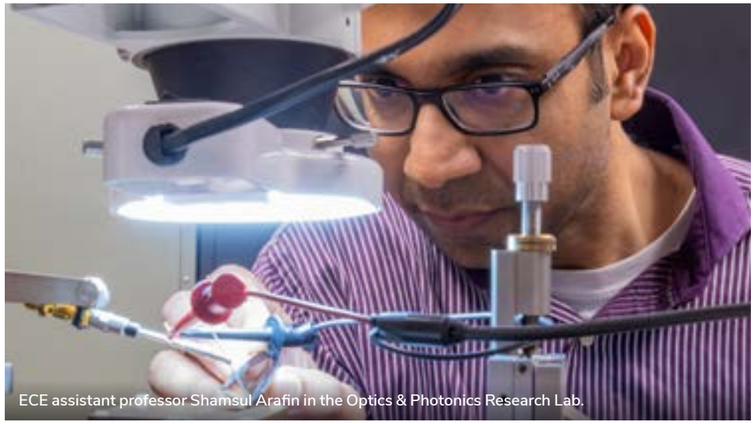
In FY24, the Frontier Center welcomed Prof. Dinesh Kabra, from the IIT Bombay Department of Physics, as its newest member of the leadership team. He joins Electrical Engineering Prof. Saurabh Lodha as faculty center leaders from the university in Mumbai, India. Their U.S. counterparts are Ohio State Prof. Anant Agarwal, in Electrical and Computer Engineering, and IMR visiting fellow Ardeshir Contractor.

Kabra said he is excited to continue the Frontier Center's work fostering collaborative efforts aimed at maximizing impact in the competitive global landscape of research and technological advancements. He added that the center has the opportunity to combine resources and knowledge from the two universities to enhance synergy and achieve greater outcomes collectively.

"My goal is to see a clear growth in diverse areas of research being carried out in these two world class institutions by exchange of students and joint ideas and grants," Kabra said.

Global Partnerships

NSF GRANT TO ADVANCE IMR-IRELAND COLLABORATION SPEARHEADING INNOVATIVE PHOTONICS RESEARCH


ECE assistant professor Shamsul Arafin in the Optics & Photonics Research Lab.

Ohio State was awarded a significant National Science Foundation (NSF) grant for pioneering research in visible light-wave generation and manipulation. The research has the potential to revolutionize biophotonics with miniaturized, cost-effective photonic circuits that would enhance healthcare diagnostics and treatment.

The $425k U.S.-Ireland partnership VIBRANT (Visible Light-wave Generation and Manipulation through Non-Linear Waveguide Technology) was seeded by the Catalyst Program, jointly operated by Ohio State's IMR and Tyndall National Institute, based at University College Cork in Ireland. The award stems from the Tyndall-IMR Catalyst Program, which supports collaborative projects leveraging the strengths of both institutions. These projects aim to generate joint publications and proposals for impactful research. The initiative is part of IMR's broader effort to foster international research and expand global collaborations. NSF funding for VIBRANT is matched by grants from the Science Foundation Ireland and the Northern Ireland Department for the Economy.

VIBRANT is a collaboration between Ohio State and Ireland's Queen's University Belfast (QUB), Munster Technological University (MTU), and Tyndall. Separate funding has been provided to Tyndall and MTU by Science Foundation Ireland (SFI) while the Department for the Economy in Northern Ireland is funding the work at QUB.

"This international partnership underscores the project's global impact, paving the way for advancements in photonic technologies across sensing, security, medical research, and communication fields," said Ohio State's Shamsul Arafin, who leads the project in the U.S. Arafin is an assistant professor in Electrical and Computer Engineering and director of the Optics and Photonics Research Lab.

Arafin's collaborating partner is senior researcher Brian Corbett, who leads the project in Ireland and heads up the III-V materials and devices group at Tyndall.

"Together, we address the integration of lasers onto tiny chips leading to the more widespread use of photonics in providing solutions across medical devices to consumer applications," Corbett said. "For example, continuous optical sensing of biomarkers in the blood will enable more effective individual management of disease such as the monitoring of glucose for diabetes. Another example is realizing efficient high brightness displays. Compact, high brightness displays are desired for phones and augmented reality displays where efficiency is required for extended battery life."

Research in biophotonics is important because it aims to improve the sensing and optical imaging techniques to study the structure and function of cells or tissue at the microscopic and nanoscopic levels.

The project will advance the forefront of optical technology by aiming to create a fully operational optical system on a centimeter-scale chip, a significant leap over the current cumbersome and costly state-of-the-art optics used in healthcare. This technological breakthrough is expected to offer significant advantages in terms of size, weight, power, and cost, thereby enabling a wide array of emerging applications.


Tyndall National Institute, in Ireland.

Arafin emphasized that the project's innovation hinges on the development of green photonic circuits, incorporating novel architectures for dense photonic integration on a chip. These circuits will employ second-harmonic-generation materials in conjunction with silicon nitride waveguides and infrared III-V pump lasers, enabling on-chip generation of green light.

The VIBRANT project places an emphasis on fostering international collaboration and educational outreach. Graduate and postdoctoral students gain invaluable experience through joint experiments and exchange visits with partner institutions, promoting a rich exchange of research knowledge and collaborative development. IMR and Tyndall have supported three Catalyst programs. The other two projects focus on investigating ferromagnetic properties of materials for future data storage applications and prototyping cutting-edge optical wireless communication technologies aimed at significantly increasing data transmission rates, respectively.

Experiential Learning

IMR INTERNSHIP PROGRAM OFFERS REAL-WORLD EXPERIENCE, EDUCATION TO UNDERGRADUATE STUDENTS

Thirteen undergraduate students in FY24 were welcomed into the IMR Internship Program to take advantage of experiential learning opportunities. The program offers paid, learning-by-doing positions in a range of spaces at Ohio State's Nanotech West Lab.

The program creates new avenues of experiential learning for students, including research experience for undergraduate students, graduate research associateships and externships.

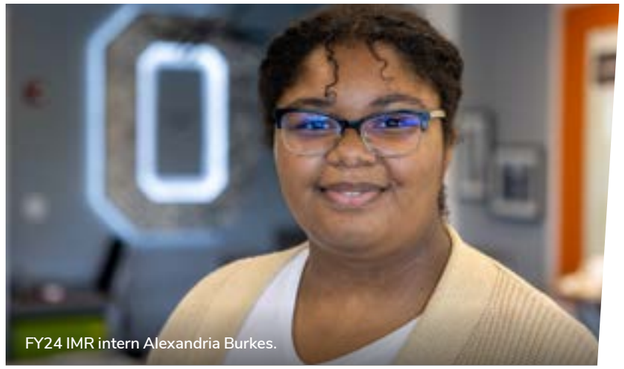
Each paid position engages students enrolled and external to Ohio State with hands-on experience and education related to their fields of study or career goals. Undergraduate student interns at Nanotech West Lab, located on West Campus, generally come from a range of studies spanning engineering to business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

Alexandria Burkes began the IMR internship in FY24 as a student web development and administrative intern. During the internship, Burkes strengthened technical skills by working with Power Apps and learning C programming, while also improving communication and teamwork through collaborative, problem-solving projects. This experience boosted Burkes' confidence in creating a strong resume and cover letter, and helped establish valuable connections that will support future career opportunities.

"Being a student at IMR has been a top professional experience for me during my college career," she said. "It provided a balance of technical and soft skills, preparing me for a professional setting. Plus, being able to have a balanced work and study schedule was great."

Chris Staudt, a recent Columbus State electro-mechanical engineering graduate, first learned about IMR's internship program in 2022, at an open house event. Staudt soon joined the internship program, and is now Nanotech West Lab's newest full-time lab research operations technician.

"Initially, I thought I had to go out of state to receive this type of experience. Through this experience, I have observed the stages and tooling needed for a device to be built up," he said. "Nanofabrication was a realm I always felt I'd be relegated to merely observing from a far-off distance, and yet this internship has offered the opportunity to step into a cleanroom and get hands-on experience right away."



FY24 IMR intern Alexandria Burkes.

Chris Staudt, former intern and new NTW lab research operations technician.

IMR PROGRAM ASSISTANT LAURIE COYNE PAVES WAY FOR STUDENT SUCCESS

IMR program assistant Laurie Coyne.

IMR program assistant Laurie Coyne serves as a crucial bridge between IMR and prospective student interns, fostering collaborative relationships that allow students to thrive through hands-on learning experiences. As a Columbus State Community College alumna, she understands firsthand the value of the programs and partnerships that help bring innovative ideas to life within the IMR internship program.

"Some of the most innovative ideas come from our student interns; they offer a fresh perspective and enthusiasm," she said.

Coyne is typically the primary point of contact for student interns, ensuring a seamless connection between IMR and its student workforce. She plays a pivotal role in the management and onboarding of IMR student intern positions. She coordinates between student candidates, IMR administration and other staff involved in the hiring process, ensuring a seamless onboarding experience for new interns. She also coordinates Nanotech West Lab facility tours for classes from Columbus State and Ohio State throughout the year. Furthermore, she manages and hosts the annual Columbus State info sessions and is program coordinator for ExLENT BATTERI student interns.

Seed Grant Awards

IMR PROVIDES SEED FUNDING FOR 29 NEW PROJECTS IN FY24

Twenty-nine new projects led or co-led by researchers at Ohio State received seed funding support in FY24 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 four international research teams through the IIT Bombay-Ohio State Frontier Center Scholars Program. Additionally, IMR awarded 18 teams through its Kickstart Facility Grant Program. Lastly, seven 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. Four Global Partnership Grants were awarded in FY24.

Frontier Center Scholars Program

Additively manufactured advanced high strength steels: linking chemistry, structure, and mechanical response
PIs: Peter M. Anderson, Ohio State, Materials Science and Engineering; N. Jaya Balila, IIT Bombay, Metallurgical Engineering and Materials Science, and Prita Pant, IIT Bombay, Metallurgical Engineering and Materials Science

Exciton Franz-Keldysh E-field spectroscopy in ultra wide gap semiconductors
PIs: Roberto Myers, Ohio State, Materials Science and Engineering, and Electrical and Computer Engineering; Bhaskaran Muralidharan, IIT Bombay, Electrical Engineering

Study of impact ionization and valence band dynamics in quaternary multipliers on InP and GaSb substrate
PIs: Sanjay Krishna, Ohio State, Electrical and Computer Engineering; Bhaskaran Muralidharan, IIT Bombay, Electrical Engineering

Topologies and control of energy efficient power electronic converters for microgrids involving energy storage system
PIs: Mahesh Illindala, Ohio State, Electrical and Computing Engineering; Anshuman Shukla, IIT Bombay, Electrical Engineering

KICKSTART FACILITY GRANTS

Kickstart Facility Grants strengthen near-term research proposals for external support by helping offset costs associated with research facilities and making shared campus research facilities more accessible. Eighteen Kickstart Facility Grants were awarded in FY24.

Autumn 2023

Enzymatic Nanofungicide as an Innovative Food Packaging Biomaterial
PI: David Wood, Chemical and Biomolecular Engineering

Role of extracellular vesicles on prospective vasculogenic cell therapies for Alzheimer's Disease
PI: Diego F Alzate Correa, Biomedical Engineering

Unrevealing the Structure-Performance Interrelationship of A Class of HydrogelBased,

Electro-Responsive Interface for Precise Chemical Release
PI: Jinghua Li, Materials Science and Engineering

Molecular Beam Epitaxy of Complex Oxides with Large Spin-Orbit Coupling
PI: Kaveh Ahadi, Materials Science and Engineering, Electrical and Computer Engineering

Non-contact, Non-destructive, Wafer-level Evaluation of Surface Properties in Antimonide Based Nanowires
PI: Punam Murkute, Electrical and Computer Engineering

Operando Insights into WSe2 Catalysis for CO2 Reduction
PI: Salva Salmani-Rezaie, Materials Science and Engineering

Seed Grant Awards

Investigating Optical Properties of Ar intercalated Low-Defect h-BN by Cathodoluminescence
PI: Shamsul Arafin, Electrical and Computer Engineering

Culinary Castoffs to Cutting-Edge Bio-Composites: Upcycling and Value addition of Cooking Waste into Sustainable, High-Performance Biodegradable Epoxy Thermosets, a Sustainability Pathway Toward a NetZero Future
PI: Sriloy Dey, Food Science and Technology

Photophysical Properties of Cu-Doped Nanoceria: Role of Cu2+-Mediated sub-bandgap states on photocatalytic properties of nanoceria
PI: Supriya Ghosh, Chemistry and Biochemistry

Visualization and Characterization of Bacterial Extracellular Vesicles used to Mediate the Sensitization of Phage-Resistant Strains
PI: Tatiana Cuellar-Gaviria, Biomedical Engineering

Topological dipole lattices in geometrically confined nematic liquid crystals
PI: Xiaoguang (William) Wang, Chemical and Biomolecular Engineering

Spring 2024

Characterization and Analysis of Additively Manufactured Maraging Steel by Analytical Electron Microscopy with Electron Energy Loss Spectroscopy and X-ray Energy Dispersive Spectroscopy
PI: Robert E A Williams, Center for Electron Microscopy and Analysis

Design and development of combination therapies for the treatment of Neovascular age-related macular degeneration
PI: Ravi Saklani, Biomedical Engineering

Exploring Tomato Cuticle Responses to Drought Stress: Insights into Plant Defense Mechanisms
PI: Pu Yuan, Plant Pathology

High-Speed Barium Titanate Electro-Optic Modulators for Photonic Integrated Circuits
PI: Shamsul Arafin, Electrical and Computer Engineering

High-throughput microstructural-based mechanical property predictions
PI: Johan Westraadt, Center for Electron Microscopy and Analysis

Prediction of Rib Structural Properties from 3D Cortical Pore Morphometry
PI: Mary Cole, Division of Radiologic Sciences and Therapy

Preparation and Characterization of Electrochemically Etched Tips for Ultrafast Element-Resolved Scanning Tunneling Microscopy
PI: TJ Ronningen, Electrical and Computer 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. Two Exploratory Materials Research Grants were awarded in FY24.

In situ resource utilization with parallel extraction and additive manufacturing of lunar regolith for aluminum alloys
PI: Sarah Wolff, Mechanical and Aerospace Engineering with a joint appointment in Integrated Systems Engineering
Co-PI: Alan Luo, Materials Science and Engineering, with a joint appointment in Integrated Systems Engineering

Phase-field modeling of morphology evolution at anode/electrolyte interfaces of Li-metal-based all-solid-state batteries
PI: Yanzhou Ji, Materials Science and Engineering
Co-PI: Jung Hyun Kim, Mechanical and Aerospace Engineering

Multidisciplinary Team Building Grants

Exploratory Materials Research Grants fund multidisciplinary materials research teams that can later compete effectively for federal block-funding opportunities. Three Multidisciplinary Team Building Grants were awarded in FY24.

Development of Metallic Alloy Anodes for Solid-State Batteries
PI: Jung Hyun Kim, Mechanical and Aerospace Engineering
Co-PI: Alan Luo, Materials Science and Engineering, with a joint appointment in Integrated Systems Engineering

Exploring Zeolite Solide State Electrolytes for Potassium Batteries
PI: Yiying Wu, Chemistry and Biochemistry
Co-PI: Nicholas Brunelli, Chemical and Biomolecular Engineering

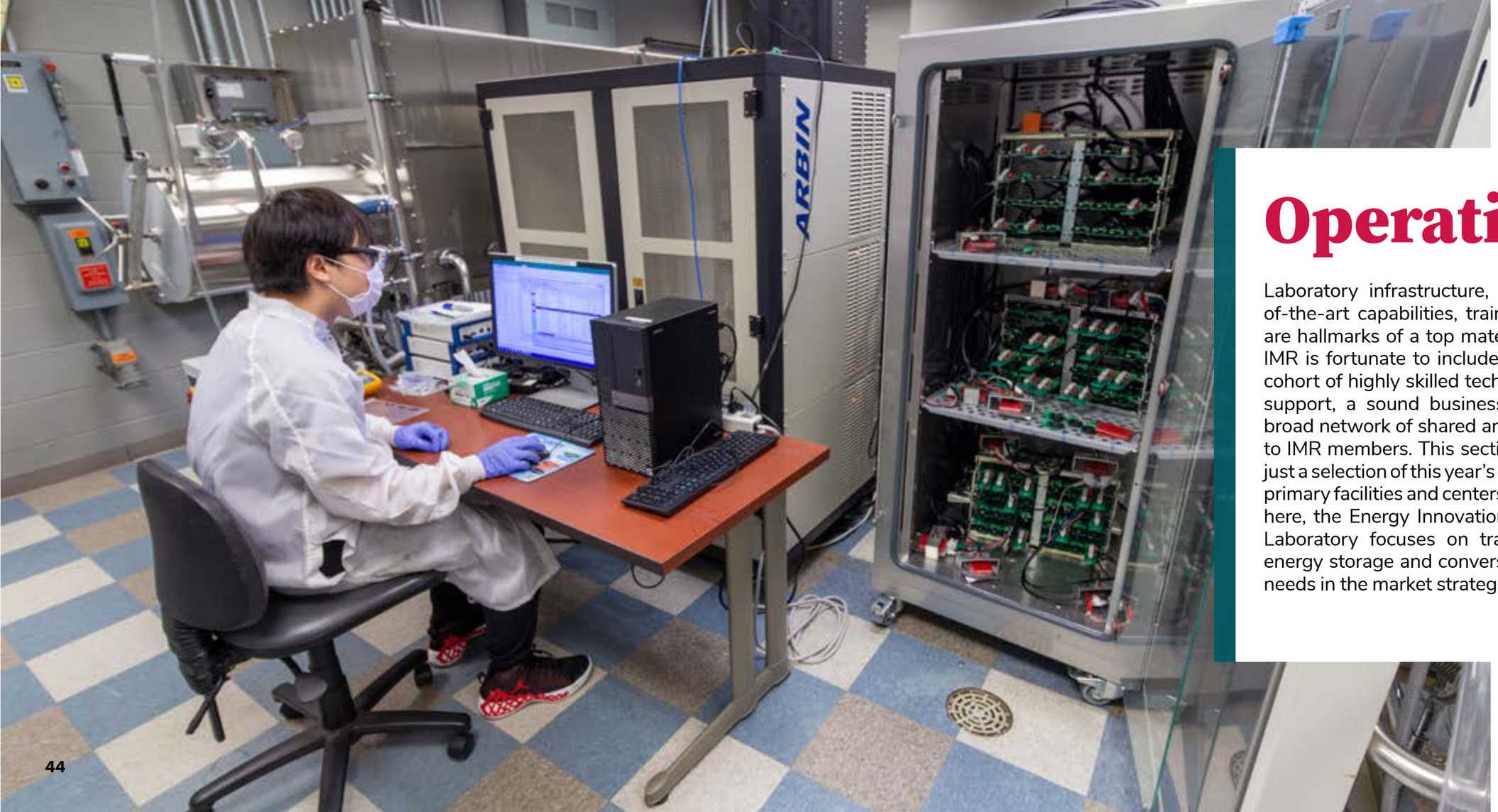
Quantum Twist Microscope
PI: Marc Bockrath, Physics
Co-PI: Jay Gupta, Physics

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 FY24.

Transducing conformational dynamics across scales
PI: Carlos Castro, Mechanical and Aerospace Engineering
Co-PI: Ralf Bundschuh, Physics
Co-PI: Michael Poirier, Physics

Superconductivity at the Nexus of Magnetism and Ferroelectricity for Quantum Applications
PI: Salva Salmani-Rezaie, Materials Science and Engineering
Co-PI: Kaveh Ahadi, Materials Science and Engineering
Co-PI: Jeanie Lau, Physics
Co-PI: Nandini Trivedi, Physics



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 (NTW) 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), NTW 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.

NTW'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 and shared labs for research in energy storage materials and devices. With nearly 300 active users and 99 new users trained in FY24, research activities at NTW 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, 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, NTW 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 IMR's Materials and Manufacturing for Sustainability Discovery Theme, starting in 2015, and its strategic faculty recruitment, NTW continues to expand its impact by continually installing new equipment and lab enhancements to support cutting-edge capabilities and additional research thrusts. While all the critical labs at NTW continue to expand capabilities offered within the user facility, FY25 will bring with it some significant equipment purchases to expand and augment existing capabilities.

Developing labs that continue to expand capabilities offered within the user facility include 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).

In March 2024, NTW welcomed Chris Staudt as a nanofab technician with primary responsibility in lithography equipment and processing. Chris is a former undergraduate intern in the Nanofab from Columbus State Community College. We send our best wishes to Dave Hollingshead as he accepted a position with the National Renewable Energy Lab in Golden, CO. Dave was a long-time staff member, starting at Nanotech West as an ECE M.S. student, then returning as a research associate and the first manager of research operations.
Learn more: nanotech.osu.edu.

Nanotech West Laboratory

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 associate 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.

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-power GaN PN diodes with record breakdown voltage of >11 kV. Funded by a new Department of Defense Multidisciplinary University Research Initiative (MURI) project, Prof. Zhao will develop the next generation ferroelectric nitrides using the nitride MOCVD reactor. The 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 MURI program, DOE ARPA-E, National Science Foundation, Semiconductor Research Corporation, among others.

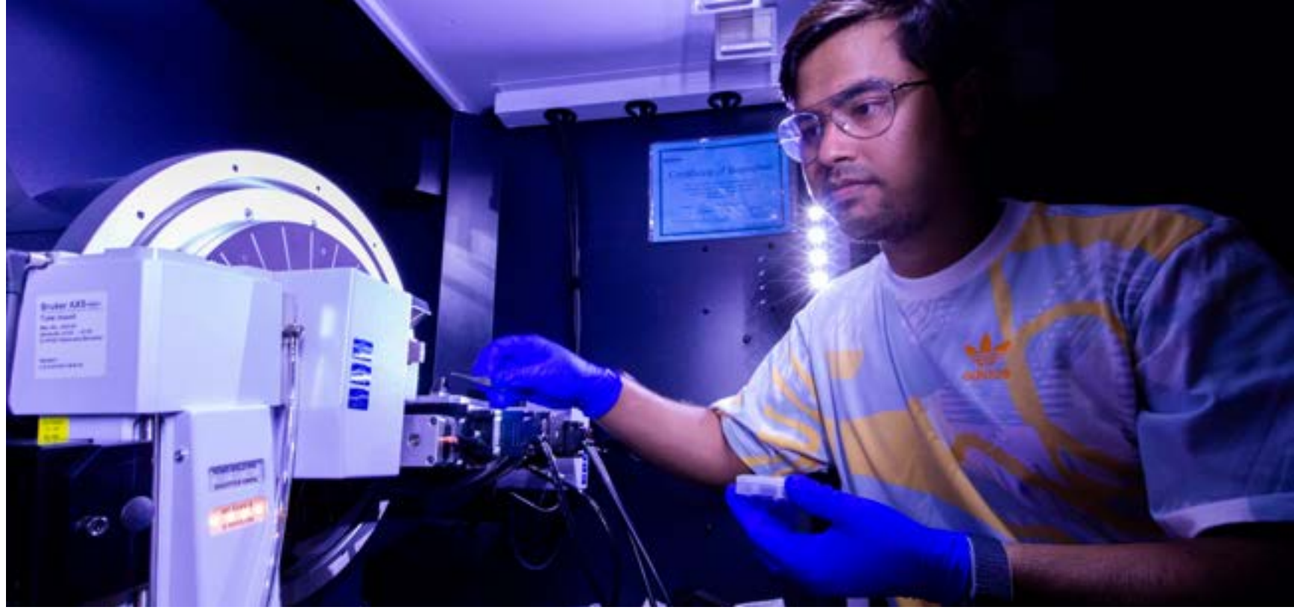
IMR INNOVATION LAB

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 350 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 two 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 has been engagement with more than 85 companies in multiple ways that 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.

Nanotech West Laboratory

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 affiliated staff members, plus graduate student super-users and undergraduates, the Nanofab supports researchers from Ohio State and many external organizations. Numerous investments in processing equipment capabilities were realized in 2024. In November '23 a new state-of-the-art 100kV Raith EBPG 5150 Plus electron beam lithography system was installed, funded by Major Research Instrumentation (MRI) award by the National Science Foundation and is now open to users for patterning. Additionally, a new Plasma Therm Takachi ICP-RIE enhanced the etch capabilities with new etch gas options and a wider substrate temperature range, enabling improved etch rates for challenging layered epitaxial compound semiconductor materials. Building on IMR's vast heterogeneous epitaxy portfolio, an addition of an X-Celeprint Micro-Transfer Printer (MTP) into the Nanofab enables assembly of diverse semiconductor devices onto various substrates. This allows researchers to choose the most appropriate path for hetereogenous materials and devices, whether it be through direct epitaxy or micro-transfer printing. Further investments in FY '25 include numerous capabilities to support the Midwest Microelectronic Consortium (MMEC) Infrastructure program. NTW will add a second Heidelberg MLA150 direct write laser lithography tool to increase photolithography capacity. For dielectric deposition, a Veeco Fiji plasma enhanced atomic layer deposition (PE-ALD) will expand breadth of ALD films at NTW to include nitrides and SiO2 which had not been possible previously at NTW. Metal deposition for high quality Ohmic and Schottky contacts on semiconductors has been a bottleneck in the Nanofab, even with two electron beam evaporators for that purpose. A third evaporator, Angstrom AMOD electron beam evaporator, will be added to increase capacity, capability, and flexibility. It has tooling to optimize either liftoff or step coverage depositions, optional cooled stage for nanostructure fabrication, and an in-situ ion beam cleaning option to remove surface oxides or contaminants prior to deposition. These improvements in etching and deposition will necessitate expanded step height, roughness, and optical inspection techniques. NTW will add both stylus and optical 3-D profilometers to the metrology suite to give researchers the option to make a physical or optical (non-contact) measurement, with either a Bruker DektakXT Advanced stylus or an RTEC UP-3000 optical profilometer respectively.



OPTO-ELECTRONIC METROLOGY (OEM) LAB

The Opto-electronic Metrology (OEM) Lab at Nanotech West Laboratory (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. 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 device promising efficient light modulation for communication and display applications.

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, completed over 700 projects and has been awarded over $140 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 430 undergraduate students across academic disciplines have been impacted by CDME to date, with over 100 students employed by the center in FY24. CDME strives to execute its innovative approach to technology translation and workforce development while shaping the national conversation on advanced manufacturing innovation.

RESEARCH REVIEW: MODERNIZING METAL CASTING WITH ADDITIVE MANUFACTURING

CDME, with industry partners and supported by America Makes, is developing an additive manufacturing-enabled approach for investment castings, which streamlines the process, improves engineering outcomes and increases efficiency. Metal casting – one of the oldest manufacturing processes – is currently undergoing a significant transformation and CDME is at the forefront of this revolution. A key innovation in the project is the use of direct 3D printed ceramic shells, cutting down on a typically a time-consuming process. By 3D printing the ceramic shell directly from a digital model, the need for wax patterns and manual shell building is eliminated, significantly reducing lead times, and improving precision. CDME is also advancing the use of 3D printed molds and patterns for sand casting, further highlighting how additive manufacturing is reshaping casting techniques across the industry.

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. 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. During FY24, the center supported 292 users, including 123 principal investigators.
Learn more at cemas.osu.edu.

RESEARCH REVIEW: VISUALIZING A NEW PLANT-BASED MEAT ALTERNATIVE

Doctoral student Ana Maria Velasquez-Giraldo is developing a new high protein plant-based meat analog with increased fat through extrusion. Using specialized equipment at CEMAS is helping ensure that the product is tasty as well as nutritious. Velasquez-Giraldo uses the Heliscan technology to perform microCT to see if the analog's fibers align correctly to create a favorable texture. The technology allows scientists to gain insight from internal structures to validate a wide range of material properties, investigate suitable extrusion conditions, classify samples and see properties that are not visible to the human eyes but impact texture. The 3D images of samples create a digital recreation of the whole muscle meat analog. Traditional characterization methods have proven challenging, like using approximate measurements from samples with no way to quantify them.

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 seven state-of-the-art MBE chambers, each dedicated to different, complementary material systems to provide epitaxial growth of crystalline layers, heterostructures, nanostructures, and device structures in a variety of material domains. Research focuses on a range of semiconductor materials, including III-V materials based on arsenides, phosphides, antimonides, and nitrides, as well as advanced oxides and 2D materials. This past year witnessed the installation of SEAL's seventh MBE system, which is dedicated to complex perovskite oxide materials and devices. This new capability is aligned with the recent hiring of Prof. Kaveh Ahadi, SEAL's newest faculty member, who has joint academic appointments in the Department of Materials Science and Engineering and the Department of Electrical and Computer Engineering. SEAL capabilities also include a wide range of advanced materials characterization tools, including high resolution x-ray diffraction, photoluminescence and Hall effect, to support epitaxial materials research. SEAL is managed by IMR and operates under the guidance of the Department of Electrical and Computer Engineering and the College of Engineering. Learn more at seal.osu.edu.

RESEARCH REVIEW: MOLECULAR BEAM EPITAXY GROWTH OF HIGH PERFORMANCE INFRARED APDS

Using the SEAL facility, researchers in Professor Sanjay Krishna's KIND Lab have demonstrated high performance avalanche photodiodes (APDs) operating beyond the 2 µm wavelength. These devices were grown on InP substrates using SEAL's Antimonide Molecular Beam Epitaxy Reactor (AMBER). The device structure required the integration of both random alloy quaternary material and type-II superlattice material into a single growth run and optimize the growth conditions for low background carrier concentration. This unique material combination enabled the resulting device to inherit the favorable gain and noise properties of the AlGaAsSb multiplier, while maintaining photosensitivity to wavelengths beyond 2 µm due to the InGaAs/GaAsSb superlattice absorber. This work was published in Nature Communications Materials in 2024.

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, C-Trap Optical Tweezers microscopy and Kerr microscopy. NSL operates two 1,100-square-foot clean rooms, housing deposition, lithography, etching, and gloveboxes. Learn more at nsl.osu.edu.

RESEARCH REVIEW: LOCALIZED PLASMONIC HEATING FOR SINGLE-MOLECULE DNA RUPTURE MEASUREMENTS IN OPTICAL TWEEZERS

The research groups of Ezekiel Johnston-Halperin (Physics, Ohio State) and Michael G. Poirier (Physics, Ohio State) in collaboration with the groups of Jessica O. Winter (Chemical and Biomolecular Engineering, Ohio State) and Carlos E. Castro (Mechanical and Aerospace Engineering, Ohio State) conducted studies on the thermodynamic and kinetic processes that underlie biological function and nanomachine actuation in biological- and biology-inspired molecular constructs. Unlike the previous studies, that had primarily focused on photothermal heating of ensemble systems, the current study presents an experimental demonstration of wavelength-selective, localized heating at the single-molecule level using the surface plasmon resonance of a 15 nm gold nanoparticle (AuNP). The demonstrated approach is compatible with force-spectroscopy measurements and can be applied to studies of the single molecule thermodynamic properties of DNA origami nanomachines as well as to biomolecular complexes. The approach demonstrated wavelength selectivity and established the temperature dependence of the reaction coordinate for base-pair disruption in the shear-rupture geometry, demonstrating the utility and flexibility of this approach for both fundamental studies of local (nanometer-scale) temperature gradients and rapid and multiplexed nanomachine actuation. The research used the C-Trap optical tweezers microscope by Lumicks (Amsterdam, The Netherlands) operated by the OSU NanoSystems Laboratory. This work was supported by the U.S. Department of Energy (DE-SC0017270 to E.J.-H., M.G.P., C.E.C., J.O.W.). The National Institutions of Health provided support for the C-Trap instrument (S10OD028705 to M.G.P.). The results and discussions are presented in the publication: Prerna Kabtiyal, Ariel Robbins, Elizabeth Jergens, Carlos E. Castro, Jessica O. Winter, Michael G. Poirier, and Ezekiel Johnston-Halperin, "Localized Plasmonic Heating for Single-Molecule DNA Rupture Measurements in Optical Tweezers" Nano Letters 2024 24 (10), 3097-3103.

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. In FY24, IMR hosted two events in the Distinguished Leacture Series and supported several other events, including the Ohio State Women in Nano networking and discussion series. 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 250 faculty members.

Events

DISTINGUISHED LECTURE SERIES, FALL '23: THE UNPRECEDENTED PROMISE OF PEROVSKITE PHOTOVOLTAICS, WITH NITIN P. PADTURE OF BROWN UNIVERSITY

During IMR's Fall 2023 Distinguished Lecture Series, Nitin Padture, the Otis E. Randall University Professor in the School of Engineering at Brown University, presented research in the development of techniques like grain-coarsening and interfacial engineering to improve the efficiency, stability and durability of perovskite solar cells, or PSCs.

These solar cells are emerging as a promising technology for generating low-cost, high-efficiency renewable electricity. At the heart of PSCs are metal-halide perovskites, which have unique crystal structures that provide excellent optical and electronic properties. However, challenges such as stability and mechanical reliability have hindered their commercialization.

Padture is the founding director of the Initiative for Sustainable Energy. He previously served as Director of Brown's Institute for Molecular and Nanoscale Innovation. He was also a College of Engineering Distinguished Professor at Ohio State and founding director of the Center for Emergent Materials.

DISTINGUISHED LECTURE SERIES, SPRING '24: DEEP TECH FOR HUMAN AND PLANETARY HEALTH: STARTUPS REINVENTING THE MEANS OF MANUFACTURING, WITH SEAN O'SULLIVAN OF SOSV

Prominent climate tech investor and SOSV founder Sean O'Sullivan experienced firsthand cutting-edge innovations from students and met with researchers driving technological advancements. O'Sullivan serves as the managing general partner at SOSV, a venture capital firm that manages $1.5 billion in assets. Its primary mission is to support founders aiming to significantly impact human and planetary health through multi-stage investments, spanning from pre-seed startup programs to deep tech ventures. In his lecture, O'Sullivan emphasized the urgent need to transform our production methods across various sectors, including food, manufacturing, and materials, to halt the emission of greenhouse gases that endanger our planet's health. After the talk, O'Sullivan participated in an interactive panel. then toured Ohio State's Main and West Campus research facilities and students at the Student Entrepreneurs' Center for the 2024 President's Buckeye Accelerator.

Events

WOMEN IN NANO
NETWORKING WITH INTEL, PROF. ANNE CO AND SEMI

The Ohio State Women in Nano (WIN) networking and discussion series hosted three events in FY24, welcoming panelists and speakers from industry and academia to connect with students. WIN strives to create a supportive community of women and grow interest in the micro and nanotechnology-related fields.

WIN kicked off the year in September 2023 with a special panel of four experts with diverse roles at Intel, ranging from department managers to a program leader. Their discussion covered a wide array of topics, including their career journeys, accomplishments, challenges, and opportunities in STEM fields and nanotech-related areas.

The following WIN event in January 2024 featured Ohio State's Anne Co, a professor in the Department of Chemistry and Biochemistry, who took attendees through her career, from industry to universities abroad, before landing in Columbus and launching her startup.

The third event followed SEMI's Semiconductor Day 2024, which encourages students to engage with industry leaders visiting Ohio State in April. Senior program manager Margaret Kindling spoke about her work at the SEMI Foundation, focusing on workforce development grounded in diversity, equity, inclusion, and belonging.

2024 ARMY RESEARCH OFFICE REVIEW MEETING
FOR ULTRA-WIDE BANDGAP RF ELECTRONICS CENTER

In late February 2024, IMR supported the 2024 Army Research Office Ultra-wide Bandgap RF Electronics Center Review Meeting. The three-day event at the Blackwell Inn and Pfahl Conference Center on Ohio State's main campus welcomed Army Research Office representatives and dozens of experts from institutions of higher education across the country to discuss collaborative development of next-gen semiconductor devices for wireless communication and radar applications.

The center facilitates collaboration between academic researchers and the U.S. Army to achieve the shared objective of developing the essential knowledge required to advance the next generation of RF electronics, delivering unprecedented capabilities in power, bandwidth, frequency flexibility, and size, weight, and power (SWaP) efficiency. The project partners Ohio State researchers led by lead principal investigator Siddharth Rajan, a professor in Electrical & Computer Engineering and Materials Science & Engineering, with experts from the Georgia Institute of Technology, MIT, Sandia National Laboratories, the State University of New York at Buffalo, the University of Arkansas, and UC Santa Barbara.

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.

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Great things happen when Buckeyes come together.

A gift of support to the IMR Development Fund helps IMR in its mission to create, nurture and grow research excellence and impact at The Ohio State University, with the long-term goal of positioning the university as a world leader in materials research and innovation.

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go.osu.edu/imr-development-fund

Interested in becoming an IMR faculty member?

An IMR faculty member is part of a community spanning 43 departments at The Ohio State University. Members join an interconnected, interdisciplinary community of researchers that share IMR's vision of creating a global reputation of excellence and impact at Ohio State through world-class basic and applied materials research, technology advancement, and innovation.

Members have access to...

- Award funding opportunities from seed grant programs managed or co-managed by IMR, including Kickstart Facility Grants, Global Partnership Grants and OSU Materials Research Seed Grants.
- IMR proposal development assistance, which supports the development of competitive proposals from pre-solicitation to submission.
- IMR-supported core research facilities that IMR operates fully, supports directly through our network of IMR staff, or through which IMR is engaged via our seed grant programs and other promotional means.
- The latest news relating to materials-allied research through the IMR newsletter.

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