INSTITUTE FOR MATERIALS RESEARCH

FISCAL YEAR 2021

ANNUAL REPORT

THE OHIO STATE UNIVERSITY

INSTITUTE FOR MATERIALS RESEARCH

Letter from Executive Director Steven A. Ringel

It would be an understatement to say that the 2021 Fiscal Year was challenging, given the wide-ranging impact of the pandemic on our students, staff, faculty and the Ohio State community. And yet I am so proud of how our Institute's amazing and talented individuals and teams defined many of Ohio State's best practices throughout all stages of our response to the pandemic, that truly "kept us researching." Thanks to them, we are now at an excellent point to move toward a normal state in the coming year.

Despite moving through the stages of ramp-downs, shut-downs, ramp-ups, while ensuring safe practices the entire time, the Institute continued to have incredible impact and experience significant growth. We landed several very large block grants to support multi-college materials research and large new instrumentation acquisition. We developed a new partnership with the College of Medicine and the Center for Design and Manufacturing Excellence that culminated in the creation of IMR's M4Lab, our newest core facility that is focused on the biomanufacturing of medical models via a shared 3D bioprinting capability. We developed and scaled up a new Energy Innovation Lab focused on translational advance energy storage technologies with industry partners and faculty members from Arts and Sciences and Engineering. We increased our global partnership activities by adding a number of new projects with IIT-Bombay, via the Frontier Center, and with the Tyndall National Institute of Ireland, and we established several new and large collaborative programs with strategically placed companies. I am delighted to introduce this report, which showcases these and many other accomplishments that amplify the interdisciplinary scope and excellence within the IMR and its vital role in leading Ohio State's strategic growth in materials-allied research and innovation.

Sincerely, Steven A. Ringel, Ph.D.

Executive Director, Institute for Materials 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

The Institute for Materials Research (IMR) was established at The Ohio State University in 2006 with a central goal: to guide Ohio State's materials-allied research enterprise to be among the very best in the nation. IMR steers this enterprise to continually impact the forefront of materials research; win the most competitive, prestigious research programs and centers; and enable the attraction of top talent in areas that exploit the multi-college breadth of the university. This institute brings together a large, diverse interdisciplinary community consisting of 267 faculty members from 34 departments and 10 colleges, all of whom are actively engaged in research and innovation across the materials continuum.

ABOUT IMR

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

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

MATERIALS & MANUFACTURING FOR SUSTAINABILITY

The M&MS Discovery Theme program shifted IMR's paradigm with an expansive research and innovation focus targeting global challenges surrounding energy transitions and environmental sustainability through the exploration and implementation of advanced materials, devices, manufacturing processes and systems. This program has led to the establishment of IMR's Innovation Lab and Ohio State's first global research center of excellence: the IIT Bombay-Ohio State Frontier Center. The two dozen faculty members hired across four colleges via the M&MS program comprise an interdisciplinary cohort who are carrying out world-leading research and producing high impact innovations to address these global challenges.

IMR SUPPORTS OHIO STATE'S MATERIALS 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 narrowly scoped 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 to guide IMR's primary directions of activities and allocating resources in research and innovation. The list is dynamic and is reviewed periodically to ensure we are sustaining and growing existing strengths, while being responsive to emerging topics of national and global impact that intersect with our capabilities and that of Ohio State.

ELECTRONIC AND PHOTONIC MATERIALS & DEVICES

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

EMERGENT MATERIALS

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

MAGNETIC MATERIALS AND PHENOMENA

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

MANUFACTURING AND PROCESSING

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

MATERIALS CHARACTERIZATION

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

MATERIALS FOR ENERGY AND SUSTAINABILITY

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

IMR STRATEGY

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

VISION

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

MISSION

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

To realize success for the IMR vision, we have developed three goals:

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*

$74.8M

TOTAL PROJECT VALUE*

$483.1M

NEW AWARDS*

$83.1M

* Sponsored projects only

268 FACULTY MEMBERS

34 DEPARTMENTS

10 COLLEGES

8 PUBLICATIONS PER MEMBER [1]

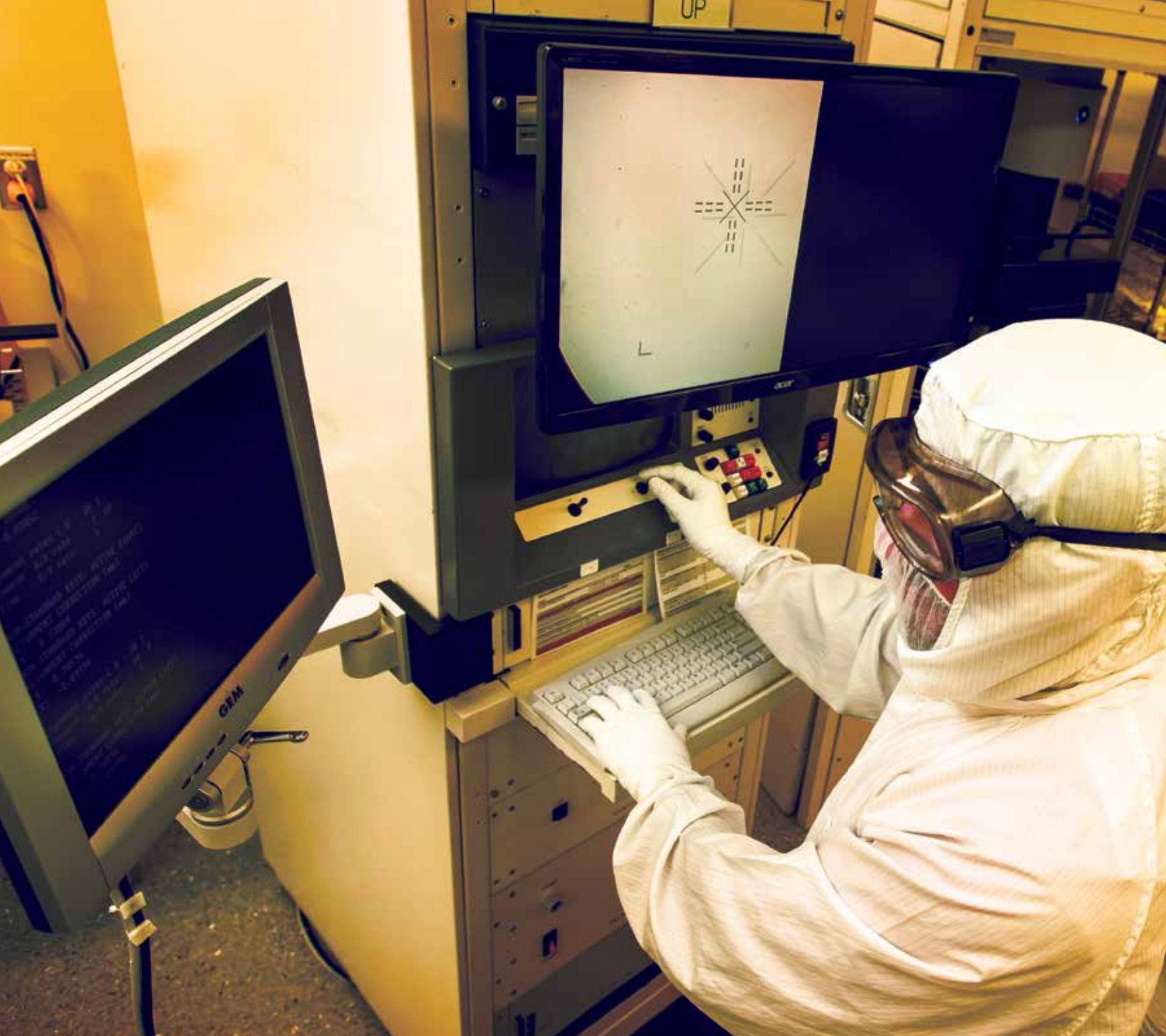
567 CITATIONS PER MEMBER [1]

144 PATENTS FILED [2]

38 PATENTS ISSUED [2]

81 INVENTION DISCLOSURES [2]

[1] Average of researchers found on Google Scholar in CY20
[2] Office of Innovation and Economic Development, FY21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RESEARCH & INNOVATION HIGHLIGHTS

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

PUSHING THROUGH THE PANDEMIC

Despite the avalanche of uncertainties and setbacks carried around the world with the COVID-19 pandemic, The Ohio State University's materials community retained an unremitting drive to continue researching, educating and pursuing new knowledge. IMR recognized these tremendous efforts among staff members with the institute's first-ever round of IMR Keep Researching Awards. IMR also aided in the support of new projects across the university by substantially increasing funding awarded to IMR faculty members through various seed grant programs. Whether researchers were taking dead aim at COVID-19 through projects probing new avenues to fight or detect the coronavirus or performing their jobs despite it, one thing was certain: Ohio State researchers remained determined despite unprecedented times.

IMR KEEP RESEARCHING AWARDS RECOGNIZE OUTSTANDING PERFORMANCE DURING THE COVID-19 PANDEMIC

As the COVID-19 pandemic began to take hold, members of the materials community at Ohio State stepped up to help ensure the health and safety of fellow Buckeyes, while remaining committed to the university's mission and supporting research efforts.

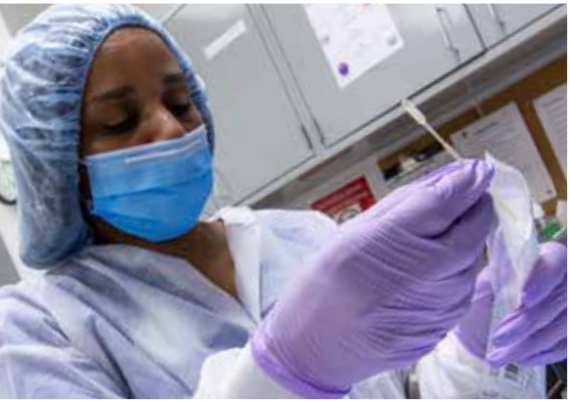
These unsung heroes went far beyond expectations, committing countless hours to ongoing research efforts at the Institute for Materials Research (IMR) network of facilities and centers, while navigating the complexities created by the pandemic and establishing best-in-class safety practices for the well-being of our community.

IMR is proud to have been able to recognize those Ohio State staff members, students and leaders' outstanding performance and commitment during these unprecedented times with the IMR Keep Researching Awards.

"This community's commitment to keep researching during the past year is why we are all able to move forward today," said Steven Ringel, IMR Executive Director. "I am so amazed by the dedication of our incredible team!"

Fifty awardees were selected for their dedication in one or more of the following areas: Outstanding Service, Exemplary Support or Advancement of Research, Diverse and Inclusive Excellence, and Outstanding Safety. Each Keep Researching Award winner received an e-gift card as a token of appreciation and gratitude for their incredible dedication to community, safety, and research efforts.

For a list of awardees, visit: go.osu.edu/IMRKeepResearchingAwards



PUSHING THROUGH THE PANDEMIC

IMR RAMPS UP FUNDING OPPORTUNITIES IN TURBULENT TIMES

Despite the persistence of the COVID-19 pandemic, IMR increased the number of projects to which it provided funding support by more than 70 percent in the past year, bringing the total number of seed grant recipients to 36 in FY21.

IMR awarded $52.5K in funding through its Kickstart Facility Grant Program to 21 projects, up from 8 the previous year. These awards assist Ohio State faculty with facility user access fees and related minor charges associated with conducting innovative materials-allied research with the goal of obtaining external research funding. IMR and the Indian Institute of Technology Bombay awarded $200,000 in funding to eight collaborative research teams through its second round of awards under the Frontier Center Scholars Program, two more collaborative projects than they did in FY20. Additionally, two new grants were awarded to teams through the new Tyndall-IMR Catalyst Program that joins IMR and Tyndall National Institute in Ireland.

IMR also helped fund and manage the FY21 round of Exploratory Materials Research Grants with the Center for Emergent Materials and the Center for Exploration of Novel Complex Materials.

Nanotech West Lab manager of nanofabrication Aimee Price (left) and student asst. Yessica Jimenez

MAEBL 2020 OFFERS SUPPORT, SOLUTIONS TO RESEARCH COMMUNITY FACING CORONAVIRUS

Despite being geographically scattered, a growing community of engineers, scientists and students working in fields utilizing e-beam lithography came together this July at the fourth annual, and first virtual, Meeting for Advanced Electron Beam Lithography (MAEBL).

But virtual attendees at this year's event had more in common than their interests in lithography; these researchers across government, industries and academic institutions from the U.S., Canada, England, Saudi Arabia, Switzerland, and Australia also shared the challenges and lessons learned in safely reopening and operating their facilities in the midst of the pandemic. For co-organizer Aimee Price, manager of nanofabrication at Ohio State's Nanotech West Laboratory, the workshop was an opportunity for researchers with

similar technical backgrounds to share best practices in an array of different work situations and support one another's similar approaches to problem solving. During the pandemic, Nanotech West ramped up its communication efforts with users within the university and throughout the region. From video conferencing software to direct-messaging apps, the team kept users in the loop with facility updates and regularly held instrument training sessions.

"It was truly a worldwide conversation. We are all going through the same thing; we're dealing with the same struggles," Price said. "And we are coming up with similar solutions or, at least, different variations on the same theme for those solutions. It was really beneficial to have that breadth of input and voices and experience coming together to discuss this moment."

The workshop also focused on navigating the challenges of safely re-opening and hosting users. Operations that can normally be fairly intense exercises, like hands-on training, demands even greater mindfulness to effectively practice social distancing and other safety precautions.

"Most of us are finding ourselves, in our jobs, doing much more than just operating research tools, in terms of ensuring higher levels of safety. Now, there are people who they can turn to for help. And they already have that relationship built. Having that community, having someone to turn to is especially helpful right now."

CAROLIN FINK'S TEACHING, MENTORING EFFORTS DURING PANDEMIC HIGHLIGHTED

Carolin Fink, an assistant professor in the Materials Science and Engineering (MSE) welding engineering program who was hired through the IMR-operated Materials and Manufacturing for Sustainability Discovery Theme, was featured in several Ohio State series focusing on faculty efforts during the pandemic.

One feature, in the university's series "Guidance through a pandemic," focuses on Fink's efforts as a mentor to encourage students to continue discovering opportunities during the coronavirus pandemic.

Fink was also featured in "Reflections," an MSE series documenting how students, staff and faculty members adapted and overcame challenges posed in 2020.

"I got into the field because I had a role model," Fink said. "But mentors can be even more effective, not just in bringing in new populations to certain fields but just by pointing out there are opportunities even though you don't see anyone who looks like you. But why wouldn't there be an opportunity there? That's where mentorship can be important."

MSE professor Carolin Fink (left) video chats with student Sydney Coates as she works in the lab.

PUSHING THROUGH THE PANDEMIC

Photo courtesy of Ohio State's Center for Design and Manufacturing Excellence.

IMR ASSOCIATE DIRECTOR GLENN DAEHN CONTRIBUTES TO THE CONVERSATION — "THE PANDEMIC HAS REVEALED THE CRACKS IN US MANUFACTURING: HERE'S HOW TO FIX THEM"

Glenn Daehn, Ohio State's Fontana Professor of Materials Science and Engineering, and University of Michigan Prof. Sridhar Kota wrote about the need to re-establish manufacturing capabilities, especially now, in the face of crisis.

Less than half a year into the U.S. declaring the COVID-19 pandemic a national emergency, the U.S. manufacturing sector revealed its own defects and inability to sufficiently provide critical products, just when the nation needed them most. Supplies like test kit components, personal protective equipment and pharmaceuticals were all in high demand.

The authors outline their thoughts on root causes at the heart of the problem, as well as their conclusions, framing the results of inaction or ineffective response in no uncertain terms: "How the U.S. responds will determine the long-term health and prosperity of the nation."

READ MORE: "The pandemic has revealed the cracks in US manufacturing: Here's how to fix them"

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

IMR FACULTY MEMBERS ARAFIN AND RAJAN EXPLORING NEXT-GEN UV LASERS IN THE FIGHT AGAINST COVID-19

A team of IMR faculty members are exploring the development of technology necessary to operate UV lasers more efficiently in the sterilization process.

Shamsul Arafin, an assistant professor in Electrical and Computer Engineering (ECE) hired through the IMR-operated M&MS Discovery Theme, and ECE professor Siddharth Rajan, earned $400,000 from the National Science Foundation for their proposal, "Tunnel Junction-based AlGaN Ultraviolet Lasers" for the NSF Electrical, Communications and Cyber Systems (ECCS) program.

According to their research, ultra-short-wavelength ultraviolet lasers emitting sub-300 nm power have proven useful for sterilizing surfaces or objects in the prevention of the global coronavirus spread. "However, energy-inefficient LEDs achieved to-date are large, compli-

cated, and expensive, which essentially limits their applicability in these key areas," their research states.

The technology could have wide-ranging benefits beyond COVID-19 and improved sterilization capabilities.

"UV light is useful due to a wide range of emerging applications, including phototherapy in the medical sector, plant growth lighting, water sterilization, trace gas sensing, curing polymers, and stimulating the formation of anti-cancerogenic substances," Arafin said.

Specifically, Ohio State proposes an innovative approach to utilize interband tunnel junctions, which alleviate the material conductivity and hole injection problems of laser materials without sacrificing the optical performance of the device. This novel approach will, in fact, help overcome the principal challenges by enhancing hole conductivity and carrier transport by generating what are called “mobile holes” at the materials level.

The team's proposed approach could enable new scientific understanding in the areas of ultra-wide band gap materials and optical devices, as well as establish the platform for a new class of AlGaN-based UV laser technology.

GPS-CONTROLLED ROBOTS HELP THE EXPLORATION OF MOBILITY AND SPACE IN AN AGE OF SOCIAL DISTANCING

Drawing Fields on the Ragdale campus, as seen from above. Photo courtesy of Outpost Office.

Since the beginning of the pandemic, many of us have been forced to reevaluate our understanding and use of space.

Outpost Office, a design practice based in Columbus, Ohio, that is co-directed by Ashley Bigham, an assistant professor at the Knowlton School of Architecture who was hired through IMR's M&MS Discovery Theme, and assistant professor Erik Herrmann, won the 2020 Ragdale Ring Competition for its design, "Drawing Fields." The installation in Lake Forest, Illinois, reimagined a performance venue for the COVID-19 era.

With the help of GPS-guided robots armed with payloads of white paint, Bighan and her partner explored the competitive theme of mobility by creating a 1:1 scale, contemporary interpretation of the Ragdale Ring garden theatre designed by architect Howard Van Doren Shaw more than a century ago.

"Drawing Fields is an expansive, minimally invasive solution that responds to the extraordinary context of 2020," said Jeffrey Meeuwsen, Ragdale Foundation executive director. "The project invites numerous opportunities for programmatic reinvention, collaboration, and education. It addresses our present-day concerns of physicality, public space, and engagement, while embracing the question that is central to this competition — What is Architecture?"

The non-toxic, zero-waste installation was also temporary, disappearing in a matter of months. In light of social distancing, the Outpost Office directors limited site access and recorded performances for the larger community.

In FY21, Bigham was awarded an IMR Kickstart Facility Grant for her proposal "Drawing Fields: Robotic Painting in Architecture." The Kickstart Facility Grant Program aims to strengthen near-term research proposals for external support by helping offset research costs.

SEED GRANT AWARDS

IMR PROVIDES SEED FUNDING TO 36 NEW PROJECTS IN FY21

Thirty-six new projects led or co-led by researchers at Ohio State received seed funding support in FY21 through IMR grant programs and the OSU Materials Research Seed Grant Program, which is co-funded and co-managed by IMR.

IMR's Global Partnership Grants provided funding for a second round of grants through the Frontier Center Scholars Program, as well as two grants through the newly launched Tyndall-IMR Catalyst Program that joins IMR and Tyndall National Institute in Ireland.

Additionally, IMR awarded 21 new projects in FY21 through its Kickstart Facility Grant Program, which assists Ohio State faculty with facility user access fees and related minor charges associated with conducting innovative materials-allied research with the goal of obtaining external research funding.

Lastly, five teams earned funding through Ohio State's Exploratory Materials Research Grants.

GLOBAL PARTNERSHIP GRANTS

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

Frontier Center Scholars Program

Design, Control and Implementation of Medium Voltage Modular Converter Using Si and SiC Devices – Principal investigators (PIs): Jin Wang (Electrical and Computer Engineering, Ohio State) and Anshuman Shukla (Electrical Engineering, IIT Bombay)

Development of Robust Catalysts for Sustainable H2 Evolution – PIs: Hannah Shafaat (Chemistry and Biochemistry, Ohio State) and Arnab Dutta (Chemistry, IIT Bombay)

Development of Robust System Designs for Maximizing the Energy Yield of Space – Efficient Photovoltaic Systems – PIs: Navni Verma and Sandip Mazumder (Mechanical and Aerospace Engineering) and Narendra Shiradkar (Electrical Engineering)

Enabling SiC based Power Converters: Gate Drivers to AI-enhanced System Design – PIs: Anant Agarwal (Electrical and Computer Engineering, Ohio State), and Sandeep Anand and Swaroop Ganguly (Electrical Engineering, IIT Bombay)

Facile synthesis of BaZrS3 nanoparticles absorber material for photovoltaic application – PIs: Patrick Woodward (Chemistry and Biochemistry, Ohio State) and K. R. Balasubramaniam (Energy Science and Engineering, IIT Bombay)

Hybrid Organic-inorganic Metal Halide Based Perovskite Infrared Detectors and its Application in Imaging – PIs: Sanjay Krishna (Electrical and Computer Engineering, Ohio State) and Dinesh Kabra (Physics, IIT Bombay)

Impact Welding of Nano-structured Bainitic Steel: Efficacy and Microstructural Study – PIs: Anupam Vivek (Materials Science and Engineering, Ohio State) and Aparna Singh (Metallurgical Engineering and Materials Science, IIT Bombay)

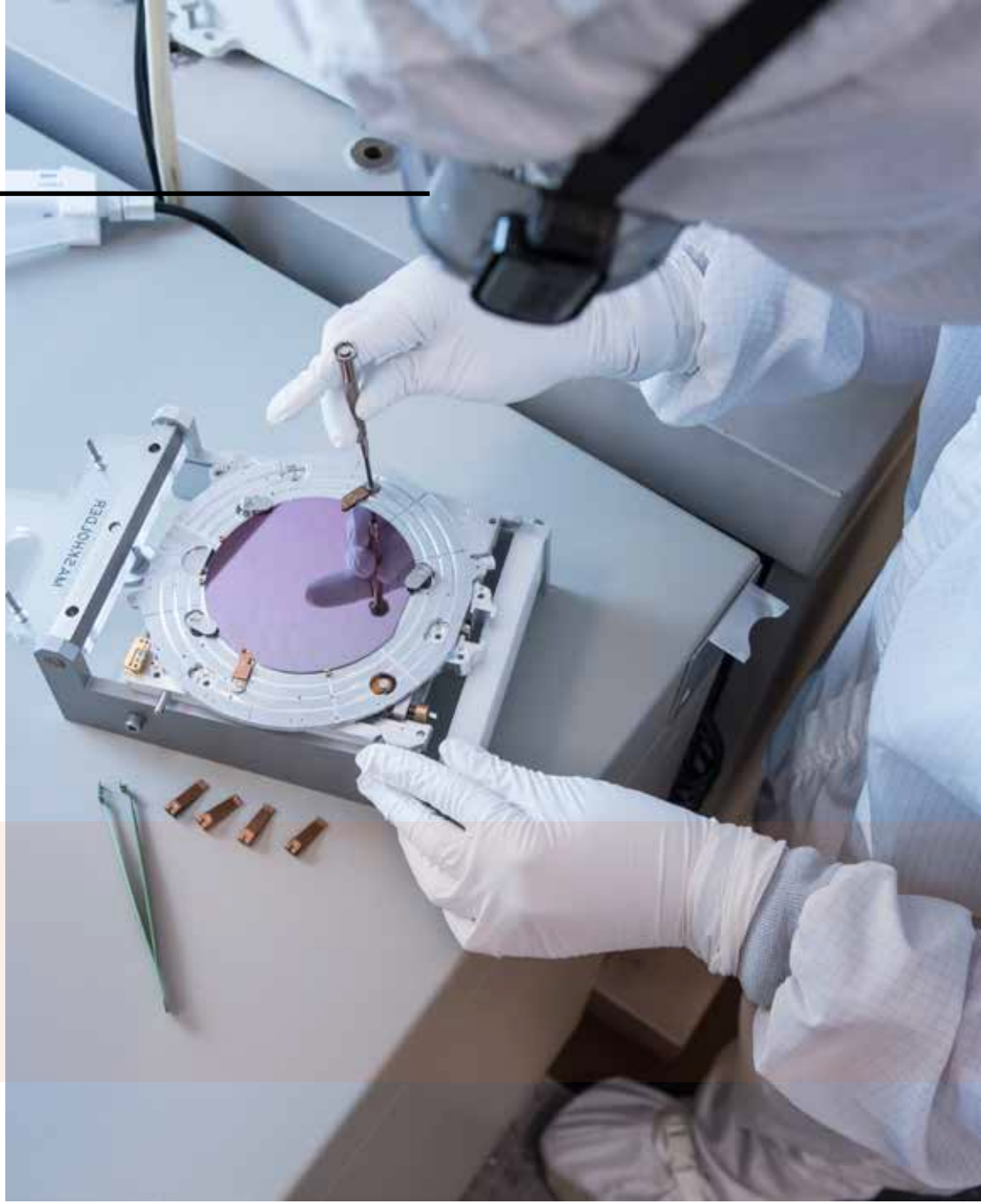
Understanding the Structure-Property Linkages in Electron Beam Melted Ti-6Al-4V – PIs: Joerg Jinschek

(Materials Science and Engineering, Ohio State) and Alankar Alankar (Mechanical Engineering, IIT Bombay)

Tyndall-IMR Catalyst Program

Development of visible light platform by heterogeneous integration – Co-PIs: Shamsul Arafin (Department of Electrical and Computer Engineering, Ohio State) and Brian Corbett (Tyndall)

Probing Factors Influencing Multiferroic Behavior Using Direct Detection Electron Energy Loss Spectroscopy – Co-PIs: David McComb (Center for Electron Microscopy and Analysis, Ohio State) and Lynette Keeney (Tyndall)



SEED GRANT AWARDS

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. Twenty-one Kickstart Facility Grants were awarded this year:

3D characterization of defects in AM builds using x-ray micro computed tomography – PI: Sriram Vijayan, Materials Science and Engineering

3D printing surgical models – PI: Kyle VanKoevering, Otolaryngology

Chemical Vapor Deposition Growth of Channel Materials and Electrolytesfor Organic Electrochemical Transistors – PI: Xiaoxue Wang, Chemical and Biomolecular Engineering

Cross-Sensitivity of Ion-Selective Biosensor Arrays in Multiple-Cation Solution – PI: Jinghua Li, Materials Science and Engineering

Design of Low-Cost Thermoelectric Materials Based on MXene Composites – PI: Xiaoguang (William) Wang, Chemical and Biomolecular Engineering

Design of Optimal Interconnection Schemes and 3D Curvature Compatibility for Vehicle Integrated Photovoltaic Modules – PI: Ardeshir Contractor, Mechanical and Aerospace Engineering

Development of micro crystal electron diffraction (micro-ED) as routine technique for structure determination of materials like metal organic frameworks (MOFs) at CEMAS – PI: Nicole Hoefer, Materials Science and Engineering

Drawing Fields: Robotic Painting in Architecture – PI: Ashley Bigham, Architecture

Effect of Local Strain Accumulation on the Mechanism of Hydrogen Assisted Cracking in Dissimilar Metal Welds – PI: Boian Alexandrov, Materials Science and Engineering (Welding Engineering Program)

Effect of Multiple Reheat Induced Carbide Precipitation on Mechanical Properties and Service Performance of Advanced Alloys – PI: Boian Alexandrov, Materials Science and Engineering (Welding Engineering Program)

Enabling 3D Corrosion Morphology Quantification using MicroCT – PI: Jenifer Locke, Materials Science and Engineering

Identification of the chemical compounds produced by beneficial bacterial microbes for contributing to plant fungal pathogen inhibitions – PI: Ye Xia, Plant Pathology

In Silico Screening of Metal-Organic Frameworks for Water Harvesting – PI: Li-Chiang Lin, Chemical and Biomolecular Engineering

Investigate the effect of beam scan strategies in EBM to achieve an equiaxed microstructure (and thereby isotropic mechanical properties) in AM Ti-6Al-4V – PI: Joerg Jinscheck, Materials Science and Engineering; Center for Electron Microscopy and Analysis

Magnetic mapping of biological iron by Lorentz microscope – PI: Robert Williams, Center for Electron Microscopy and Analysis

Material Characterization of Redox-Responsive Nanoparticles – PI: Katelyn Swindle-Reilly, Biomedical Engineering; Chemical and Biomolecular Engineering

Materials and Interfaces for Low-

Temperature Lithium-ion Batteries – PI: Jung-Hyun Kim, Mechanical and Aerospace Engineering

Methods for the post-synthetic electrocatalytic functionalization and upcycling of chloropolymer – PI: Christo Sevov, Chemistry and Biochemistry

Structural and Optical Characterizations of Cubic Boron Nitride: A Material with Extreme Properties – PI: Shamsul Arafin, Electrical and Computer Engineering

Transfer of Large-Area and Polymer-free Hexagonal Boron Nitride and its Optical Characterization – PI: Shamsul Arafin, Electrical and Computer Engineering

Ultra-Low Loss Electron Energy Loss Spectroscopy at CEMAS – PI: Tyler Grassman, Materials Science and Engineering; 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. Five Exploratory Materials Research Grants were awarded this year:

Boosting Neuromorphic Computing Using Chemical Vapor Deposition Polymers – PI: Xiaoxue Wang, Chemical and Biomolecular Engineering; Co-PI: Wu Lu, Electrical and Computer Engineering

Computational Design and Fabrication of Tunable 4D Shape-shifting and Highly Stretchable Ultra-light Architected Materials – PI: Alok Sutradhar, Mechanical and Aerospace Engineering

Interaction of Ultrafast Lasers with Quantum Materials – PI: Alexandra Landsman, Physics; Co-PI: Mohit Randeria, Physics

Investigating Charge Transport Behavior and Electrical Coupling Effect in Si Thin-Film Electronics with ssDNA Interfaces during Biosensing – PI: Jinghua Li, Materials Science and Engineering

Sustainable Organic Electrode Materials – PI: Shiyu Zhang, Chemistry and Biochemistry

SPOTLIGHTS

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

US AIR FORCE PARTNERS WITH OHIO STATE TO IMPROVE DIVERSITY IN SCIENCE, ENGINEERING

The Ohio State University and the U.S. Air Force are creating a national consortium to increase opportunities in the Air Force for minority STEM students and graduates.

Ohio State will co-lead the new effort with Wright State University, North Carolina A&T State University, and the Air Force Research Laboratory (AFRL) at Wright-Patterson Air Force Base.

The six-year, $40 million project, funded by the AFRL, will include summer internships for minority engineering students, access to specialized research equipment and laboratory space at AFRL, Ohio State and Wright State, and support for projects to be determined by collaborating with historically black colleges and universities and other minority-serving institutions. Ohio State will also work with minority institutions in developing technical proposals for research funding and will work collaboratively to create lasting infrastructure that encourages diversity in Air Force hiring.

"This funding provides an exciting opportunity for Ohio State to partner with minority institutions from across the nation to develop creative approaches to cultivating a prepared, diverse research workforce for the next generation of scientists for the U.S. Air Force," said Morley Stone, former senior vice president of research at Ohio State. "In addition, through this work, these organizations will be better positioned to propose and perform on AFRL research opportunities and the larger U.S. Department of Defense enterprise."

Michael Groeber, an associate professor in integrated systems engineering (ISE) at Ohio State and research director for the project, said the primary goal of the project is to help the Air Force hire a more diverse STEM workforce.

"And the longer-term, grander goal is to better position HBCUs and other minority-serving institutions to be able to competitively respond to any science and technology call for proposals, and specifically to defense-related calls," he said.

Groeber joined Ohio State through the Materials and Manufacturing for Sustainability Discovery Theme, operated by the Institute for Materials Research (IMR). To achieve those goals, Ohio State will host monthly online seminars for collaborating institutions on such topics as proposal writing, developing research partnerships and establishing and sustaining facilities. Ohio State will also subcontract federal project awards to member institutions to create internal research programs and infrastructure that can help underrepresented minority science and engineering students get internships and jobs.

The AFRL has previously funded individual graduate student research projects in an effort to increase diversity; those projects will continue, but this effort is specifically designed to create a national infrastructure that will build a lasting pipeline that brings science and engineering students from minority-serving institutions to the AFRL and strengthens research connections between the AFRL and MSIs.

That includes education and training for individual students, as well as education and training for institutional leaders, with the goal of making HBCUs and MSIs more competitive in proposing and winning technical research opportunities with the AFRL and with the U.S. Department of Defense as a whole.

The consortium will help member institutions identify potential projects and develop proposals for AFRL and other DOD research projects. The consortium will also subcontract awards to the participating members: The consortium leadership (Ohio State, WSU and AFRL) will review proposals, select projects for funding and offer technical support to MSI teams that receive funding through the consortium for research. And, the AFRL will work with researchers throughout the lab to identify projects that would benefit from outside help.

Ohio State plans to leverage existing centers and groups, including the Center for Design and Manufacturing Excellence, the Center for Electron Microscopy and Analysis, the STEAM Factory and the Battelle Center for Science, Engineering and Public Policy, Groeber said. Those centers and others offer facilities, equipment and in-person training opportunities for students from minority-serving institutions that may not be currently available at their home universities.

Michael Groeber in the IMR Innovation Lab.

SPOTLIGHTS

NEW RESEARCH STRATEGY SHARED BY OHIO STATE AND HONDA ADVANCES ENERGY INNOVATION

Accelerating research pertaining to advanced materials and technologies for sustainability is a key aspect of IMR's Materials for Energy and Sustainability Signature Area.

In its first year, a jointly held research strategy between The Ohio State University and Honda has blossomed into multiple projects advancing next-generation energy systems research.

IMR worked with Honda to focus the research direction for multiple projects and shape the overall strategy to further energy experimentation. The relationship grew from an energy agreement signed last year by Ohio State and Honda that secured nearly half a million dollars in financial support to advance experimental energy systems research at the university.

"This mutually beneficial agreement with Honda will further efforts at Ohio State that explore new energy storage and conversion devices capable of helping create a sustainable future through research, education and collaboration," said IMR Director of Innovation Jay Sayre.

The strategy supports new, collaborative R&D, testing and services projects that include faculty, staff and students. So far, it has helped launch more than a dozen new research projects that focus on topics ranging from advanced battery development to advanced joining.

"IMR is the first point of entry I look to when wanting to do research related to materials with Ohio State. They help put together interdisciplinary teams to solve multi-faceted problems, within or outside energy," said Chris Brooks, chief scientist at Honda Development & Manufacturing of America and project director of 99P Labs, a Honda and Ohio State-backed collaborative space for mobility and energy innovators. "I see this relationship as an important direction toward longer-term research which will realize a push toward electrification and reduced CO2 emissions in the near- and long-term future."

The agreement also included funding for a new research scientist at Ohio State. Qingmin Xu was hired as IMR's newest technical staff member working at the institute's Energy Innovation Lab at Nanotech West Laboratory. There, she performs fundamental and applied energy systems research in conjunction with Honda. Xu works with a network of Ohio State faculty, staff, and graduate students in areas related to energy storage and conversion, including battery development research.

DEVELOPING THE NEXT GENERATION OF SUSTAINABLE ENERGY LEADERS THROUGH emPOWERment

Ohio State undergraduate and graduate students are rising to the challenges and needs for sustainable energy in the 21st century.

Multiple students in the EmPOWERment Research In Sustainable Energy (RISE) summer program were mentored by IMR faculty members, including Christian Blanco, who was hired through the IMR-operated M&MS Discovery Theme, Tyler Grassman, Giorgio Rizzoni and Ajay Shah. The NSF-funded program is conducted by the College of Engineering, with support from the Graduate School and Office of Diversity and Inclusion.

The 10-week intensive experience

Tali Look, undergraduate student in Materials Science and Engineering.

developed and enhanced the students' research skills by providing them opportunities to work on independent research projects related to sustainable energy with the support of academic and peer mentors.

IMR Director of Innovation Jay Sayre advised Tali Look, an undergraduate student in Materials Science and Engineering. For Look, a board member on the Ohio State student organization Buckeye Precious Plastics, the program goals aligned with her long-established passion for sustainability.

"Sustainability is something I have been trying to focus on for all of my college career," she said. "Growing up, my mom was extremely conscious about plastic use and, even, wasting food was not allowed in our house, ever, so I kind of grew up with that mentality."

And she hopes her future career pertains to sustainability too. Her experience working with Sayre won't hurt her preparation. Look focused her time in the lab investigating bio-based or natural materials to act as a filler in plastics found in automobiles.

The overall goal of the project is to better understand how we might supplant the mineral talc in plastics.

"This was a great program," Look said. "I encourage anyone to do it, if they have any interest in research, grad school or sustainability."

NSF FUNDS $1.5M LITHOGRAPHY TOOL TO ADVANCE NEXT-GEN NANOTECHNOLOGY AT NANOTECH WEST LABORATORY

Scientists at The Ohio State University earned another key tool for semiconductor research, which is paving the way for advanced technologies beneficial to society.

The National Science Foundation approved a $1.5 million Major Research Instrumentation (MRI) toward the purchase and installation of an electron-beam lithography system at Nanotech West Laboratory, operated by IMR.

Principal Investigator Siddharth Rajan, professor of Electrical and Computer Engineering (ECE) and Materials Science and Engineering, said the system is expected in 2022.

“It will be a highly capable, fast, and user-friendly system, and I look forward to all the great research this new tool will enable,” Rajan said.

The team involved in the award includes not only co-investigator and Nanotech West Lab director John Carlin, but Nanotech West Lab's manager of nanofabrication Aimee Price.

The new tool is expected to increase accessibility to lithography capabilities to a broad range of researchers, Price said.

“As an open-use facility, Nanotech West Lab serves a wide-ranging mix of users from Ohio State and from across the state and region. We want to continue to lead in lithography capabilities and keep pushing forward, past the current limitations in fabrication,” she said. “This system will make training easy and, in turn, allow more of our users to become hands-on in the lab.”

Price said she expects the new electron-beam lithography system funded by NSF will continue to widen the range of Nanotech West’s user capabilities, from contact aligners to e-beam lithography and direct laser-writer tools.

A key goal of this project is to increase outreach and to create unique educational opportunities beyond the research community.

Photo courtesy of Ohio State ECE.

QUANTUM EFFORTS GAIN STEAM AT OHIO STATE

Ohio State is making new strides in the advancement of the rapidly evolving field of quantum information science and engineering (QISE). In FY20, IMR created a task force on behalf of the Office of Research that coordinated and focused university efforts in fields related to quantum information science by building on the university's existing multidisciplinary strengths. Physics professor Ezekiel Johnston-Halperin led that campaign to articulate university strengths in physics, mathematics, computer science, engineering into an interdisciplinary assemblage able to deliver impactful projects that advance our understanding of quantum's potential to improve information transmission and processing.

Concurrently, Ohio State led a newly launched, National Science Foundation-funded educational initiative to develop a revolutionary undergraduate curriculum that provides a national educational model for the emerging field of quantum information science and engineering. In FY21, the program, QuSTEAM: Convergent undergraduate education in Quantum Science, Technology, Engineering, Arts and Mathematics, concluded its initial phase with IMR web and proposal development assistance. IMR also teamed up with Ohio State's Institute for Optical Science to host a webinar series covering topics that included quantum computing, sensing and communication technologies.

Ezekiel Johnston-Halperin

SPOTLIGHTS

IMR, CDME AND THE COLLEGE OF MEDICINE LAUNCH M4 LAB TO UTILIZE 3D PRINTING TO MEET NEEDS IN CLINICAL MEDICINE

A newly formed, interdisciplinary team of researchers at Ohio State's Nanotech West Laboratory is utilizing 3D printing to find innovative engineering solutions for real-world needs in clinical medicine.

Current 3D printing technologies at Ohio State allow experts in the recently established Medical Modeling, Materials and Manufacturing (M4) Lab to quickly create complex geometries and shapes for patient-specific applications. The new clinical 3D printing and engineering facility will meet specific needs of the medical community, while being managed and operated by biomedical engineering and clinical experts with firsthand experience commercializing medical devices.

"The goal of the M4 Lab is to support the life-saving efforts of Ohio State's medical professionals and faculty by stimulating and centralizing research innovation around bioengineering, medical device development and clinical 3D printing," said M4 Lab Program Manager Mary Hoffman Pancake, who is also program manager at the Center for Design and Manufacturing Excellence (CDME).

CDME research specialist Rachel Herster (right) and collaborators working on a project in the M4 Lab.

The M4 Lab is a hub for innovative approaches to health care and advanced manufacturing techniques that brings together experts from IMR, CDME and the College of Medicine's Department of Otolaryngology under one roof at Nanotech West Lab.

And researchers at the M4 Lab hit the ground running. By late 2020, M4 Lab Director Kyle VanKoevering, M.D., an assistant professor in the Department of Otolaryngology who treats patients at The Ohio State University Comprehensive Cancer Center – Arthur G. James Cancer Hospital and Richard J. Solove Research Institute, had led M4's first project to create a 3D model of a patient's mandible, or lower jawbone. The team used imaging from a CT scan to create an exact replica of the 3D anatomy of the patient's jawbone. That model was soon used in the operating room to successfully facilitate the reconstruction of that patient's jaw after the removal of a segment of bone.

Since that project, the lab has printed 2 to 3 patient-specific models per week that have been used in the operating room, as well as a customized airway stent for a patient with a tracheal obstruction.

"As we think about personalizing medicine, we want to customize each reconstruction or make a special device that is custom-fitted to a patient's specific anatomy," said VanKoevering, who specializes in tumors and cancers of the head and neck at the OSUCCC – James. "3D printing allows us to do that."

The lab's advanced manufacturing capabilities are enabled by an array of 3D printers, as well as a team of engineers with medical device experience. The 3D printers housed at the M4 Lab enable various fabrication methods, including stereolithography, fused deposition modeling, and silicone casting and processing. On top of research and clinical support activities, the lab is used as an experiential education platform for undergraduate research assistants, providing students with real-world experience and job training that will position them as top candidates for medical device company hires. Additionally, postdoctoral researchers, medical students and residents from across disciplines collaborate there to create innovative health care solutions.

The M4 Lab builds on the collaborative, multidisciplinary foundation established by that massive clinical 3D printing endeavor and will continue pursuing innovative approaches to advance health and well-being in our society.

"At our core, IMR is an institute of centers, many of which resulted from developing labs just like the M4," said IMR Director of Innovation Jay Sayre. "We are excited to support this new lab at Nanotech West and enable its success by further strengthening our relationship with CDME and building on our recent collaborations with the College of Medicine."

WATCH NOW: M4 Lab prints mandible model for use in operation room

Use your phone's camera app to scan the QR code or visit go.osu.edu/B97g

SPOTLIGHTS

U.S. Air Force photo by Joshua J. Seybert.

IMR BACKS DESIGNATION OF STATE OF OHIO AS US AIR FORCE DEFENSE MANUFACTURING COMMUNITY

The State of Ohio recently earned a new designation by the U.S. Department of Defense that paves the way for long-term community investment opportunities that can strengthen national security innovation and expand the capabilities of defense manufacturing in the state.

Ohio Gov. Mike DeWine and Lt. Gov. Jon Husted announced Sept. 3 the state had been named a Defense Manufacturing Community under a Defense program that makes a commitment to Ohio's defense manufacturers and puts the state in position to receive a $5 million grant to improve manufacturing processes and train workers for next-generation jobs.

"The agility, speed, and resilience of Ohio's manufacturing base offers a vital resource to the Department of Defense in its efforts to broaden and deepen the domestic defense supply chain," DeWine said. "The same model that realigned the entire Ohio manufacturing base to fight COVID-19 can be realigned to re-shore, innovate to solve Defense Department challenges, and produce equipment at scale."

Representatives from across the manufacturing community at Ohio State backed the designation early with a letter of support. "The Ohio State University Center for Design and Manufacturing Excellence (CDME), Ohio Manufacturing

Institute (OMI), and Institute for Materials Research (IMR) are honored to play a role in Ohio's defense manufacturing community," reads the statement by CDME Executive Director Nate Ames; OMI Director Kathryn Kelley; Ned Hill, professor of Economic Development in the John Glenn College of Public Affairs; and IMR Director of Innovation Jay Sayre.

"The U.S. Department of Defense is enhancing our nation's security by investing in Ohio's world-class manufacturing capabilities. The designation of Ohio as a Defense Manufacturing Community solidifies this bond and enables Ohio to create a more streamlined connection between manufacturers and small businesses."

Noted among the state's resources to anchor the Ohio Defense Manufacturing Community and serve small- and mid-sized defense manufacturers was the university's Ohio Manufacturing Institute (OMI), a manufacturing public policy and advocacy center at Ohio State. OMI plans to support the new community through ongoing research and surveys that will inform the effort from a macro scale.

IMR and CDME work together to advance Ohio State's presence and leadership in manufacturing research, development and deployment, identifying and leading major block-funding efforts, and enabling the expansion of manufacturing-relevant national and global partnerships.

NEW DEGREE PROGRAM RESPONDING TO NEEDS OF OHIO MANUFACTURING

A new bachelor's degree program that launched last fall on Ohio State's regional campuses is preparing students to excel as business-oriented engineering leaders in the highly automated manufacturing industry.

"We need to listen very attentively to Ohio businesses in order to create the workforce they need and to get our students ready for emerging opportunities," said Ohio State President Kristina M. Johnson. "It was the advice from Ohio manufacturers, for example, that led us to create a new engineering technology degree program with an emphasis on advanced manufacturing at three regional campuses and expanding to a fourth campus soon."

Ohio's manufacturing industry provided the Ohio Manufacturing Institute, the program organizer, with critical input on curriculum. More than a dozen local companies have served as mentors who provide hands-on learning opportunities. The bachelor of science in engineering technology (BSET) with a concentration in manufacturing is offered on the Lima, Mansfield and Marion campuses.

An industry mentor speaks to an engineering technology student during her visit to Charter Next Generation, near Mansfield, Ohio. Image from video published by the College of Engineering.

SPOTLIGHTS

ENGINEERING STARTUP GROWS FROM OHIO STATE ENTREPRENEURIAL ECOSYSTEM

Glenn Daehn (right) and former student Anupam Vivek. Photo courtesy of the College of Engineering.

Ohio startup Applied Impulse, Inc. grew from a foundation of knowledge created by Glenn Daehn's research at Ohio State, where he is the Mars G. Fontana Professor of Metallurgical Engineering and leads the university's Impulse Manufacturing Lab.

The company is based on Daehn's development of impulse manufacturing technology, with an initial commercial focus is to join dissimilar materials with high strength joints that do not degrade the parent materials.

"Our journey in Impulse Manufacturing spans back about 30 years," says Daehn. "Through that time, we have become one of the world's leading groups in this area."

Impulse manufacturing technologies of Daehn and Anupam Vivek, a former student and now research scientist in the lab, have benefited from several funding mechanisms available through Ohio State and other sources.

GLENN DAEHN HONORED FOR TECHNOLOGY COMMERCIALIZATION

Glenn Daehn's dedication to research and the transference of knowledge was recognized in FY21 with the Ohio Faculty Council's annual Technology Commercialization Award.

Daehn, a professor of metallurgical engineering at Ohio State, has dedicated much of his career to the investigation of impulse manufacturing.

"Professor Daehn is an innovator, collaborator and influencer in his field, and his impact has benefited both Ohio State and the state of Ohio," said Executive Vice President and Provost Bruce A. McPheron. "His cross-disciplinary work and collaboration with industry have strengthened Ohio's manufacturing industry, and we are proud to call him a member of the Ohio State faculty."

Daehn was also recently recognized among the 20 most influential professors in smart manufacturing by nonprofit SME.

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

Ohio State's Center for Emergent Materials (CEM) was awarded Materials Research Science and Engineering Center (MRSEC) funding from the National Science Foundation (NSF) for the third time since 2008. The new six-year, $18 million grant will fund transformative science and complex materials discovery by two multidisciplinary, collaborative groups of researchers and includes funding to help ease entry into science from underrepresented groups.

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

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

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

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

Left to right: CEM Director P. Chris Hammel and CEM Associate Director La'Tonia Stiner-Jones.

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

SPOTLIGHTS

SHARED-USE ATOMIC FORCE MICROSCOPE TO ENABLE NEW DIRECTIONS IN BIOMEDICAL RESEARCH

A newly installed atomic force microscope (AFM) coupled to a fluorescence light microscope is open for shared use in Scott Laboratory at Ohio State.

This multi-user facility is home to a state-of-the-art Bruker Resolve AFM, enabling novel applications in imaging, analyzing and manipulating matter at the nanoscale. Atomic force microscopy enables the imaging and nano-mechanical analysis of most types of surfaces, including polymers, ceramics, and biological samples.

"The nanoscale and molecular-level insights that can be provided by AFM are expected to generate new research directions for basic and translational biomedical research as well as in nanotechnology and polymer science," said Gunjan Agarwal, professor in Mechanical and Aerospace Engineering (MAE) who leads the lab. "This AFM can analyze samples in a liquid environment at the nanoscale level, which cannot be achieved by other existing AFMs on campus or by electron microscopy."

The microscope was acquired via a National Institutes of Health (NIH) S10 award, led by Agarwal. This is the second S10 award led by Agarwal, who had previously established and directed another Bio-AFM facility in the Davis Heart and Lung Institute, in 2006.

The AFM laboratory as a university-wide shared resource will enable collaborations across various departments and colleges, as can already be witnessed in some of the user projects.

IMR is set to provide the lab further support through its first five years of operation. Along with IMR, the Office of Research, departments of MAE and Biomedical Engineering, and the colleges of Engineering, Arts and Sciences, and Pharmacy have committed funds to support this facility.

The new AFM system offers unique capabilities to users at Ohio State.

First, it is the only shared AFM on campus capable of imaging in fluid, making it an invaluable resource for biomedical research.

"In biological samples, it is really important that we can keep the samples hydrated (e.g. live or fixed cells, tissues and even biomolecules) and in their desired conditions," Agarwal said. "The instrument is very bio-friendly."

Additionally, the instrument's AFM module sits above a light microscope, allowing the coupling of fluorescence and AFM images from the same region. In the examination of bio samples, fluorescent signals will allow users to perform AFM analysis of specific regions of interest identified in fluorescence images.

Finally, the new AFM is equipped with state-of-the art features like the PeakForce Tapping mode, Quantitative Nano mechanics, and even Kelvin Probe Microscopy.

Agarwal has also developed and offers a new course MECHENG 6194 (ME 6711) "Microscopy in Biomechanics" that discusses the fundamental principles of light microscopy and AFM in imaging and nanoscale mechanical analysis.

Gunjan Agarwal, professor in Mechanical and Aerospace Engineering

SPOTLIGHTS

U.S. Air Force photo by Senior Airman River Bruce.

IMR FACULTY MEMBERS, GRADUATE STUDENTS EARN STATE FUNDING TO SUPPORT AEROSPACE RESEARCH

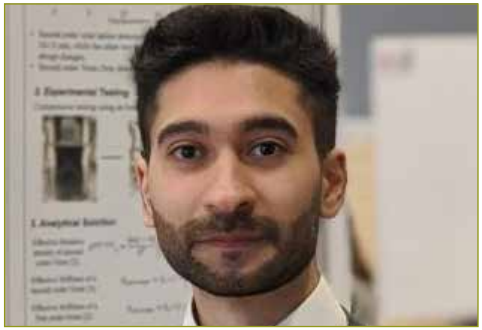
Several IMR faculty members and graduate students at Ohio State earned fellowship awards from the Southwestern Ohio Council for Higher Education (SOCHE) in 2020 and 2021 to support their research endeavors.

The program, the Air Force Research Laboratory (AFRL)/Dayton Area Graduate Studies Institute (DAGSI) Ohio Student-Faculty Research Fellowship, is funded primarily by the Ohio Department of Higher Education.

The program supports science and engineering graduate students and faculty who conduct research in areas targeted by the Air Force Research Laboratory at Wright-Patterson Air Force Base.

Multiple recipients were hired to Ohio State through the Materials and Manufacturing for Sustainability Discovery Theme, operated by IMR. Read more about them, graduate students and their work below.

Mechanical and Aerospace Engineering graduate student Mohamad Al Nashar and Asst. Prof. Alok Sutradhar aim to improve the performance of integrated electromagnetic-mechanical designs in their project, "Topology Optimization of Coupled Mechanical and Electromagnetic Designs."



Mohamad Al Nashar

Materials Science and Engineering doctoral student Patricia Loughney and Asst. Prof. Vicky Doan-Nguyen will col-

laborate on the project, "Identification of Structure-Processing-Property Relationships for Designing New Functional Polymer-Derived Ceramics."

Patricia Loughney

Electrical and Computer Engineering doctoral student Joseph McGlone and Prof. Steven Ringel were selected for their proposal, "Basic Studies of Defects, Carrier Transport, and MBE Growth of Beta Gallium Oxide Materials and Devices."

Joseph McGlone

In 2021, Electrical and Computer Engineering graduate student Brennan Swick and Integrated Systems Engineering Assoc. Prof. Michael Groeber were selected for their proposal, "Training Robotic Agents via Natural Language and Gestures." The research team will work toward accomplishing this goal via robotic learning of expert tasks via synced natural language processing and gesture recognition.

Brennan Swick

IMR SUPPORTS NEW CENTER FOR WIDE BANDGAP SEMICONDUCTORS

The newly launched Center for Wide Bandgap Semiconductors at Ohio State is a multi-disciplinary center focused on research and education in the area of wide and ultra-wide bandgap semiconductor materials and devices.

IMR faculty member Siddharth Rajan, professor of Electrical and Computer Engineering, serves as director of the center.

Wide and ultra-wide bandgap semiconductors Silicon Carbide, Gallium Nitride, and Gallium Oxide have a wide range of applications including next-generation high bandwidth communications, compact energy-efficient electronics, solid-state lighting, disinfection and disease-prevention, space technology, and radiation-hard extreme-environment electronics.

With more than 50 faculty and researchers with expertise across several disciplines, Ohio State is making key advances in the science and technology of wide bandgap semiconductors. Several talented undergraduate students are performing cutting-edge research with faculty and researchers within the center.

In FY21, the center held multiple seminars that featured experts in research related to wide bandgap semiconductors from around the world. The center plans to continue the series in FY22.

The Center for Wide Bandgap Semiconductors is supported by several Ohio State organizations, including IMR, the Office of Research, the College of Engineering, and the Department of Electrical and Computer Engineering.

SPOTLIGHTS

SOFT ROBOTS, ORIGAMI COMBINE FOR POTENTIAL WAY TO DELIVER MEDICAL TREATMENTS

Researchers from Ohio State and the Georgia Institute of Technology found a way to send tiny, soft robots into humans, potentially opening the door for less invasive surgeries and ways to deliver treatments for conditions ranging from stomach cancer to aortic artery blockages.

The researchers detailed their discovery, which makes use of the ancient Japanese practice of origami, in a study published Sept. 14 in the Proceedings of the National Academy of Sciences.

Under this system, doctors would use magnetic fields to steer the soft robot inside the body, bringing medications or treatments to places that need them, said Renee Zhao, corresponding author of the paper and assistant professor of Mechanical and Aerospace Engineering. She joined Ohio State in 2018 through the IMR-operated Materials and Manufacturing for Sustainability Discovery Theme.

"The robot is like a small actuator," Zhao said, "but because we can apply magnetic fields, we can send it into the body without a tether, so it's wireless. That makes it significantly less invasive than our current technologies."

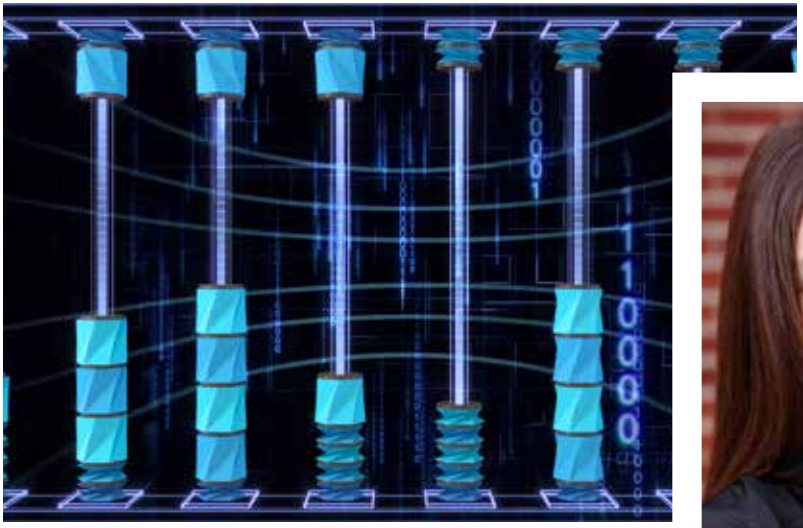


Illustration of cylindrical origami systems featured above is courtesy of Renee Zhao (right).

That soft robot is made of magnetic polymer, a soft composite embedded with magnetic particles that can be controlled remotely. Robotic delivery of medical treatment is not a new concept, but most previous designs used traditional robots, made of stiff, hard materials. In this case, they can be used to deliver multiple treatments selectively based on the independently controlled folding and deploying of the origami units. The origami allows the material to "open" when it reaches the site, unfurling the treatment with it to apply the treatment to the place in the body that needs it.

Researchers have explored for decades how to leverage origami folding techniques in advanced engineering applications, such as morphing structures and devices. However, most actuation methods driving the force that is needed to enable movement and folding have been bound to external stimuli and can require excessive wiring. The new, untethered system is freed from that bulkiness, allowing faster speed and distributed actuation of the multifunctional structure. To demonstrate this, researchers constructed a system of magnetic-responsive materials in a cylindrical origami pattern that consists of identical triangular panels

known as a Kresling pattern. This pattern allows the cylinder's walls to buckle under axial or torsional load. By controlling the magnetic field, researchers were able to control the direction, intensity and speed of the material's folding and deployment. In the tests, researchers achieved untethered actuation as fast as one tenth of a second with instantaneous shape locking.

Next, researchers attached a magnetized plate to each of the Kresling unit cells. This allowed researchers to utilize a 2D magnetic field to actuate the unit cells simultaneously or independently by using different magnetic torques of the plates and distinct geometric-mechanical properties of each unit cell.

"The multi-unit Kresling assembly is an origami robot in which the bistable folding and unfolding create robotic motion. It can passively sense and actively respond to the external environment. By integrating electronic circuits into the origami robot, it further enables intelligent autonomous robots with integrated actuation, sensing, and decision making," she said. "For example, the external pressure or forces that act on the robot will trigger the passive folding of the robot, indicating the presence of an obstacle. The robot can then actively unfold itself and decide the next move."

WATCH NOW: Untethered control of functional origami microrobots

Use your phone's camera app to scan the QR code or visit go.osu.edu/B97g

IMR FACULTY MEMBERS TYLER GRASSMAN AND BRIAN SKINNER RECEIVE PRESTIGIOUS NSF CAREER AWARDS

Two IMR faculty members from the departments of Materials Science & Engineering and Physics received Faculty Early Career Development (CAREER) awards

from the National Science Foundation (NSF) in fiscal year 2021.

Tyler Grassman (pictured above), an assistant professor in the Department of Materials Science and Engineering, received a five-year, $613,995 CAREER award for research aimed at identifying atomic structures of defects and understanding how they degrade the parent materials' electronic and optical properties. His project, "Revealing the Fundamental Mechanisms Behind the Dislocation-Induced Electronic States in III-V Semiconductors" focuses on determining the atomic-level underlying cause of dislocations in semiconductors caused by the integration of materials with dissimilarities in a crystal structure.

Brian Skinner (pictured right), assistant professor in Physics, received a five-year, $505,407 continuing grant through the NSF Division Of Materials Research for his project, "Electrical and Thermoelectric Transport Beyond the Metal/Insulator Paradigm." He joined Ohio State in 2020 through the Materials and Manufacturing for Sustainability Discovery Theme, operated by IMR.

The CAREER award is the NSF's most prestigious award in support of early-career faculty who exemplify roles of teacher-scholars through outstanding research, excellent education and their integration.

SPOTLIGHTS

K.I.N.D. LAB'S NICOLE PFIESTER LATHAM EARNS MISTLETOE RESEARCH FELLOWSHIP TO STUDY SUSTAINABLE TECHNOLOGIES

Nicole Pfiester Latham, a postdoctoral researcher in Electrical and Computer Engineering (ECE), won the Mistletoe Research Fellowship for 2020-2021.

The Ohio State University partnered with the Momental Foundation to support the program, which offers a combination of career and funding support for postdoctoral scholars by providing $10,000 in unrestricted research funding, along with professional development training via remote entrepreneurial collaboration. The grants go toward research advancing sustainability through technology.

Pfiester is a President's Postdoctoral Scholar with ECE Professor Sanjay Krishna's Infrared Detector Lab. She uses resonant structures to reduce the dark current in infrared photodetectors based on Type II superlattice materials. Krishna joined Ohio State though the IMR-operated Materials and Manufacturing for Sustainability Discovery Theme in 2017.

Pfiester said the fellowship allows her to use funding for her research, and participate in the StartUp Collaboration, which pairs fellows with startups as consultants for their product development. The Mistletoe Fellows collaborate in areas such as Sustainability, Civil Society, and Autonomy/Mobility.

"The startups all aim at improving the world," she said. "I think the 'Civil Society' topic better aligns with my skills, but I could fit into any of them, depending on what problem is trying to be solved."

The Mistletoe Research Fellowship initiative partners with 11 top universities – 10 in the United States and one in Singapore.

ECE postdoc Nicole Pfiester Latham

SANJAY KRISHNA HONORED WITH SPIE TECHNOLOGY ACHIEVEMENT AWARD

Sanjay Krishna, George R. Smith Chair in Engineering and professor of Electrical and Computer Engineering, accepted the 2020 SPIE Aden and Marjorie Meinel Technology Achievement Award during a virtual ceremony this year for his pioneering work and impact in the infrared field. The award recognizes technical accomplishments in the fields of optics, electro-optics, photonic engineering and imaging. Krishna, who joined Ohio State through the IMR-operated Materials and Manufacturing for Sustainability Discovery Theme, received the award for his presentation of the first demonstration of single-color and dual-color nBn superlattice detectors and focal plane arrays.

His work in the field of infrared technologies has advanced imaging capabilities by allowing increased sensitivity and operating temperatures, while lowering costs. This work has led to applications among manufacturers in both industry

WATCH NOW: Sanjay Krishna accepts the 2020 SPIE technology achievement award

Use your phone's camera app to scan the QR code or visit go.osu.edu/B97g

EMERGING INNOVATION DISTRICT SET TO SPUR ECONOMIC GROWTH, ADVANCE ENERGY RESEARCH

The emerging Innovation District on Ohio State's West Campus, which is set to propel research advancements and economic growth, took another major step forward in its development with a significant financial push from the state and JobsOhio.

Ohio Gov. Mike DeWine in February helped announce the rapidly developing district will receive a large portion of a $100 million investment from JobsOhio, a nonprofit economic-development corporation in central Ohio.

The Visionary Project Advisory Committee was formed early in the conceptual stages to guide the university in the governance of the center's development. Jay Sayre, who serves as Assistant Vice President in the Office of Research and Director of Innovation in the Institute for Materials Research (IMR), chairs the committee, which is composed of Ohio State, OSEP, and Columbus community members.

"We envision the Energy Advancement and Innovation Center as a vehicle to propel innovation beyond the R&D stage to commercial successes in the market where everyone can benefit," Sayre said. "This will be a place where our students will benefit by connecting with the creativity of faculty, staff, ENGIE researchers, and our local community to leave a lasting, impactful legacy on our academic mission."

Rendering courtesy of Ohio State News.

The Energy Advancement and Innovation Center will help anchor this new district just west of the Olentangy River. It will be centered on finding innovative solutions for energy reduction and encouraging new collaborations to propel the next generation of convergent energy research and technology development.

The center is set to be a hub where Ohio State faculty members, students, alumni, ENGIE researchers, local entrepreneurs and industry experts work together on the next generation of smart energy systems, renewable energy and green mobility solutions.

Ohio State researchers are already working to advance next-generation convergent energy research and tech development at IMR's Energy Innovation Lab at Nanotech West Laboratory. Leading the lab are Jung-Hyun Kim and Vicky Doan-Nguyen, both of whom are assistant professors hired through the Materials and Manufacturing for Sustainability Discovery Theme, operated by IMR.

The project is a cornerstone of the university's public-private partnership with Ohio State Energy Partners (OSEP).

Serdar Tufekci, OSEP's first CEO and now Head of Major Partnerships at ENGIE North America Inc., said last year that he was very excited to see the watershed project moving forward and that "...as a fellow Buckeye, I feel very lucky to be a part of the development of the innovation district."

INTERNATIONAL COLLABORATIONS

IMR PARTNERSHIP WITH TYNDALL NATIONAL INSTITUTE OF IRELAND ADVANCES INTERNATIONAL RESEARCH PROJECTS

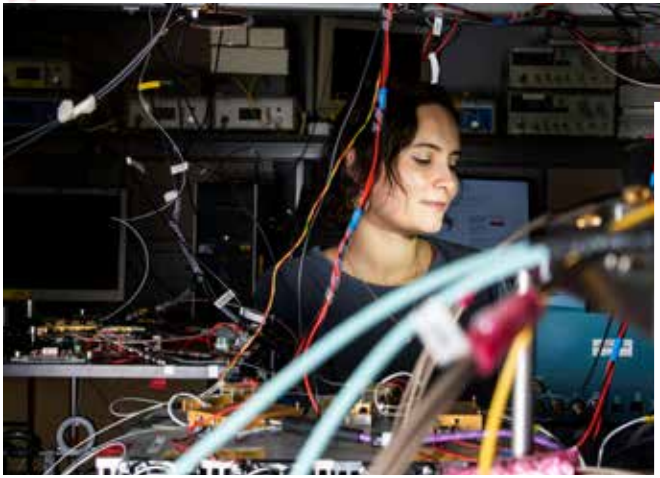
IMR partnered with the Tyndall National Institute of Ireland in FY21 to initiate a new program to immediately advance international research projects and lay the groundwork for increasing research collaborations between the two entities.

The goal of the Tyndall-IMR Catalyst Program is to stimulate new projects, which build on complementary assets of both institutions and are likely to lead to near-term joint publication and joint proposal development for high-impact research in areas aligned with priorities of both IMR and Tyndall. These include scientific and engineering endeavors in areas that include, but are not limited to, advanced semiconductors, photonics, emergent materials, quantum science and technologies, medical devices, sustainable materials and advanced manufacturing.

"Tyndall is a powerhouse research and innovation center in a number of areas that are well aligned with IMR's signature areas and the interests of many of our faculty," said Prof. Steven Ringel, IMR Executive Director. "We are honored by the establishment of this strategic, international partnership. The two pilot projects already underway highlight the wide range of our common interests, and I am looking forward to their success and further growing the Tyndall-IMR collaboration."

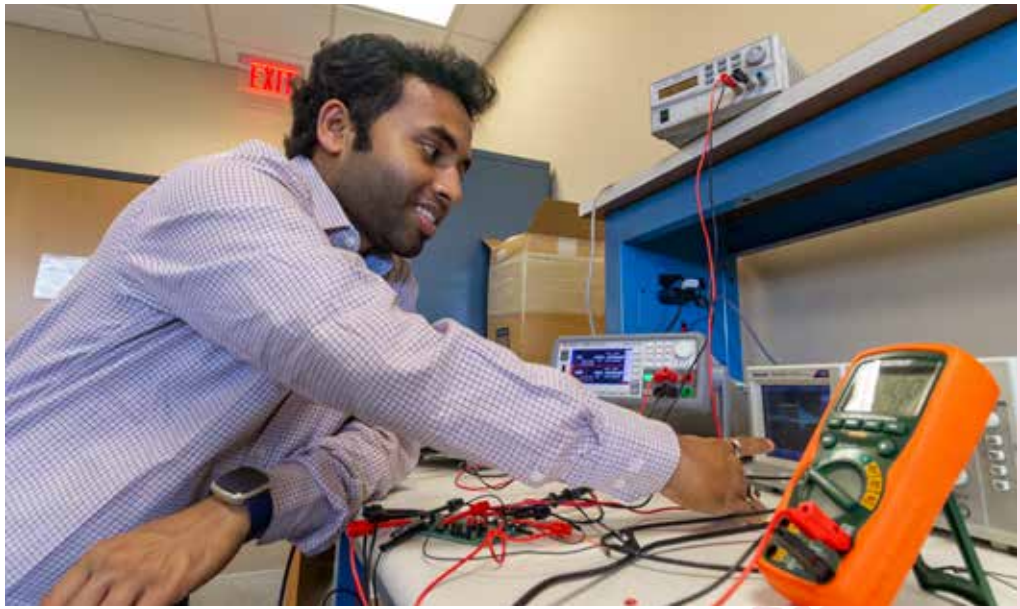
Each Catalyst research team consists of two principal investigators, one from each institution, with complementary expertise and access to research facilities and instruments. The Catalyst Program has already launched with two pilot projects in the areas of nanomagnetic materials with implications for future data storage technologies, and compound semiconductor-based photonic integration for future applications in fields that include on-chip biomolecule sensing for next generation medical devices. Projects receive funding for six months, covering facility and user fees, and other specific costs associated with lab work.

"I am delighted to see our first joint Catalyst Award is off to such a successful start and I look forward to welcoming new applications later this year," said Tyndall team lead Dr. Graeme Maxwell.



Tyndall works with industry and academia to transform research into products in its core market areas of electronics, communications, energy, health, agri-tech and the environment.

Tyndall National Institute. Photos courtesy of Tyndall.



Frontier Center Scholar Sumit Saha, who visited Ohio State from IIT Bombay for a semester in FY21, conducts research related to "Integration of Zero-Leakage NEMS Switch with a Flexible Antenna for RF Energy Harvesting" at the ElectroScience Laboratory on West Campus.

FRONTIER CENTER AWARDS MORE THAN $200K TO TEAMS JOINING OHIO STATE AND IIT BOMBAY RESEARCHERS

In FY21, the IIT Bombay-Ohio State Frontier Center announced more than $200,000 in funding to eight collaborative research teams through its second round of awards under the Frontier Center Scholars Program.

The IIT Bombay-Ohio State Frontier Science and Engineering Research Center is a joint research center operated by IMR and the Indian Institute of Technology Bombay that builds on both institutions' research strengths in materials and their applications to systems.

Teams receiving the total of $208,412 in funding bring together investigators with complementary expertise from India and the U.S. to enable unique projects that push the frontier of science and engineering research beyond what could be accomplished by a single institution. Funding costs are shared by Ohio State and IIT Bombay.

"I'm thrilled at the diverse strength of this year's proposals and funded awards," said Frontier Center co-leader Ardeshir Contractor, professor of practice in Ohio State's Department of Mechanical & Aerospace Engineering and the Fisher College of Business. "Even within our targeted areas, we are seeing a range of ideas brought to the table that will increase the reach and impact of this collaboration."

Fourteen seed projects are now supported through the Frontier Center Scholars Grant Program. Research areas of these projects include renewable energy, advanced manufacturing, electronics, photonics, and emergent materials.

Each supported project under the Frontier Center Scholars Program is carried out by a team that includes a pair of principal investigators, one from Ohio State and one from IIT Bombay, and a graduate student from one of the partnering institutions. These students, or Frontier Scholars, spend approximately one semester visiting the host institution to complete the research project.

COMMUNITY

The breadth of the Ohio State materials-allied research community reaches across colleges. To promote this diversity of disciplines, and to identify and establish critical areas of research at their intersections, IMR hosts several outreach and engagement events each year. Although the global coronavirus pandemic forced considerable changes this year, IMR remained determined to maintain and, even, grow the ties that articulate our strengthening materials research community. IMR continued supporting workshops that promote Ohio State's presence in strategic areas of interest, while augmenting how we host other events. IMR moved its annual OSU Materials Week online, amplifying its reach and widening its audience.

2021 OSU MATERIALS WEEK

The materials community at Ohio State adapted quickly as the pandemic caused by COVID-19 led to shakeup after shakeup to how research and innovative endeavors were achieved.

IMR was quick to adapt to these changes too — in its approaches to research support, strategy and celebration.

For more than a decade, IMR has dedicated one week each year to celebrate the innovative research and accomplishments of the materials-allied community. This year, that tradition continued with 2021 OSU Materials Week, a virtual series of celebrations that welcomed hundreds of faculty, professional researchers and students from around the world.

In fact, OSU Materials Week saw nearly one thousand visits during its series of research presentations, student-led virtual lab tours, and other interactive sessions.

Research areas covered in 2021 reflected the breadth of the materials community at Ohio State, with topics ranging from quantum information science and engineering to manufacturing and clinical 3D printing.

FRONTIERS IN QUANTUM INFORMATION SCIENCE AND ENGINEERING

Sessions kicked off early in January with a look into the current and future states of the rapidly evolving landscape of quantum information science during the series "Frontiers in Quantum Information Science and Engineering."

IMR collaborated with Ohio State's Institute for Optical Science across seven sessions that welcomed world leaders in the field to discuss the full spectrum of science and engineering opportunities in QISE, including quantum computing, quantum sensing and quantum communication technologies, as well as the fundamental principles, materials development and measurement challenges central to their rapid advance.

LIES, DAMN LIES, AND CONSULTANTS

On Feb. 25, Ned Hill, a professor In The John Glenn College Of Public Affairs and College Of Engineering's Knowlton School Of Architecture, presented an extensive research project on corporate strategies and implementation of digital operations technologies within the context of digitally connected manufacturing enterprises during the session "Lies, Damn Lies, and Consultants: What Manufacturing and Supply Chain Leaders Need to Know About Digital Manufacturing, Industry 4.0, and the Internet of Things." He then led a panel discussion on systems integration, workforce, equipment and operational excellence with panelists from the Center for Design and Manufacturing Excellence, Center for Operational Excellence, Ohio Manufacturing Institute, and the Department of Integrated Systems Engineering.

INTERNATIONAL COLLABORATIONS ADVANCING WIDE BANDGAP SEMICONDUCTORS

On March 4, IMR hosted an in-depth look at two international research projects in wide bandgap semiconductors, based on β-Ga2O3 and SiC, respectively. Additionally, student and young researchers took attendees on virtual tours of research labs at Ohio State and the Indian Institute of Technology Bombay, where some of this innovative work is conducted. Anant Agarwal, a professor in Electrical and Computer Engineering at Ohio State and a leader of the Frontier Center, presented his work in a collaborative research project focusing on silicon carbide semiconductors. Saurabh Lodha, a professor in Electrical Engineering at IIT Bombay who is also a co-lead of the Frontier Center led a discussion on his collaborative research on gallium oxide semiconductors.

NSF NeXUS AND THE FUTURE OF ULTRAFAST OPTICAL SCIENCE

The March 18 installment took an in-depth look at Ohio State's new NSF National eXtreme Ultrafast Science (NeXUS) Facility in the session "NSF NeXUS and the Future of Ultrafast Optical Science." The NSF NeXUS facility is designed to fill a key strategic gap in U.S. research infrastructure and will make the university an international focal point serving a broad user community in ultrafast optical science. Facility leaders and experts from NeXUS led attendees through a showcase of groundbreaking research, state-of-the-art equipment and impact enabled by this new facility on Ohio State's campus.

BIOFABRICATION AND CLINICAL 3D PRINTING AT OHIO STATE

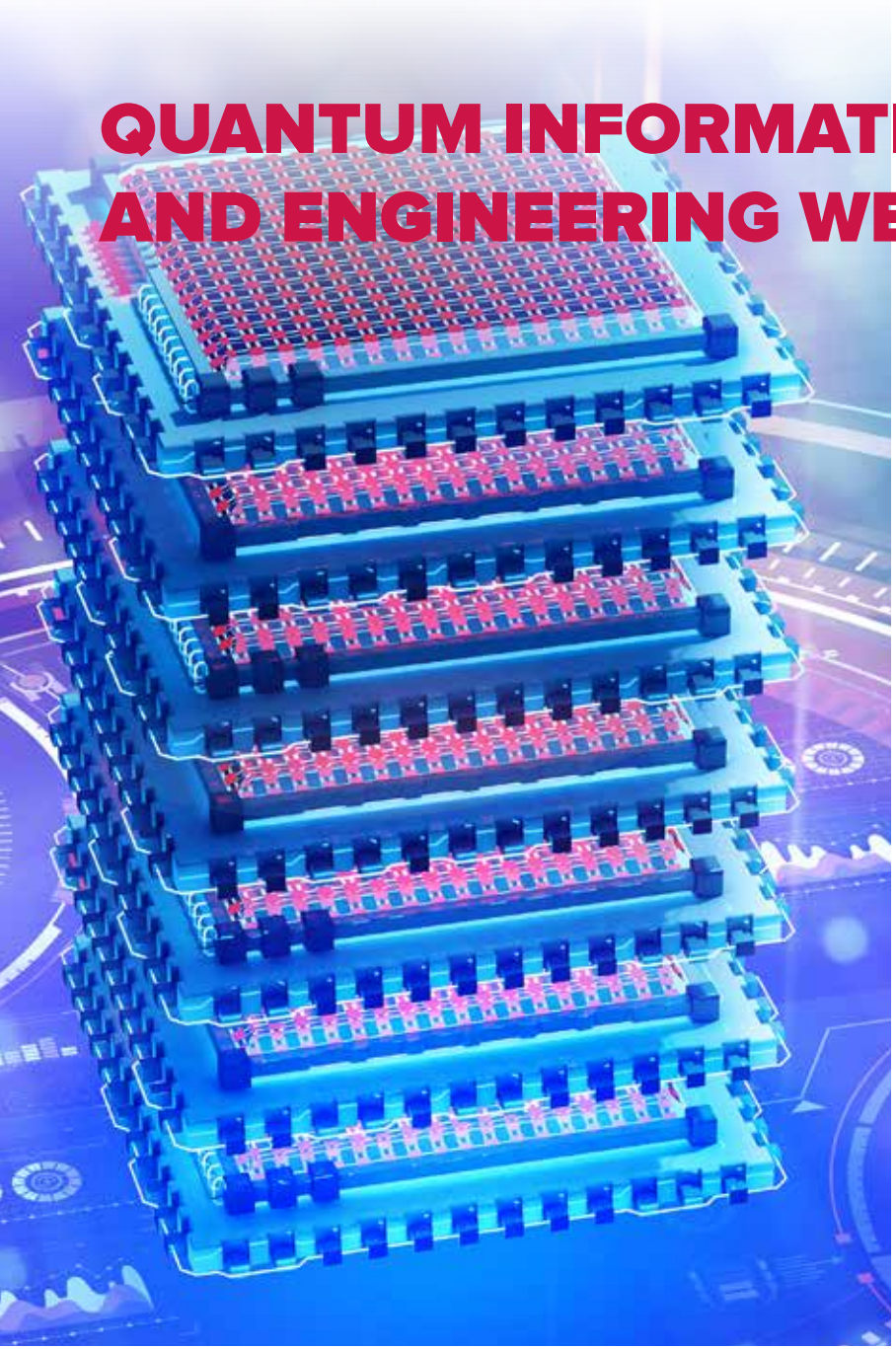
The April 1 session "Biofabrication and Clinical 3D Printing at Ohio State" showcased activities across Ohio State in biofabrication, as well as new projects bringing 3D printing into a clinical setting at the Ohio State University Wexner Medical Center and College of Medicine. Experts from Mechanical and Aerospace Engineering to Biomedical Engineering and beyond presented innovative biofabrication activities underway. Attendees were also guided through video tours of lab spaces in which some of these interdisciplinary research and developments take place.

WATCH NOW: The 2021 OSU Materials Week playlist

Use your phone's camera app to scan the QR code or visit go.osu.edu/CA39

Clockwise from top left: Ohio State Research Scientist TJ Ronningen, IMR Executive Director Steven Ringel, IIT Bombay Prof. Saurabh Lodha, and Ohio State Prof. Anant Agarwal.

QUANTUM INFORMATION SCIENCE AND ENGINEERING WEBINARS



The Frontiers in Quantum Information Science and Engineering (QISE) webinar series welcomed world leaders in the field to paint a broad perspective of the current state of QISE while looking toward the future of this rapidly evolving landscape.

The seven-part webinar series was presented by both IMR and Institute for Optical Science, as part of 2021 OSU Materials Week.

Topics covered during Frontiers in QISE included the full spectrum of science and engineering opportunities in QISE, including quantum computing, quantum sensing and quantum communication technologies, as well as the fundamental principles, materials development and measurement challenges central to their rapid advance.

Speakers included experts Michel Devoret of Yale University, Christopher Monroe of Duke University and IonQ Inc., Carl Williams of the National Institute of Standards and Technology, Mikhail Lukin of Harvard University, Zhenghan Wang of the University of California, Santa Barbara, Brian DeMarco of the University of Illinois at Urbana-Champaign, and Scott Aaronson of the University of Texas at Austin.

Each webinar was followed by an open discussion with the speaker, which provided a unique opportunity for both experts and novices in QISE to come up to speed with the latest developments and challenges in this evolving field.

WATCH NOW: Frontiers in QISE webinar series presentations

Use your phone's camera app to scan the QR code

...or visit go.osu.edu/qise-webinars

FRONTIER CENTER WEBINAR SERIES

The IIT Bombay-Ohio State Frontier Science and Engineering Research Center in FY21 hosted a series of webinars showcasing research areas and projects currently underway that show great potential for growth and collaboration in the future.

The series was capped with the presentation of projects set to receive seed grant support through the Frontier Center Scholars Program. Eight research teams, each joining researchers from IIT Bombay and Ohio State, received more than $200,000 in funding in FY21. Fourteen seed projects are now supported through the Frontier Center. Research areas of these projects include renewable energy, advanced manufacturing, electronics, photonics, and emergent materials. Seed grant awardees were welcomed by Frontier Center co-leads Ardeshir Contractor (Ohio State) and Prof. Saurabh Lodha (IIT Bombay). During the webinar, student scholars presented overviews of their team's proposals and participated in follow-up question-and-answer sessions with attendees.

The preceding webinars were centered on three main research areas: photonics and photonic devices, quantum information and science, and advanced manufacturing.

Prof. Lodha and Ohio State research scientist TJ Ronningen welcomed attendees to the first of these webinars and introduced the Frontier Center. They were followed by presentations focusing on developing collaborations related to photonics and photonic devices, given by Ohio State faculty members Shamsul Arafin, Dan Gauthier, Jay Gupta and Sanjay Krishna, and IIT Bombay faculty members Dinesh Kabra and Kasturi Saha. Based on their respective presentations, Kabra and Krishna would soon collaborate on a proposal that was awarded funding through the Frontier Center Scholars Program.

The next webinar "Quantum Science and Quantum Information Research at IIT Bombay and Ohio State" was presented by Ohio State Physics Prof. Zeke Johnston-Halperin and IIT Bombay Physics Prof. Sai Vinjanampathy. The webinar concluded with overviews of each university's materials and device research capabilities. Finally, experts in the field of advanced manufacturing research at both IIT Bombay and Ohio State led attendees through several summaries of cutting-edge research being conducted at both institutions. Presenters included IIT Bombay faculty members Alankar Alankar, PJ Guruprasad, Shyamprasad Karagadde and Asim Tewari, as well as Ohio State faculty members Michael Groeber, Alan Luo, Steve Niezgoda and Farhang Pourboghrat.

M&MS FACULTY

IMR faculty members are central to the strength and success of Ohio State's expanding materials community. FY21 marked the first full year with all 24 new faculty members hired through the IMR-operated Materials and Manufacturing (M&MS) for Sustainability Discovery Theme. The Discovery Theme has enabled IMR to carry out the careful, strategic recruitment and selection of these faculty members. The new hires now work in a myriad of departments in colleges across Ohio State, with foci spanning from engineering and manufacturing to business and architecture; a multidisciplinary cohort of talent that truly reflects the university-wide scope of the Discovery Theme's aim to stimulate interdisciplinary activity to address the grand challenges facing our society in the 21st century. This M&MS hiring initiative is the third major talent scouting campaign IMR has led at the university. In FY15, IMR completed the hiring of five Ohio Research Scholars within its state-funded Technology-Enabling and Emergent Materials program. In 2006, IMR began collaborating with two Ohio State colleges to hire technical staff and faculty through its Targeted Investment in Excellence program, part of a five-year initiative funded by the Office of the Provost.

ANANT AGARWAL
Professor, Department of Electrical and Computer Engineering

MARC BOCKRATH
Professor, Department of Physics

SHAMSUL ARAFIN
Assistant Professor, Department of Electrical and Computer Engineering

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

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

CAROLIN FINK
Assistant Professor, Department of Materials Science and Engineering

CHRISTIAN BLANCO
Assistant Professor, Fisher College of Business

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

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

JOERG JINSCHEK
Associate Professor, Department of Materials Science and Engineering

ERIN MCKIE
Assistant Professor, Fisher College of Business

ALOK SUTRADHAR
Assistant Professor, Department of Mechanical and Aerospace Engineering

AYONGA HEREID
Assistant Professor, Department of Mechanical and Aerospace Engineering

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

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

SHIYU ZHANG
Assistant Professor, Department of Chemistry and Biochemistry

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

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

ZACHARY SCHULTZ
Associate Professor, Department of Chemistry and Biochemistry

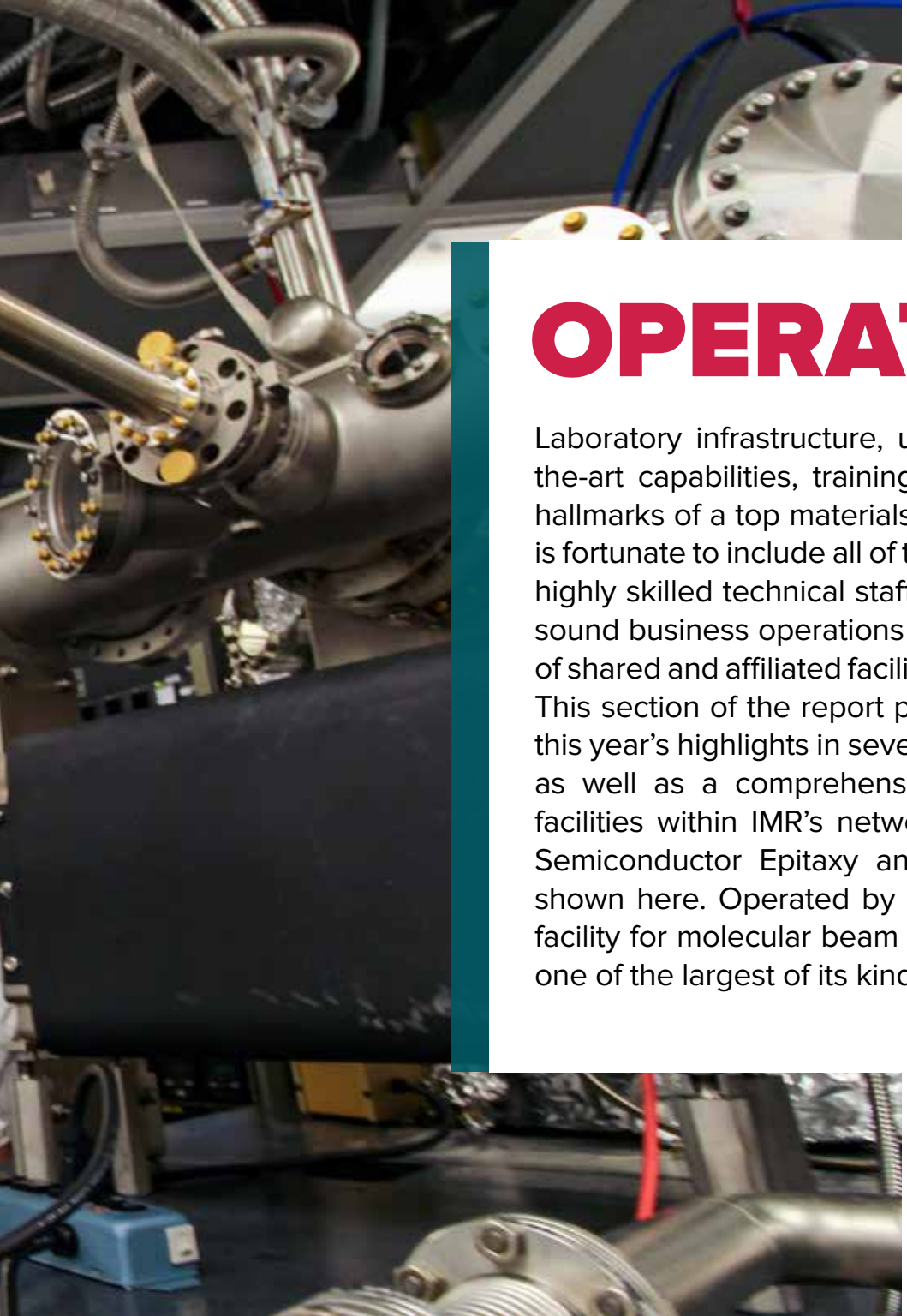
HONGPING ZHAO
Associate Professor, Department of Electrical and Computer Engineering

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

CHUNNING (JEANIE) LAU
Professor, Department of Physics

BRIAN SKINNER
Assistant Professor, Department of Physics

RENEE ZHAO
Assistant Professor, Department of Mechanical and Aerospace Engineering



OPERATIONS

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

NANOTECH WEST LABORATORY

Nanotech West Laboratory (NTW) is 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 IMR, NTW is an extensively equipped and fully staffed space where researchers can access laboratories and equipment, as well as take advantage of in-house training, process and project support. NTW's user-accessible facility resources include a 6,000-square-foot cleanroom, major shared facilities for semiconductor and oxide epitaxy, materials and device characterization, 3D printing for clinical applications, and shared labs for research of energy storage materials and devices.

With more than 300 active users and 86 new users trained in FY21, research activities at NTW span a range of cutting-edge materials research that is rather extraordinary for a single facility – from GaN/AlGaN and β-Ga_2O_3 materials and devices, solar cells and infrared focal plane arrays to microfluidics, biotechnology, 3D printing of anatomic models, material synthesis and testing for energy storage, and the fabrication of structures for use in the study of basic physics and chemistry. As the primary IMR location on Ohio State's West Campus, NTW provides substantial impact and continues to be a centerpiece of collaborative research to the university's materials research community.

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

NANOFABRICATION LAB

The Nanofabrication Lab (Nanofab) within Nanotech West is a class 100 clean room with more than 50 pieces of user accessible materials synthesis, device fabrication, and metrology equipment. The Nanofab operates as a user facility with 11 full and part time staff engineers and 4-5 undergraduate student interns providing both equipment and process support for researchers from academic institutions (both within OSU and externally), industry, and government labs.

In FY21, significant investment is bringing new capability and flexibility to the nanofab, specifically in the lithography area. Newly qualified, the Heidelberg MLA150 Maskless Alignment System quickly became one of the most highly utilized tools in the fab, with more than 50 users trained in FY21. Capable of features sizes of 600nm or better, the laser writer has both 405nm and 375nm sources and removes the need for a physical mask in the patterning process. Additionally, Professor Siddharth Rajan (lead-PI) was awarded a Major Research Instrumentation (MRI) award by the National Science Foundation for the purchase a state-of-the-art electron beam lithography (EBL) system (installation FY22/FY23). The new EBL will replace an aging Raith/Leica EBL system with updated technology capable of handling the most demanding nanopatterns. Together, the MLA150 and new EBL systems push the NTW Nanofab to the top level of lithography capabilities within U.S. academic labs.

ENERGY INNOVATION LAB

The Energy Innovation Lab (EIL) is focused on translating electrochemical energy storage (e.g. batteries) and conversion (e.g. fuel cells) 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 requires 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 enabling multiple projects that resulted from a jointly held research strategy recently established by IMR and Honda. The space is also home to two faculty members hired through the Materials and Manufacturing for Sustainability Discovery Theme, Vicky Doan-Nguyen and Jung-Hyun Kim. 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.

MEDICAL MODELING, MATERIALS AND MANUFACTURING (M4) LAB

The Medical Modeling, Materials and Manufacturing (M4) Lab is where medicine, advanced manufacturing, and materials-related research converge to pursue innovative approaches to advance the health and well-being in our society. The M4 Lab opened its doors November 2020 to bring together an interdisciplinary team of experts under one roof at the Nanotech West Lab facility, utilizing 3D printing to provide innovative engineering solutions for real-world needs in clinical medicine. The lab is a collaboration of the Department of Otolaryngology, the Center for Design and Manufacturing Excellence, and the Institute for Materials Research with a focus on supporting the life-saving efforts of clinicians and faculty by stimulating and centralizing research innovation around bioengineering, medical device development and clinical 3D printing. This new lab was established to meet specific needs of the medical community, while being managed and operated by biomedical engineering and clinical experts with firsthand experience commercializing medical devices. On top of research and clinical support activities, the lab serves as an experiential education platform for undergraduate research assistants, providing students with real-world experience and on-the-job training that will position them as top candidates for medical device company hires. Additionally, postdoctoral researchers, medical students and residents from across medical and engineering disciplines collaborate to create innovative health care solutions.

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 allows to grow (i) III-nitrides (Al-, Ga-, In-, N), their alloys and heterostructures; and (ii) novel materials/structures based on II-IV-nitrides [e.g., $Zn(Mg)Ge(Si, Sn)N_2$]. Funded by Department of Energy, PI Hongping Zhao is currently developing high performance visible light emitting diodes for solid state lighting, using III-N and II-IV-N_2 heterostructures. The system is also coupled with a high power CO_2 laser source. PI Zhao is leading an ARPA-E project to develop vertical high power GaN power devices, using a laser-assisted MOCVD growth technique.

The newest oxide MOCVD tool has successfully developed the state-of-the-art Ga_2O_3, an emerging ultrawide bandgap semiconductor for next generation power electronics. This tool supports research projects funded by Department of Defense Multidisciplinary University Research Initiative (MURI) program, National Science Foundation, Semiconductor Research Corporation, among others.

OPTO-ELECTRONIC METROLOGY (OEM) LAB

In FY21, the Nanotech West Laboratory (NTW) increased its footprint on the first floor and established the Opto-electronic Metrology (OEM) Lab. The OEM Lab is a suite of instruments and techniques that enables NTW users to examine crystal structures with a state-of-the-art X-ray diffractometer (XRD), image devices with a scanning electron microscope (SEM), map the photoluminescence and lifetime of narrow-bandgap materials, and quantify the electro-optical response of fabricated devices.

The two newest capabilities in the OEM lab are the XRD and the photoluminescence/lifetime mapper. XRD is an invaluable tool for characteristics the atomic-level structure of crystalline materials. NTW acquired a Bruker D8 XRD that provides Nanotech users with a highly efficient and highly accurate measurement system. Samples grown using the Nanotech chemical vapor deposition systems, or SEAL molecular beam epitaxy systems, have been able to reduce their analysis times by more than a factor of 10.

The photoluminescence/lifetime mapper supports the investigation of narrow-bandgap semiconductors that are responsive to infrared radiation. The system was acquired from 8D and offers the unique capability to map the characteristics of a wafer (up to 6-inch diameter) with a resolution of 100 µm. The measured characteristics predict the electro-optical performance of a final device and can be used to prioritize wafers or regions of wafers.

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 305 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 160 externships and internships and several sponsored projects. The lab has also attracted state and federal funding to engage local community college students and train Ohio State graduate students to attract a wider array of talent and skills for collaborations with regional and global industry partners. Thanks to the Innovation Lab, there are now more than 70 companies engaged in multiple ways that will enable long-term, mutually beneficial relationships with students, faculty and external partners.

IMR operates the Innovation Lab as the place where Ohio State guests and industry visitors can engage each other, as well as students and faculty. It is home to a number of IMR events, including INNOVATE-O-thon and other collaborative programs involving faculty, staff and industry partners. It is where students wanting real-world, experiential learning connect with companies wanting better access to the university and undergraduates through externship opportunities. Learn more at imr.osu.edu/innovation-lab.

CENTER FOR 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 and has completed over 520 applied engineering projects. Projects are executed in a 37,600 square-foot ITAR compliant manufacturing facility within Ohio State's Innovation District. In all, the center houses more than $13 million in industrial-scale equipment. CDME's areas of emphasis impact a wide range of manufacturing sectors, including robotics, machine learning, additive manufacturing, entrepreneurship, biomedical, cybersecurity, and defense systems. The center employs 20 full-time technical staff members and supports 114 affiliate faculty members. These professionals execute projects while mentoring and advising CDME student employees. More than 200 undergraduate students across academic disciplines have been impacted by CDME to date, with approximately 80 students employed by the center in Autumn Semester 2021. CDME strives to execute its innovative approach to technology translation and workforce development while shaping the national conversation on advanced manufacturing innovation.

RESEARCH REVIEW: ADVANCES IN LASER POWDER BED FUSION ADDITIVE MANUFACTURING

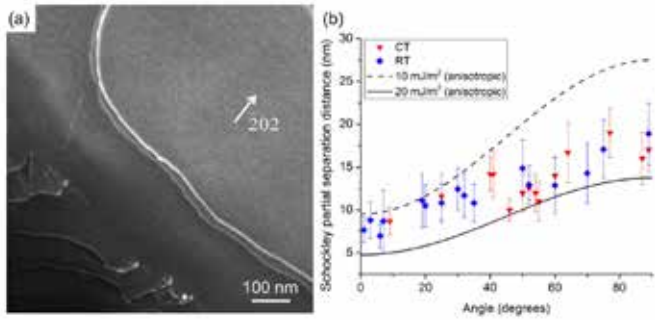
In collaboration with America Makes, the U.S. Air Force, Lockheed Martin, Rolls-Royce, and Proto Precision Additive, CDME led a program to create advanced surrogate defect generation techniques for laser powder bed fusion (LPBF) additive manufacturing (AM). The CDME team consists of Mike Groeber, faculty director of CDME's Artificially Intelligent Manufacturing Systems Lab; Ed Herderick, director of additive manufacturing at CDME; and Jacob Rindler, lead research engineer at CDME. LPBF has shown significant promise in creating complex component geometries manufactured with various metallic alloys of engineering significance. However, understanding these components' mechanical performance and qualification still lags traditional processing methods (wrought & casting), especially in fatigue and fracture critical applications. U.S. Department of Defense partners have identified crucial gaps in their qualification road maps regarding the understanding of defect formation mechanisms and the resultant effects and detectability of the flaws that arise from AM. The project team developed critical data and tools to help overcome the qualification hurdles related to the formation of AM manufacturing defects and their effect on performance. Understanding the process characteristics driving these defects in LPBF and the resultant effect of varying defects on performance is critical to advancing qualification methods. To develop a fundamental understanding of the effects of defects, engineers needed to generate representative defects in a controlled manner, allowing for quantitative studies of their debit on material properties and their ensuing probability of detection. Ohio State's work delivers methodologies for generating multiple classes of controlled representative defects in relevant component geometries. These findings will serve as standards for continued DOD work focused on rapid qualification and certification of the exciting components produced by additive manufacturing.

CENTER FOR ELECTRON MICROSCOPY AND ANALYSIS

Ohio State's Center for Electron Microscopy and Analysis (CEMAS) is the preeminent materials characterization hub for business and academia. CEMAS was established to provide a world-class environment for the teaching and practice of advanced microscopy across all scientific disciplines. The point of difference lies in the multidisciplinary approach taken to drive synergy, amplify characterization capabilities, and challenge what is possible in analytical electron microscopy. With one of the largest concentrations of electron and ion beam microscopy instruments for materials characterization, CEMAS strives to be the most advanced microscopy facility in the world. CEMAS was partly funded by IMR's ORSP award – Technology Enabling and Emergent Materials (TEEM), which also provided the position filled by David McComb, who is the CEMAS director and an IMR associate director. CEMAS facilitates electron microscopy application to an incredible breadth of science — from biomaterials and bio-inspired materials to nanoelectronics, energy materials, advanced structural materials, and medicine. Capabilities include scanning electron microscopy (SEM), focused ion beam microscopy (FIB), transmission electron microscopy (TEM), X-ray diffraction (XRD), micro-computed tomography (micro-CT), and cryo-electron microscopy (cryo-EM). Among the highlights of its $40M equipment portfolio, CEMAS houses a Thermo Scientific Themis Z S/TEM and Thermo Scientific Glacios Cryo-TEM. CEMAS offers a full-service, expertly designed environment for researchers to execute their entire microscopy and analysis program. The center enabled $149M in research during FY20 and has supported 829 users, including 202 principal investigators, since opening its doors in 2013. Learn more at cemas.osu.edu.

RESEARCH REVIEW: STACKING FAULT ENERGY IN CONCENTRATED ALLOYS

Ohio State researchers leveraged CEMAS to advance their work interpreting stacking fault energy (SFE) in alloys and explaining the discrepancy between experiments and computations. The result, published in Nature Communications, was a collaboration between Mulaine Shih, Jiashi Miao, Michael Mills, and Maryam Ghazisaeid, representing Ohio State's Materials Science and Engineering Department. According to Shih, the experiential images obtained clearly captured the defect configurations, specifically dislocations, in CrCoNi alloy. Motivated by the experimental observations, the work examined the critical factors resulting in the captured dislocation configurations. The team performed atomistic simulations on a model fcc alloy to enclose all possibilities. Ultimately, they revisited the conditions for the equilibrium dissociation of a lattice dislocation and showed that considering the interaction of dislocations with local solute environments is critical in concentrated alloys such as CrCoNi alloy.



Characterization of dissociated dislocations in equiatomic CrCoNi medium entropy alloy. (a) An example image showing both Shockley partial dislocations of a dissociated dislocation obtained by Weak beam dark field scanning transmission electron microscopy (WB DF STEM); and (b) experimentally measured dissociation distances in equiatomic CrCoNi medium entropy alloy at room temperature (RT) condition and cryogenic temperature (CT) condition.

THE IIT BOMBAY–OHIO STATE FRONTIER CENTER

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

SECOND ROUND OF FRONTIER CENTER SCHOLAR GRANTS AWARDED

The Frontier Center announced in FY21 its second round of awards to eight collaborative research teams under the Frontier Center Scholars Program. The program provides seed funding designed to lay the groundwork for larger, externally funded projects that advance science and technology. Awarded projects bring together investigators with complementary expertise from across the globe to enable unique projects that push the frontier of science and engineering research beyond what could be accomplished separately.

FY21 AWARDEES

Design Control and Implementation of Medium Voltage Modular Converter Using Si and SiC Devices – Principal investigators (PIs): Jin Wang (Electrical and Computer Engineering, Ohio State) and Anshuman Shukla (Electrical Engineering, IIT Bombay)

Development of Robust Catalysts for Sustainable H2 Evolution – PIs: Hannah Shafaat (Chemistry and Biochemistry, Ohio State) and Arnab Dutta (Chemistry, IIT Bombay)

Development of Robust System Designs for Maximizing the Energy Yield of Space – Efficient Photovoltaic Systems – PIs: Navni Verma and Sandip Mazumder (Mechanical and Aerospace Engineering) and Narendra Shiradkar (Electrical Engineering)

Enabling SiC based Power Converters: Gate Drivers to AI-enhanced System Design – PIs: Anant Agarwal (Electrical and Computer Engineering, Ohio State), and Sandeep Anand and Swaroop Ganguly (Electrical Engineering, IIT Bombay)

Facile synthesis of BaZrS3 nanoparticles absorber material for photovoltaic application – PIs: Patrick Woodward (Chemistry and Biochemistry, Ohio State) and K. R. Balasubramaniam (Energy Science and Engineering, IIT Bombay)

Hybrid Organic-inorganic Metal Halide Based Perovskite Infrared Detectors and its Application in Imaging – PIs: Sanjay Krishna (Electrical and Computer Engineering, Ohio State) and Dinesh Kabra (Physics, IIT Bombay)

Impact Welding of Nano-structured Bainitic Steel: Efficacy and Microstructural Study – PIs: Anupam Vivek (Materials Science and Engineering, Ohio State) and Aparna Singh (Metallurgical Engineering and Materials Science, IIT Bombay)

Understanding the Structure-Property Linkages in Electron Beam Melted Ti-6Al-4V – PIs: Joerg Jinschek (Materials Science and Engineering, Ohio State) and Alankar Alankar (Mechanical Engineering, IIT Bombay)

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

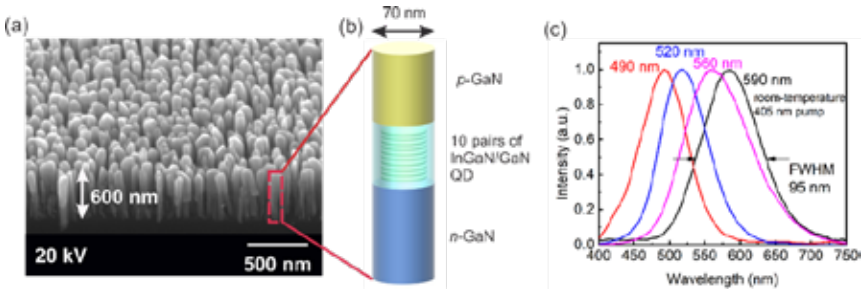
Use your phone's camera app to scan the QR code ...or visit go.osu.edu/frontier-launch

SEMICONDUCTOR EPITAXY AND ANALYSIS LABORATORY

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

RESEARCH REVIEW: MOLECULAR BEAM EPITAXY-GROWN QUANTUM EMITTERS

SEAL is facilitating Prof. Shamsul Arafin's research group, the Optics and Photonics REsearch Lab (OPREL), in the development of monolithic optically-pumped single-photon sources based on deterministic InGaN quantum dots (QD) in GaN nanowires (NWs) using molecular beam epitaxy (MBE) growth technology. Below is the SEM image, showing self-assembled NWs grown on top of Si(111) substrates. The schematic view of each NW grown on the substrates is also shown (middle). By controlling the substrate temperature, III/V flux ratio and indium incorporation within QDs, emission wavelengths were tuned across a wavelength range, spanning between 490-590 nm, as confirmed by the photoluminescence spectra (right). The next step is to deterministically grow InGaN/GaN QDs-in-NWs based on selective area growth. This is an essential first step toward the development and demonstration of high-performance SPSs for quantum technologies.



SEM image of self-assembled nanowires (left), schematic view of each NW (middle), and photoluminescence spectra of InGaN/GaN with different indium compositions at QD regions (right). Image courtesy of Syed M N Hasan.

NANOSYSTEMS LABORATORY

NanoSystems Laboratory (NSL) provides users with access to advanced material characterization and fabrication tools for research and development applications. NSL operates a diverse set of research instrumentation and research capabilities including Focused Ion Beam/Scanning Electron Microscopy, X-ray diffractometry, SQUID magnetometry, Atomic Force/Magnetic Force microscopy, EDS X-ray microanalysis, e-beam lithography, Electron Spin Resonance spectroscopy, Physical Vapor material deposition, ion milling, ICP/RIE etching, maskless photolithography, Low-Temperature/High Magnetic field magnetotransport measurements, diamond CVD growth, material polishing, Kerr microscopy, critical point drying and magneto-optical material studies. NSL also operates two 1,100-square-foot clean room facilities. One clean room houses instruments for material deposition and processing for photo/e-beam lithography, while the other clean room is devoted to processing organic spintronic devices, and other air and moisture sensitive materials. It is equipped with four interconnected gloveboxes with Ar and N_2 atmosphere. Recently, NanoSystems Laboratory expanded its capabilities through acquisition of a new Broadband 330 GHz Variable Temperature Magnetic Resonance Spectrometer System funded by NSF MRI award obtained by the team of Ohio State researchers led by Fengyuan Yang. The new instrument will allow measurements of material properties in the frequency ranges previously unattainable in a user facility. Final commissioning of the instrument was delayed due to the COVID-19 shutdown and restriction. The instrument is expected to become operational in FY22. Learn more at nsl.osu.edu.

RESEARCH REVIEW: NONLOCAL UNIFORM-MODE FERROMAGNETIC RESONANCE SPIN PUMPING

Supported by the Air Force Office of Scientific Research, the OSU Center for Emergent Materials (CEM), and the U.S. Department of Energy (DOE) Fengyuan Yang's group (Physics) in collaboration with the group of Chris Hammel (Physics) reported a new nonlocal spin injection scheme using uniform-mode ferromagnetic resonance (FMR) spin pumping in Pt/Y3Fe5O12 (YIG) lateral structures. This scheme is enabled by well-separated resonant fields of Pt/YIG and bare YIG due to substantial change of anisotropy in YIG films induced by a Pt overlayer, allowing for clearly distinguishable local and nonlocal spin pumping. The work was done with participation of the NSL director Denis Pelekhov. Sample fabrication and some characterizations were performed at NSL. These results have led to the following recent publication: Nano Letters 20, 7257 (2020).

Physical vapor deposition system in the NanoSystems Laboratory clean room. Photo courtesy of NSL.

RESEARCH CENTERS & CORE LABORATORIES

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

CENTER FOR AUTOMOTIVE RESEARCH (CAR)

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

CENTER FOR DESIGN AND MANUFACTURING EXCELLENCE (CDME)

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

CENTER FOR EMERGENT MATERIALS (CEM)

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

CENTER FOR ELECTRON MICROSCOPY AND ANALYSIS (CEMAS)

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

RESEARCH CENTERS & CORE LABORATORIES

CENTER FOR HIGH PERFORMANCE POWER ELECTRONICS (CHPPE)

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

CENTER FOR INNOVATION STRATEGIES (CIS)

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

ELECTROSCIENCE LAB (ESL)

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

ENERGY INNOVATION LAB

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

FONTANA CORROSION CENTER (FCC)

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

INFECTIOUS DISEASES INSTITUTE (IDI)

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

IIT BOMBAY-OHIO STATE FRONTIER SCIENCE AND ENGINEERING RESEARCH CENTER

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

IMR INNOVATION LAB

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

LIGHTWEIGHT INNOVATIONS FOR TOMORROW (LIFT)

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

METALORGANIC CHEMICAL VAPOR DEPOSITION (MOCVD) LAB

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

RESEARCH CENTERS & CORE LABORATORIES

NANOSYSTEMS LABORATORY (NSL)

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

NANOTECH WEST LAB (NTW)

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

OHIO 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.

OPTO-ELECTRONIC METROLOGY (OEM) LAB

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

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.

SEMICONDUCTOR EPITAXY AND ANALYSIS LAB (SEAL)

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

SIMULATION INNOVATION AND MODELING CENTER (SIMCENTER)

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

SUSTAINABILITY INSTITUTE (SI)

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

TRANSLATIONAL DATA ANALYTICS INSTITUTE (TDAI)

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

Anant Agarwal, Electrical and Computer Engineering

Gunjan Agarwal, Biomedical Engineering

Sudha Agarwal, Oral Biology

Sheikh Akbar, Materials Science and Engineering

Boian Alexandrov, Materials Science and Engineering

Heather Allen, Chemistry and Biochemistry

Douglas Alsdorf, Earth Sciences

Peter Anderson, Materials Science and Engineering

Betty Lise Anderson, Electrical and Computer Engineering

Shamsul Arafin, Electrical and Computer Engineering

Aaron Arehart, Electrical and Computer Engineering

Aravind Asthagiri, Chemical and Biomolecular Engineering

Jovica Badjic, Chemistry and Biochemistry

Robert Bailey, Mechanical and Aerospace Engineering

Robert Baker, Chemistry and Biochemistry

Jim Beatty, Physics

Avraham Benatar, Materials Science and Engineering

Alison Bennett, Evolution, Ecology and Organismal Biology

Paul Berger, Electrical and Computer Engineering

Ashley Bigham, Architecture

Christian Blanco, Management Sciences

Thomas Blue, Mechanical and Aerospace Engineering

Marc Bockrath, Physics

Dennis Bong, Chemistry and Biochemistry

Janet Box-Steffensmeier, Political Science

Leonard Brillson, Electrical and Computer Engineering

Jonathan Brown, Chemical and Biomolecular Engineering

Nicholas Brunelli, Chemical and Biomolecular Engineering

Rafael Bruschweiler, Chemistry and Biochemistry

Ralf Bundschuh, Physics

Lisa Burris, Civil, Environmental and Geodite Engineering

Michael Camp, Center for Design and Manufacturing Excellence

Lei (Raymond) Cao, Mechanical and Aerospace Engineering

William Carson, Surgery Oncology

Luis Casian, Mathematics

Jose Castro, Mechanical and Aerospace Engineering

Carlos Castro, Mechanical and Aerospace Engineering

Jeffrey Chalmers, Chemical and Biomolecular Engineering

Heather Chandler, Optometry

Hanna Cho, Mechanical and Aerospace Engineering

William Clark, Materials Science and Engineering

John Clay, Chemical and Biomolecular Engineering

Anne Co, Chemistry and Biochemistry

James Coe, Chemistry and Biochemistry

Edward Collings, Materials Science and Engineering

Terry Conlisk, Mechanical and Aerospace Engineering

Ardeshir Contractor, Mechanical and Aerospace Engineering

Stuart Cooper, Chemical and Biomolecular Engineering

Katrina Cornish, Horticulture and Crop Science

Glenn Daehn, Materials Science and Engineering

Karen Dannemiller, Civil, Environmental and Geodite Engineering

Marcelo Dapino, Mechanical and Aerospace Engineering

Frank De Lucia, Physics

David Dean, Plastic Surgery

Justin Diles, Materials Science and Engineering

Dennis Dimiduk, Materials Science and Engineering

Vicky Doan-Nguyen, Materials Science and Engineering

Suliman Dregia, Materials Science and Engineering

Charles Drummond, Materials Science and Engineering

Rebecca Dupaix, Mechanical and Aerospace Engineering

Prabir Dutta Fox, Chemistry and Biochemistry

Thaddeus Ezeji, Animal Sciences

Liang-Shih Fan, Chemical and Biomolecular Engineering

Dave Farson, Materials Science and Engineering

Ayman Fayed, Electrical and Computer Engineering

Carolin Fink, Materials Science and Engineering

Gerald Frankel, Materials Science and Engineering

Hamish Fraser, Materials Science and Engineering

Dan Gauthier, Physics

Samir Ghadiali, Biomedical Engineering

Nima Ghalichechian, Electrical and Computer Engineering

Maryam Ghazisaeidi, Materials Science and Engineering; Physics

Josh Goldberger, Chemistry and Biochemistry

Keith Gooch, Biomedical Engineering

Pelagia-Iren Gouma, Materials Science and Engineering

Thomas Gramila, Physics

Tyler Grassman, Electrical and Computer Engineering

Dorota Grejner-Brzezinska, College of Engineering

Michael Groeber, Integrated Systems Engineering; Mechanical and Aerospace Engineering

Yann Guezennec, Mechanical and Aerospace Engineering

Liang Guo, Electrical and Computer Engineering

Prabhat Gupta, Materials Science and Engineering

Abhishek Gupta, Electrical and Computer Engineering

Jay Gupta, Physics

Terry Gustafson, Chemistry and Biochemistry

Christopher Hadad, Chemistry and Biochemistry

Lisa Hall, Chemical and Biomolecular Engineering

Nathan Hall, Radiology

P. Chris Hammel, Center for Emergent Materials; Physics

Derek Hansford, Biomedical Engineering

Ryan Harne, Mechanical and Aerospace Engineering

Richard Hart, Biomedical Engineering

Andrew Heckler, Physics

Carin Helfer, Food, Agricultural and Biological Engineering

Ayonga Hereid, Mechanical and Aerospace Engineering

Joseph Heremans, Mechanical and Aerospace Engineering

Richard Higgins, Professional and Distance Education Programs

Ned Hill, Public Affairs

George Hinkle, Pharmacy

W.S. Winston Ho, Chemical and Biomolecular Engineering

Nicole Hoefer, Materials Science and Engineering

John Horack, Mechanical and Aerospace Engineering

Ayanna Howard, College of Engineering

Jinwoo Hwang, Materials Science and Engineering

Joerg Jinschek, Materials Science and Engineering

Joel Johnson, Electrical and Computer Engineering

Ezekiel Johnston-Halperin, Physics

Roland Kawakami, Physics

Marat Khafizov, Mechanical and Aerospace Engineering

Waleed Khalil, Electrical and Computer Engineering

Jung-Hyun Kim, Mechanical and Aerospace Engineering

Matt Kleinhenz, Horticulture and Crop Science

Rachel Kleit, College of Engineering

Kurt Koelling, Chemical and Biomolecular Engineering

Sanjay Krishna, Electrical and Computer Engineering

Ashok Krishnamurthy, Electrical and Computer Engineering

Gregory Lafyatis, Physics

Alexandra Landsman, Physics

John Lannutti, Materials Science and Engineering

Gil Latz, Office of International Affairs

Jeanie (ChunNing) Lau, Physics

Robert J. Lee, Pharmacy

Robert Lee, Electrical and Computer Engineering

L. James Lee, Chemical and Biomolecular Engineering

Jennifer Leight, Biomedical Engineering

John Lenhart, Civil, Environmental and Geodite Engineering

Jinghua Li, Materials Science and Engineering

Blaine Lilly, Mechanical and Aerospace Engineering

Li-Chiang Lin, Chemical and Biomolecular Engineering

John Lippold, Materials Science and Engineering

Jun Liu, Biomedical Engineering

Xun Liu, Materials Science and Engineering

Jenifer Locke, Materials Science and Engineering

Wu Lu, Electrical and Computer Engineering

Alan Luo, Materials Science and Engineering

Anthony Luscher, Mechanical and Aerospace Engineering

Raghu Machiraju, Computer Science and Engineering

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