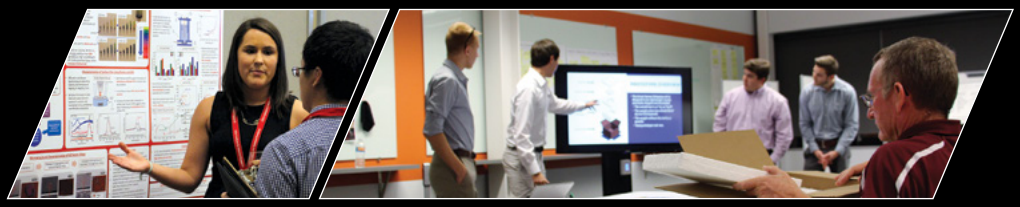
INNOVATIONS IN MATERIALS RESEARCH

Newsletter of The Ohio State University Institute for Materials Research

Volume 9
Issue 1
Winter 2017



2006 - 2016 10 YEAR ANNIVERSARY

Inside this Issue

THE OHIO STATE UNIVERSITY
INSTITUTE FOR MATERIALS RESEARCH

IMR Global Partnership Grants Fund Ohio State/ IIT-Bombay Research Collaborations

The Materials and Manufacturing for Sustainability (M&MS) Discovery Theme focus area and the Institute for Materials Research have established a new Global Partnership Grants program to support international research collaborations between Ohio State researchers and global partners in materials science. Global Partnership Grants (GPGs) establish global impact in research and development, technology innovation and shared multinational education following the themes and goals defined by the M&MS program. GPGs require matching funds from the partner institution, and these awards encourage rich collaborations between research groups by hosting a graduate student from one university at the other's campus for several months, allowing international research teams to work together in the lab daily to investigate materials-led solutions to global sustainability challenges.

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Innovative Energy Research Advances Have Origins at SEAL

Recent advances in sustainability-related research published by Ohio State scientists involved substantial work at the Semiconductor Epitaxy and Analysis Laboratory (SEAL). One of IMR's core materials research facilities, SEAL is the primary facility for molecular beam epitaxy (MBE) at The Ohio State University. The state-of-the-art MBE systems found at SEAL are used for the growth of various III-V compounds that are central to a broad range of research, spanning from applied physics and chemistry of unique electronic and photonic materials and nanostructures, to device-driven epitaxy for advanced photovoltaics, light emitting devices, high speed transistors and sensors.

The three research projects described below show innovations with great promise for high-efficiency, low-cost solar cells and ultraviolet light-emitting diodes. Such breakthroughs could eventually lead to devices with major societal impacts such as more widespread, "clean" electricity and water purification.

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Dear Colleagues,

You may have noticed that starting with this first issue of 2017, our newsletter is now arriving to you at the beginning of each academic semester. The goal is to bring you more forward-looking content and engage our community before the academic workload reaches fever pitch each semester. This current issue marks this transition and as a result we have an action-packed newsletter for January 2017.

I'd like to note that 2016 marked IMR's 10-year anniversary, a key milestone in any organization's history. Reflecting on this past decade, it is gratifying to see the immense progress that our materials community and research enterprise have achieved during this period of growth. In 2006, Ohio State did not have an NSF Materials Research Science and Engineering Center, Nanotech West was in its early stages of operations, the Center for Electron Microscopy and Analysis was not even a glimmer in anyone's mind, we had not had a Wright Center of Excellence in Photovoltaics, we had never run a faculty cluster hiring program, there were no Ohio Research Scholars, and Materials Week was just an idea as was research facility coordination in general. We were a community of multiple disciplines instead of "inter-disciplines," despite the best of intentions by most of us. However, at that time we all hoped we could build from that point and create a whole that was greater than the sum of our parts, without barriers between disciplines and with full appreciation of the richness across the range of materials-allied research that is present throughout the nearly 250 IMR members from 26 departments in 7 colleges. The impact on our quality and stature is both palpable and real in terms of all quantitative and qualitative metrics – top center grants, citations of publications, faculty and student quality, global reach, return on investment, and so on. Our research base has never been stronger. We are well positioned for the next 10 years, when we hope to amplify our research impact even further.

In this issue, you will read about some highlights of initiatives leading to that future, many of which are a direct result of our Materials and Manufacturing for Sustainability (M&MS) Discovery Theme program — the successful start to our new Global Partnership Grant program; IMR's new innovation strategy that builds around translational R&D involving graduate and undergraduate students together with industry partners; and the welcoming of several new faces who have joined IMR to solidify and advance the innovation strategy. Of course, the research that is the backbone of Ohio State's advances in its materials enterprise has enjoyed yet another spectacular round of great successes, and some of these are highlighted in this issue as well — the awarding of yet another, highly competitive Major Research Instrumentation Award (MRI) from the National Science Foundation; several high profile research publications emanating from a cohort of young faculty who have built their interdisciplinary research around one of IMR's core facilities – the Semiconductor Epitaxy and Analysis Lab; and another successful 2016 OSU Materials Week conference which included 118 incredible student research posters to go along with a stellar lineup of speakers and symposia topics.

Reflecting on this past decade, it is gratifying to see the immense progress that our materials community and research enterprise have achieved during this period of growth... the impact on our quality and stature is both palpable and real in terms of all quantitative and qualitative metrics.

Wishing you all a Happy New Year and a GREAT 2017!

Warmest regards,

Dr. Steven A. Ringel

Neal A. Smith Endowed Chair Professor
Executive Director
Institute for Materials Research
The Ohio State University

NEW FACES AT IMR HELPING BUILD ITS FUTURE

As the Institute for Materials Research celebrates its tenth anniversary and enters its next phase of development, you will notice that some of our activities are becoming more externally focused. A few new roles have been filled to support our strategic efforts to further engage the external materials community and connect them with Ohio States faculty, staff and students to create innovative materials solutions.

Kari Roth, Senior Technology Integrator

Kari Roth joined us this August as a Senior Technology Integrator with the Materials and Manufacturing for Sustainability (M&MS) program, part of the university's Discovery Themes initiative. An experienced engineer and technical program manager with a strong industry background, Roth will lead projects and manage client relationships within our materials innovation framework. The mission of M&MS program is to connect, create and deliver value while translating science and engineering discoveries into economic and societal benefits through strategic partnerships.

Roth joins us from Honeywell International where she was a Technical Project Leader of sensing and productivity solutions for over nine years, responsible for the management of multimillion-dollar programs for customers within the medical, industrial, transportation, retail and automotive markets. Prior to joining Honeywell, she worked for twelve years with Delphi Corporation as a Program Manager and Application/Design Engineer working with next-generation controlled brake and suspension systems. Roth earned a Bachelors degree in Electrical Engineering from The Ohio State University and a Masters degree in Electrical Engineering from University of Dayton.

Ardeshir Contractor, Executive in Residence

Effective June 1, Ohio State alumnus Ardeshir Contractor (MS '86, mechanical engineering) became an Executive in Residence with the Institute for Materials Research. In this role, Mr. Contractor works closely with IMR and university leaders and faculty to help shape an integrated strategy to access emerging global markets, augment research activities, and implement new and innovative technology/business innovation constructs. He is developing new opportunities in the Asian market arena, in particular India in collaboration with the Global Gateway Initiative, and plans to work with student organizations, clubs and class projects in the areas of renewable energy, entrepreneurship and innovation. We are fortunate to have such an esteemed and accomplished alumnus dedicated to sustainability efforts work with IMR and serve as a liaison with the Indian materials community.

Contractor is the Founder and CEO of Kiran Energy, India's largest solar energy utility, supplying power to the government and top industrial firms from large power plant sites in Rajasthan, Gujarat and Maharashtra. He was invited to represent the business and industry presence at the 2015 Paris Climate Change Conference (COP21), speaking before the United Nations main assembly on behalf of the entire private sector. He was also honored with the College of Engineering's Distinguished Alumni Award in 2015.

Glenn Daehn, Deputy Faculty Director

While not a new presence on Ohio State's campus or to the university's materials community, Professor Glenn Daehn has agreed to support the leadership of IMR and its M&MS program in a new role as Deputy Faculty Director. His responsibilities include shared leadership on the manufacturing aspects of M&MS, particularly with respect to coordination of faculty engaged in manufacturing-related research, aligning across entities that include CDME and OMI, and working very closely with Dr. Jay Sayre, IMR Innovation Director.

An Ohio State faculty member since 1988, Daehn is the Fontana Professor in the department of materials science and engineering and recently served as the executive director of the Honda-Ohio State Partnership Program and founding director of the Ohio Manufacturing Institute. Daehn's research, education and service efforts are all broadly related to the interwoven themes of Midwestern manufacturing revival, which in turn depends on technology development, integration of the university mission with regional industry, and the development of a world-class workforce that is both smart and creative as well as able to make things. Recently, most of his research has focused on impulse-based manufacturing, a technology allowing new ways of shaping, cutting, joining and processing materials.

Greg Ames, Visiting Innovator

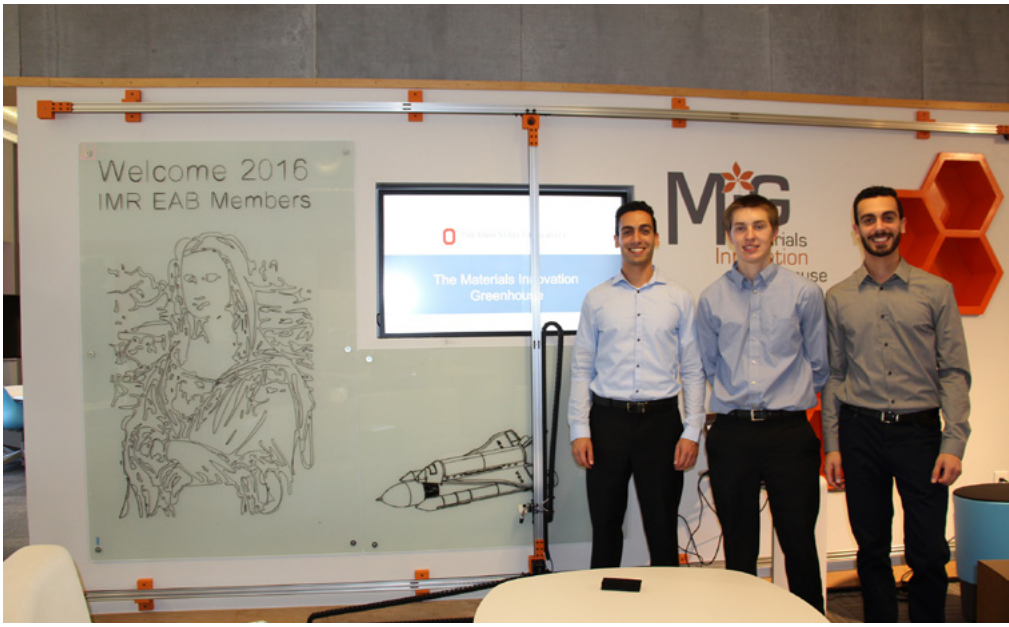
This fall, Greg Ames began working with us as a Visiting Innovator, providing consultation on strategy and capacity as IMR moves into its next, expanded phase of development. IMR members and staff will find Ames supporting us in different ways in this role, such as facilitating strategic brainstorming sessions with our External Advisory Board at its annual meeting.

Ames' professional experience includes a 30+-year career with Proctor and Gamble, where he filled many roles in new product research and development, brand development, and innovation strategy, leading up to his role as Principal of Innovation in the company's global Design Thinking Community of Practice. He then worked with Worthington Industries as the Director of Innovation and New Product Development, focusing on consumer products innovation strategy, product design and retail design. Ames is currently the Senior Director of Global New Ventures with Guardian Industries Corp., one of the world's largest manufacturers of advanced, high value coatings on plastics for the automotive, commercial truck and consumer goods industries.

Plotting a Path to Innovation

This article was contributed by the College of Engineering Communications office

Becoming a commissioned designer for a client like The Ohio State University is an accomplishment sought out by many professional designers and engineers. One collection of undergraduate students is now adding this achievement to their resume.



The trio of second-year students—Tyler Bair (electrical and computer science engineering), Andrew Merz (materials science and engineering) and Phillip Merz (mechanical engineering)—recently imagined and built an innovative, interactive feature in the Institute for Materials Research (IMR) new Materials Innovation lab, a central component of the Materials & Manufacturing for Sustainability discovery theme.

Jay Sayre, assistant vice president at Ohio State and IMR's director of innovation, wanted two things: an interesting feature to welcome guests and a way to engage undergrads in the process. "We work very closely with the Center for Design and Manufacturing Excellence (CDME)," he said. "So I knew they had a lot of really bright undergraduates working for them."

Sayre and his colleagues at CDME and the Center for Innovation and Entrepreneurship (CIE) encouraged those bright undergrads to form teams over the summer and pitch their ideas to IMR's leadership.

The only requirements were that the design had to contain a flat-screen display, a space to hold 3D sample products and clear identification that the space was dedicated to Materials Innovation.

This fall, IMR, in collaboration with Paul Reeder, Executive Director, CIE, completed renovation of 2,500 square feet in the Nanotech West Laboratory on Kinnear Road. The Materials Innovation space exemplifies an operational model that allows people and ideas to "collide," as Sayre puts it, while fostering collaboration to maximize innovation. Think few walls, lots of group work areas and energetic colors.

Bair and the brothers Merz knew their design idea had to match the new space's cool factor. Featuring a large-scale plotter attached to the wall, their design allows users to program an image to be drawn on an erasable surface in mere minutes.

"We work very closely with the Center for Design and Manufacturing Excellence (CDME), so I knew they had a lot of really bright undergraduates working for them."

— DR. JAY SAYRE, ASSISTANT VICE PRESIDENT OF MATERIALS AND MANUFACTURING FOR SUSTAINABILITY AND IMR INNOVATION DIRECTOR

"We wanted there to be moving parts and we wanted the display to not just be one-and-done, just there and nothing else happens," said Phillip Merz. "The coolest displays are the interactive ones, ones that can change up. So we decided to have a part of the display that can change to whatever the user wants, make it dynamic."

Their pitch was made in the form of a video that quickly caught the eye of those judging the designs.

Bair had the idea to incorporate a plotter into the design, wanting to mimic the work of 3D printers on a 2D wall surface. The plotter has already been used to draw the Mona Lisa, a rocket ship and, of course, a Block O.

The group also incorporated influences from 3D printer technology in other ways. Many 3D printer parts contain hexagonal infrastructure, which is represented in their design as hexagonal shelves to hold 3D-printed pieces.

Next the students want to create a smartphone app that can convert any image to a drawing on the wall.

Some supporters have hinted that the group should commercialize the design, with the possibility of building another plotter elsewhere on campus. But for now, the aspiring engineers will focus on their upcoming final exams.

Engineering Technical Communications Class Design Challenge Is No Bull!

An undergraduate Engineering Technical Communications class recently had the unique opportunity to work with local industry leaders and create innovative designs to address a real need. Students in a section of this Fall's ENGR 2367 class piloted a collaborative educational model with representatives of Worthington Industries, a leader in the diversified metal manufacturing industry headquarted in central Ohio, and one of Worthington's customers, Select Sires, a Plain City, Ohio-based industry leader in reproductive management solutions for dairy and beef producers.

The two companies presented their real-world problem to the class: they needed a vessel custom designed to effectively and safely transport hundreds of bull semen samples to farmers around the U.S. Select Sires specializes in providing highly fertile, superior genetic products to enhance the productivity and profitability of their customers, dairy and beef producers. The transportation of such a sensitive biological product faces many challenges, from temperature control to complex logistics management. This challenge was not a typical assignment for the undergraduate students, who needed to quickly become knowledgeable about a broad range of topics including livestock breeding, shipping regulations, and the cost, use and limitations of raw materials such as stainless steel and expanded polystyrene.

"Working with an industry-led project, we were able to get hands-on experience and that is very rare to get as a first- or even second-year student. That really helps for resume building and just experience for the future."

— DAVID MCGEE, SECOND-YEAR STUDENT, INDUSTRIAL AND SYSTEMS ENGINEERING

Participants in the student design presentations event included ENGR 2367 students, instructor Mary Faure, and representatives from Worthington Industries, Select Sires, and the Materials and Manufacturing for Sustainability program.

A student design team presents their prototype to the audience.

The course was led by instructor Mary Faure, Director of the Engineering Technical Communications unit in the Department of Engineering Education, while the collaboration with Worthington Industries was facilitated by the Materials and Manufacturing for Sustainability staff at Ohio State's Institute for Materials Research (IMR), Dr. Jay Sayre, Assistant Vice President, and Kari Roth, Senior Technology Integrator. This multidisciplinary pilot project attempted to fill gaps within the engineering curriculum by offering instruction and practice in communication through a high-quality, industry-led learning experience for students. Industry partners engaged in conversations with students about their teams' design responses to the problem, allowing the students to gain one-on-one attention from practicing engineers and to hone their interpersonal and communication skills while completing their projects.

"Today's engineering students need engaging, contextually-positioned technical communications, project management, entrepreneurial thinking, and teamwork instruction and practice in order to perform well in advanced discipline-specific engineering classes, internships, capstone, and in their entry level engineering positions," said Faure. "This project was designed to provide important skill-building through an authentic, hands-on experience, which today's students crave, while fulfilling an essential component of the General Education curriculum. It gives students a unique experience without adding credit hours to their curriculum or cost to their college expenses."

A student design team shares their proposal with the class and judges.

Student design groups were able to present their final designs at an evening event in the new Materials Innovation Lab on Kinnear Road. Each group was given up to 15 minutes to present their vessel design to the judges, Dr. Bill Benson and Michael Luh from Worthington Industries, and Mel DeJarnette with Select Sires. The lively presentations included videos, prototypes, and many unique suggestions to best transport Select Sires' bull semen samples across the country safely to its customers. All teams received constructive feedback from the judges, who had the difficult task of selecting a winning design. Worthington Industries generously provided gift cards to all members of the winning team – Alex Machtay, Matt Rowland, Robert Jankovsky, and Adam DeNise.

The winning student design team (Alex Machtay, Matt Rowland, Robert Jankovsky, and Adam DeNise) joined by judges Mel DeJarnette with Select Sires and Dr. Bill Benson and Michael Luh from Worthington Industries

The industry partners who participated in the pilot said they enjoyed working with the students, were surprised and pleased at the quality of their projects, and would welcome continuing the collaboration in the future with another cohort. One student from this class is now being considered for a summer internship with Worthington Industries.

The hope is that the success of this authentic, interdisciplinary learning experience paves the way for an "integrated curriculum" that crosses college boundaries, offering students of all majors engaging, high-quality learning experiences that more accurately prepare students to be effective in the workplace or in graduate schools regardless of their disciplinary interests.

"This wasn't just a hypothetical situation... It was a very real problem and we talked to real engineers, real businessmen from real companies, to solve a real need."

– BEN BEECROFT, SECOND-YEAR STUDENT,
COMPUTER SCIENCE AND ENGINEERING

IMR Global Partnership Grants

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This inaugural Global Partnership Grant award funds the research project "Development and Characterization of Gallium Oxide Transistors," a collaboration between Siddharth Rajan, Associate Professor in the Electrical and Computer Engineering and Materials Science and Engineering departments at Ohio State, and Saurabh Lodha, an Associate Professor of Electrical Engineering at IIT-Bombay. This grant will enable collaborative research on energy-efficient electronic devices based on a new semiconductor material, Gallium Oxide. This material has the highest electric breakdown strengths among known semiconductor materials, and can enable transistors with higher efficiency and power than possible from conventional Silicon. Electronics based on such transistors could enable a new class of ultra-efficient high voltage electrical systems for next-generation technologies including electric cars, solar and wind farms, and data servers.

Chandan Joishi, an IIT Bombay PhD student, is now on Ohio State's campus working with a team of researchers on various aspects of Gallium Oxide material growth and device design, with a primary focus on developing high-quality and robust gate and passivation dielectrics for high voltage transistors based on Gallium Oxide. He will also investigate new topologies for lateral and vertical transistors based on Gallium Oxide, and investigate unique properties related to electronic transport, carrier doping, implantation, and electric breakdown in this material.

The second Global Partnership Grant, funded this fall, supports a new collaborative research effort toward the development of materials and device structures that will improve both the performance and manufacturability of future generations of high-efficiency solar cells. The specific target of this research project, "Advanced Passivation for Next-Generation Si-Based Tandem Solar Cells," is related to the passivation of the rear (i.e. back-side) of silicon-based solar cells that are designed to be included as part of a new multi-material architecture that has been developed by Dr. Tyler Grassman, Assistant Professor of Materials Science and Engineering and Electrical and Computer Engineering, and his colleagues. Grassman is working with Professor Rajiv Dusane, Metallurgical Engineering and Materials Science, IIT Bombay, on this research effort. One of Prof. Dusane's PhD students will spend several months at Ohio State in 2017, collaborating with a team of researchers involved with III-V/Si solar cell development projects. His work will focus on the development of a-Si passivation process steps – deposition, etching, metallization, annealing – that are compatible with the full range of III-V materials and process steps, as well as the characterization of fabricated test structures and devices.

Chandan Joishi, Electrical Engineering Ph.D. candidate at IIT Bombay, is working with Ohio State researchers through IMR's first Global Partnership Grant.

Chandan Joishi is a Ph.D. student in electrical engineering at IIT Bombay and has been on Ohio State's Columbus campus since early November to conduct research related to the collaboration between Professors Siddharth Rajan at Ohio State and Saurabh Lodha at IITB. While adjusting to Columbus' winter climate, seeing snow for the first time, and sampling American cuisine, Joishi is working on the fabrication of highly efficient electronic devices at IMR's Nanotech West Lab. Two projects are currently underway through this Global Partnership Grant, one centered at Nanotech West, the other in the Semiconductor Epitaxy and Analysis Laboratory (SEAL), with the potential for additional, related sub-projects in the future.

Joishi explained that one of the collaborations particularly leverages the complementary instrumentation and expertise of the two universities - Nanotech West's vertical etch process and SEAL's gallium oxide MBE facility offer capabilities not available at IIT Bombay, while IITB has a plasma process for atomic layer deposition that is currently not offered at Ohio State. For the current project, after samples are grown in SEAL's MBE facility, they are sent to IIT Bombay and used to fabricate a device. That device is then returned to Columbus where it undergoes further analysis and testing.

The goal is to create transistors and devices that are more power efficient, with higher breakdown voltage than currently available. These changes could also improve the lifetime of devices, reducing consumers' costs and consumption. If successful, Joishi says this work could have "many applications, ultimately replacing current silicon carbide and gallium nitride power devices. The new transistors could eventually be used in cars, windmills, satellites, and many other applications."

World's First Dual-Junction and Triple-Junction Solar Cells

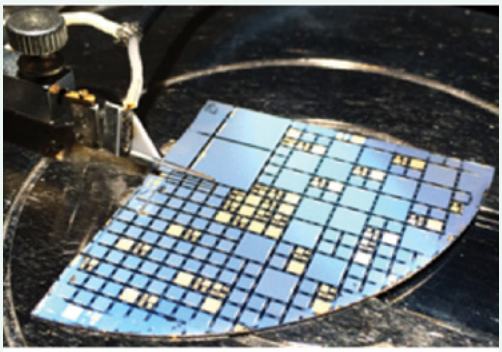
Continued from page 1

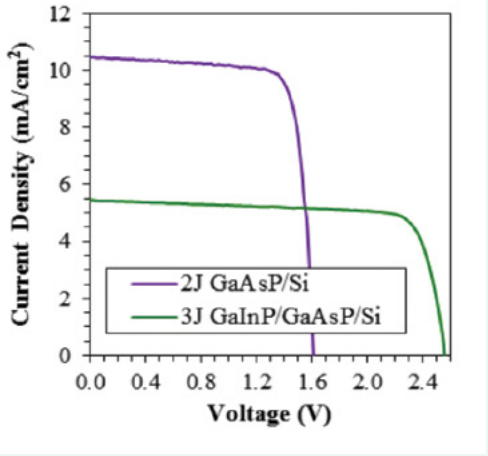
The world's first true epitaxial GaAsP/Si dual-junction and GaInP/GaAsP/Si triple-junction Si tandem solar cells were designed, grown, fabricated, and characterized by SEAL and Nanotech West researchers, who have been leaders in the field for nearly two decades. Tandem, or multijunction, solar cells combine multiple semiconducting materials into a single device that is able to subdivide and make more efficient use of the solar spectrum than single-junction, single-material devices.

These initial prototype cells show promising performance and indicate several important pathways for further device refinement. The demonstration of these breakthrough devices represents an important step forward in the development of next-generation high-efficiency, low-cost photovoltaics and hold the potential for high conversion efficiencies on par with pure III–V multijunction structures, at substantially lower costs. The prototypes pave the way for significantly more efficient and affordable solar cells than the current state-of-the-art III-V multijunction solar cells, which are used almost exclusively in the space industry, powering satellites and exploration spacecraft.

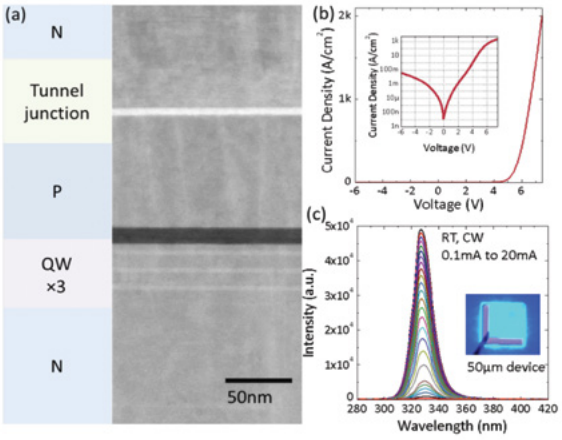
This work is the culmination of numerous developments and discoveries made at SEAL and other research facilities at The Ohio State University. This work was funded by the DOE-EERE SunShot Initiative (DE-EE0005398), with contributions over the years by NASA, AFRL, ARO, and the State of Ohio.

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





The top image shows a processed solar cell wafer being tested under a simulated solar spectrum. The bottom figure presents solar power generation test data (light current-voltage) collected from these new cells.



Rajan group images: (a) High-angle annular dark-field scanning transmission electron microscopy (HAADF-STEM) image, (b) Current-voltage characteristics, (c) Electroluminescence of the tunneling injected UV LED (50 μm × 50 μm) devices. The inset shows an optical micrograph of a tunnel-junction UV LED device (50 μm × 50 μm) driven at 10 mA.

Tunnel-Injected Ultra Violet Light Emitting Diodes (UV LEDs)

Efficient, compact UV LEDs could serve many applications, including water purification, air disinfection and sensing. Researchers at The Ohio State University are working to overcome the limitations of low efficiency and high cost by pioneering a novel device architecture. Conventional UV LEDs are limited by low electrical efficiency due to a low thermal-activated hole density and poor p-type contacts, and poor light extraction efficiency resulting from high absorption loss and internal reflections. The emitters being developed at SEAL are radically different from conventional UV LEDs, employing a tunnel-junction to improve hole transport through the heterostructure. The tunnel junction allows holes to 'tunnel' into the p-AlGaN layer, an approach that enables low resistance and ultimately high electrical-injection efficiency. Thanks to the transparency of the n-AlGaN top contact, this architecture also cuts optical extraction losses. High efficiency values similar to the state-of-the-art have been achieved based on this technique, showing the potential of tunnel injection in achieving high performance UV light emitters.

Y. Zhang, et. al., "Interband tunneling for hole injection in III-nitride ultraviolet emiters," Applied Physics Letters, 106 (14), 141103 (2015)
Y. Zhang, S. Krishnamoorthy, F. Akyol and S. Rajan, "Quantum tunneling boosts UV LED efficiency," Compound Semiconductor Magazine, 22 (3) 40-45 (2016)

New LEDs may offer better way to clean water in remote areas

FROM THE DEPARTMENT OF MATERIALS SCIENCE AND ENGINEERING

For the first time, researchers have created light-emitting diodes (LEDs) on lightweight flexible metal foil. Ohio State engineers are developing the foil based LEDs for portable ultraviolet (UV) lights that soldiers and others can use to purify drinking water and sterilize medical equipment.

In the journal Applied Physics Letters, the researchers describe how they designed the LEDs to shine in the high-energy "deep" end of the UV spectrum. The university will license the technology to industry for further development.

Deep UV light is already used by the military, humanitarian organizations and industry for applications ranging from detection of biological agents to curing plastics, explained Roberto Myers, Associate Professor of Materials Science and Engineering. The problem is that conventional deep-UV lamps are too heavy to easily carry around. "Right now, if you want to make deep ultraviolet light, you've got to use mercury lamps," said Myers. "Mercury is toxic and the lamps are bulky and electrically inefficient. LEDs, on the other hand, are really efficient, so if we could make UV LEDs that are safe and portable and cheap, we could make safe drinking water wherever we need it."

He noted that other research groups have fabricated deep-UV LEDs at the laboratory scale, but only by using extremely pure, rigid single-crystal semiconductors as substrates— a strategy that imposes an enormous cost barrier for industry.

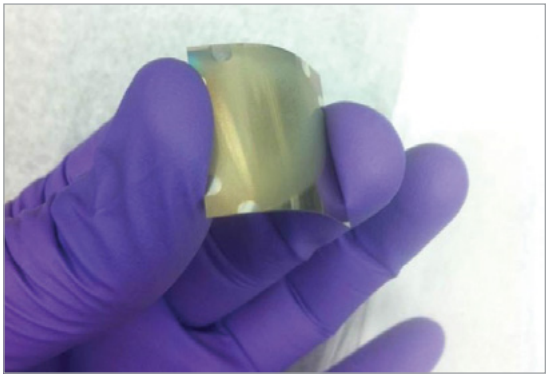
Foil-based nanotechnology could enable large-scale production of a lighter, cheaper and more environmentally friendly deep-UV LED. But Myers and materials science doctoral student Brelon J. May hope that their technology will do something more: turn a niche research field known asnanophotonics into a viable industry. "People always said that nanophotonics will never be commercially important, because you can't scale them up. Well, now we can. We can make a sheet of them if we want," Myers said. "That means we can consider nanophotonics for large-scale manufacturing."

In part, this new development relies on a well-established semiconductor growth technique known asmolecular beam epitaxy, in which vaporized elemental materials settle on a surface and self-organize into layers or nanostructures. The researchers used this technique to grow a carpet of tightly packed aluminum gallium nitride wires on pieces of metal foil such as titanium and tantalum.

The individual wires measure about 200 nanometers tall and about 20-50 nanometers in diameter—thousands of times narrower than a human hair and invisible to the naked eye. In laboratory tests, the nanowires grown on metal foils lit up nearly as brightly as those manufactured on the more expensive and less flexible single-crystal silicon. The researchers are working to make the nanowire LEDs even brighter, and will next try to grow the wires on foils made from more common metals, including steel and aluminum.

This research was funded by the Army Research Office and the National Science Foundation. Study co-author A.T.M. Golam Sarwar earned his doctoral degree in the course of this work at Ohio State, and is now at Intel.

Brelon J. May, A. T. M. Golam Sarwar, and Roberto C. Myers, "Nanowire LEDs grown directly on flexible metal foil," Applied Physics Letters 108, 141103 (2016); doi: 10.1063/1.4945419

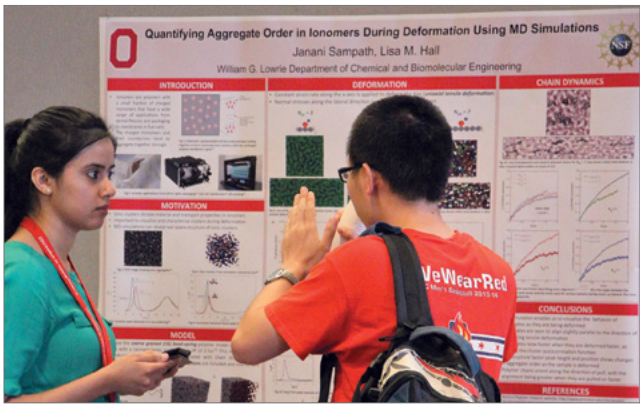


"People always said that nanophotonics will never be commercially important, because you can't scale them up. Well, now we can. We can make a sheet of them if we want. That means we can consider nanophotonics for large-scale manufacturing."

— ROBERTO MYERS, ASSOCIATE PROFESSOR OF MATERIALS SCIENCE AND ENGINEERING

2016 OSU Materials Week Recap

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



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

2016 OSU Materials Week included a total of 36 scientific presentations in eight technical sessions:

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

IMR KEYNOTE ADDRESS
Rechargeable Batteries for Electric Cars

John Goodenough, *Virginia H. Cockrell Centennial Chair in Engineering,* University of Texas at Austin

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

2016 OSU Materials Week – Student Poster Awards

Over 110 research posters were presented by Ohio State students from across the university at Materials Week's two poster sessions. Each poster and presentation was evaluated by volunteer judges and the top fifteen posters were recognized by Ohio State President Michael Drake during our Student Poster Awards at the conference's closing ceremony. The full list of student award winners can be found on IMR's website, imr.osu.edu.

Join us for 2017 OSU Materials Week, held at the Blackwell on Ohio State's Columbus campus May 9-12, 2017! Details will be available at: go.osu.edu/2017OSUMaterialsWeek

IMR Member News

Jim Beatty, Professor and Chair, Physics, was selected to serve on the NASA Physics of the Cosmos Program Analysis Group (PhysPAG) Executive Committee for the term December 2016-December 2019. The PhysPAG collects community input on a variety of issues, and prepares summaries of their findings or analyses. The PhysPAG will play an important role in the future of NASA's investment in Physics of the Cosmos science, and its analysis will be particularly important in the areas of determining technology development priorities and future science requirements.

Hanna Cho, Assistant Professor, Mechanical and Aerospace Engineering, was the recipient of a DARPA Young Faculty Award in the amount of $499,769. This new award identifies and engages rising stars in junior faculty positions in academia early in their careers to develop innovative new research enabling transformative capabilities for the U.S. Department of Defense. The DARPA award supports Dr. Cho's research to utilize intentional nonlinearity constructively to manipulate the mechanical resonance to achieve performance otherwise unattainable in linear settings. Cho has reported that the IMR Facility Grant she received to support her research was instrumental in advancing her activities and strengthening her DARPA proposal.

Ryan Harne, Assistant Professor, Mechanical and Aerospace Engineering, was awarded the 2016 Haythornthwaite Young Investigator Award by The American Society of Mechanical Engineers. This award is based on selection by the ASME Applied Mechanics Division and recognizes excellence in theoretical and applied mechanics research for early career faculty and provides a grant to support the acquisition of key research equipment. In particular, the award will support research conducted in Harne's Laboratory of Sound and Vibration Research, which will formulate a detailed understanding of the complex dynamic responses of built-up structural systems subjected to loads that promote post-buckling, regularly encountered by aircraft which are slender structural platforms.

Ezekiel Johnston-Halperin, Associate Professor, Physics, was elected to the 2016 class of American Physical Society Fellows. He was nominated by the Division of Materials Physics "for pioneering studies of the magnetic, spintronic, and electronic properties of organic and inorganic materials, including groundbreaking work with organic based ferromagnets."

Vicki Wysocki, Professor, Chemistry and Biochemistry, was awarded the Frank H. Field and Joe L. Franklin Award for Outstanding Achievement in Mass Spectrometry by the American Chemical Society. She is the Ohio Eminent Scholar of Macromolecular Structure and Function and Director of Ohio State's Campus Chemical Instrument Center.

Materials Facilities Updates

In each issue of our newsletter, IMR provides relevant updates from our core materials research facilities — the NanoSystems Laboratory (NSL), Nanotech West Laboratory, the Center for Electron Microscopy and Analysis (CEMAS), and the Semiconductor Epitaxy and Analysis Laboratory (SEAL). More information on these facilities and over a dozen other open user materials research facilities on OSU's Columbus campus, visit our website at: imr.osu.edu/research/facilities.

Center for Electron Microscopy and Analysis (CEMAS) cemas.osu.edu

CEMAS-ENABLED RESEARCH FEATURED IN RESEARCH PUBLICATIONS:

Several CEMAS researchers have had their innovative research published in 2016, including an article in Nature Communications by CEMAS research scientist Smith et al., a second publication in Nature Communications that involves collaboration with Dr. Jos Hereman's group in the Department of Mechanical and Aerospace Engineering, and a CEMAS-Physics collaboration on double perovskites in *Physical Review Letters.*

Tim Smith and collaborators discovered a new 'phase-transformation strengthening' mechanism that resists high-temperature creep deformation in nickel-based superalloys. Ultra-high-resolution structure and composition analysis via scanning transmission electron microscopy, combined with density functional theory calculations, shows titanium, tantalum and niobium encourage a solid-state transformation from the γ′ to η phase. The nanoscale η phase leads to significant improvement in creep properties.

Phase transformation strengthening of high-temperature superalloys, T. M. Smith, B. D. Esser, N. Antolin, A. Carlsson, R. E. A. Williams, A. Wessman, T. Hanlon, H. L. Fraser, W. Windl, D. W. McComb, & M. J. Mills. Nature Communications 7, 13434 (2016)

The high resolution electron microscopy and spectroscopy facilities at CEMAS enabled Stephen Boona and collaborators to be the first to demonstrate the spin Seebeck effect in nanocomposite materials.

Observation of spin Seebeck contribution to the transverse thermopower in Ni-Pt and MnBi-Au bulk nanocomposites, S.R. Boona, K. Vandaele, I.N. Boona, D.W. McComb, J.P. Heremans. Nature Communications 7, 13714 (2016)

Using one of our Titan scanning transmission electron microscopes, investigators examined ordering phenomena in epitaxial thin films of the double perovskite Sr_2CrReO_6. Experimental and simulated imaging and diffraction were used to identify antiphase domains in the films. They showed that probe channeling results in ±20% variation in intensity for a given composition, allowing 3D ordering information to be probed using quantitative STEM.

Quantitative STEM Imaging of Order-Disorder Phenomena in Double Perovskite Thin Films, B. D. Esser, A. J. Hauser, R. E. A. Williams, L. J. Allen, P. M. Woodward, F. Y. Yang, and D. W. McComb, Physical Review Letters. 117, 176101 (2016)

ORIUS CAMERA ADDED TO TEM/STEM

We recently acquired a Gatan Orius 830 camera to enhance CEMAS' Tecnai F20 FEG scanning transmission electron microscope. This fiber-optically coupled CCD camera is ideal for applications that require high sensitivity and pixel resolution. This addition allows greater flexibility for acquiring TEM images and diffraction patterns than the MSC camera previously available on the microscope.

Henk Colijn and Isabel Boona staffing the CEMAS exhibit at the M&M 2016 conference.

CEMAS BRINGS REMOTE OPERATION TO MICROSCOPY & MICROANALYSIS 2016

CEMAS was well represented at the Microscopy & Microanalysis 2016 conference, which was held in Columbus for the first time this July. With the help of OARnet, we were able to demonstrate remote operation of our microscopes from both the CEMAS and the FEI Instruments booths in the conference's Expo Hall. Remote workstations were set up to allow visitors to sample CEMAS' unique remote microscopy operations. Our remote access services provide electron microscopy training and use from other OSU campuses and other academic institutions in Ohio and elsewhere, removing barriers to hands-on microscopy education. The use of electron microscopes from sites outside CEMAS is also a key enabler of remote collaboration with academic, government and industrial research partners. Operation of our microscopes from the M&M conference was smooth and users reported that they could not tell they were operating remotely and weren't actually on-site at the microscope itself.

NORTH CAROLINA A&T LINKING TO CEMAS

North Carolina Agricultural and Technical University in Greensboro was recently awarded funds to establish a remote workstation to access CEMAS microscopes. The addition of this remote workstation will leverage the investments made in CEMAS' instrumentation to allow researchers across the country greater access to state-of-the-art microscopy and analytical facilities. This collaboration will see the fourth remote station installed at an off-campus location, and the first outside Ohio. The connection will provide seamless operation of all of the microscopes available at CEMAS to the NC A&T faculty, staff and students. NC A&T is a historically black university and ranks first in the number of engineering degrees awarded to African American students.

Nanotech West Laboratory – nanotech.osu.edu

In addition to the academic and industrial research activities we support daily at Nanotech West, our staff continue to conduct their own innovative research. We learned that the Ohio Development Services Agency granted a six-month, no-cost extension to our Ohio Sensor and Semiconductor Innovation Platform (OSSIP) Program (Principal Investigator: Dr. Bob Davis, Nanotech West Lab). This extension allows us to complete exciting research and development activities with infrared sensors and semiconductor-based devices and materials. In addition, two programs that heavily involve metal-organic chemical vapor deposition (MOCVD) growth have just begun; one is a Phase I Small Business Technology Transfer (STTR) program award in infrared materials (PI: Dr. John Carlin, Nanotech West Lab), and the second is a Department of Energy Sunshot program to develop high-efficiency solar cells (PI: Dr. Tyler Grassman, Mechanical and Aerospace Engineering).

NEW CAPABILITIES COMING IN SPRING 2017

We are pleased to announce that users of the Nanotech West Lab will enjoy numerous new capabilities that will arrive in the spring. An Energy Storage Hub is being installed on the first floor, and many tools and instruments will be installed to support those activities. In addition, users will soon see the following additions:

- A new wafer / sample polishing capability, including chemical mechanical polishing (CMP), will be added to our cadre of tools. The purchase of a Logitech PM5 was enabled by the Ohio Sensor and Semiconductor Innovation Platform (OSSIP) Program, which is funded by the Ohio Development Services Agency (ODSA) through the Ohio Third Frontier Program;
- Considerable new electro-optical test capabilities are arriving as part of the hiring of Prof. Sanjay Krishna through the Materials and Manufacturing for Sustainability program and Discovery Themes initiative;
- A precision flip-chip bonder to support manufacturing components and devices, also arriving with Prof. Krishna's group;
- A second Plasma-Therm SLR 770 inductively coupled plasma reactive ion etcher will complement our current 770 instrument. This tool will be donated to us by the Air Force Research Lab and will be configured as a deep reactive ion etch (DRIE) tool

The winning team of researchers using an NSF award to develop a broadband high frequency magnetic resonance spectrometer at Ohio State.

NSF Awards IMR Team $1M to Build New Spectrometer

The National Science Foundation recently announced that an IMR-led Major Research Instrumentation proposal totaling over $1 million has been awarded to a multidisciplinary team of Ohio State researchers. This proposal submission was coordinated by administrative staff at the Institute for Materials Research, who will also manage the project. The project, titled "Development of a Broadband 330 GHz Variable Temperature Magnetic Resonance Spectrometer System," has Professor Fengyuan Yang, Professor of Physics and IMR Associate Director, as the Principal Investigator. The project team includes five other Ohio State professors – Chris Hammel, Physics; Rolando Valdes Aguilar, Physics; Joseph Heremans, Mechanical and Aerospace Engineering; John Volakis, Electrical and Computer Engineering; and Ezekiel Johnston-Halperin, Physics – as well as IMR Member of Technical Staff and NanoSystems Lab director, Dr. Denis Pelekhov.

Together, these researchers will develop a broadband high frequency magnetic resonance spectrometer with the frequency ranging from 1 to 330 GHz between liquid helium and room temperature. This will be the first magnetic resonance spectrometer in the 100's GHz at a shared user facility in the Midwest region. It will significantly strengthen and expand the investigation of novel fundamental phenomena and the development of paradigm-changing technologies for researchers within The Ohio State University and beyond. The technology developed could make Ohio State a center for high-frequency magnetic resonance research across the Midwest.

Center for Emergent Materials Updates

The following update was provided by the Center for Emergent Materials (CEM), a National Science Foundation Materials Research Science and Engineering Center (MRSEC) at The Ohio State University. The MRSEC program funds teams of researchers from several different disciplines who work collaboratively on materials research in order to address fundamental problems in science and engineering. By working in teams, called Interdisciplinary Research Groups (IRG), the researchers at CEM tackle scientific problems that are too large and complex for a scientist working alone to solve. For more information about CEM, visit their website: http://cem.osu.edu.

News and Events

INDUSTRY DAY, PARTNERSHIP RENEWAL

In December, CEM renewed its partnership with Columbus-based manufacturer, Lake Shore Cryotronics. The collaborative partners hosted a joint workshop centered on measurement and instrumentation challenges. Motivation for the workshop was to determine shared research interests for future sponsorship or collaboration, and to provide networking and professional development opportunities for students.

INTERNATIONAL MATERIALS RESEARCH CONGRESS

In August, Michelle McCombs, CEM Program Manager, traveled to the International Materials Research Congress (IMRC). At this conference the NSF Materials Research Science and Engineering Centers (MRSEC) program was presented to conference participants, specifically recruiting potential graduate students and postdoctoral researchers to any of the 21 universities that have a MRSEC Center. Northwestern University's MRSEC spearheaded this joint effort which will continue for the next three years.

GRADUATE-DESIGNED "PHYSICS IS BEAUTIFUL" APP WINS 2016 STUDENT PROJECT GRANT FROM TECHHUB

Physics Ph.D. candidates Nicolas Scozzaro and Hiran Wijesinghe were awarded a 2016 Student Project Grant from Tech Hub for their app, "Physics is Beautiful." The award is a $2,000 grant to continue developing their project: an interactive website/app of physics lessons presented in a game-like environment. Scozzaro approached CEM to request minor/administrative support to get the collaborative idea off the ground, and CEM is proud to have supported their innovative and successful idea.

IRG-2 AWARDED ICAM GRANT FOR 2017 WORKSHOP

CEM's IRG-2 was recently awarded $15,000 from the Institute for Complex Adaptive Matter (ICAM) for a workshop. Titled "Spins, Valleys, and Topological States in 2D and Layered Materials," the workshop is tentatively planned for June, 2017. Topics will include graphene spintronics, valley/spin polarization in transition metal dichalcogenides, and new materials for topological states and magnetism. In addition to invited speakers and posters, the workshop will also include a student tutorial day.

Partnerships for Research and Education in Materials

CEM and New Mexico Highlands University (NMHU) were awarded a Partnership for Research and Education in Materials (PREM) grant, the objective of which is to broaden participation and enhance diversity in materials research and education by stimulating the development of long-term, multi-investigator research and education partnerships between minority-serving colleges/universities and NSF materials-related centers and facilities.

NMHU STUDENT RESEARCH DAY

To kick off the summer, CEM participated in Highlands' student-centered Research Day. CEM Associate Director, Dr. Jessica Winter met with researchers and gave a talk. CEM also sent three graduate student representatives to participate in collaborations and a poster session: Abhilasha Dehankar, Michael Chilcote, and Nicolas Scozzaro.

NMHU SCIENTISTS VISIT OSU

Autumn Semester, NMHU Professor Jiao Chen visited Ohio State. Prof. Chen gave a talk on "Development and Applications of Gold-Silica Nanohybrids for Bioanalysis." In addition to collaborative interaction, Prof. Chen's visit also laid the groundwork for one student and one postdoc from NMHU to research at OSU spring semester. CEM is excited to host these researchers starting January, 2017.

Education & Outreach

SUCCESSFUL SUMMER REU

This summer, CEM completed another successful Summer Research Experience for Undergrads. The Center hosted eight students this year, two of whom applied from the PREM program at New Mexico Highlands University. The students participated in research and professional development, took two laboratory trips to Air Force Research Labs in Dayton and Argonne National Lab in Chicago, and topped off their experience with presentations of their research.

RESEARCH INTERNSHIPS FOR COLUMBUS STATE COMMUNITY COLLEGE

Three Columbus State Community College students recently began an academic year research internship program with the CEM. In this research experience, now in its third year, students come to the OSU campus and are paired with a faculty mentor and either a graduate student or postdoctoral researcher from a core CEM department. This years' students are Robert Arthur, working with Prof. Jos Heremans; Said Haji, working with Prof. Psaras McGrier, and Abigail McCormick, working with Prof. Pat Woodward.

CEM AT COLUMBUS CITY SCHOOLS' INNIS ELEMENTARY FOR ANNUAL "SCIENCE DAY"

This year, the Center mobilized another 45 volunteers, including undergraduates, graduate students, faculty, and staff. About 450 students at Innis Elementary School in Columbus, Ohio benefited from the program, with demos such as Shrinky Dinks, Elephant Toothpaste, Squishy Circuits, Hex Cells, and many others. CEM's Science Day is a yearly culmination of the Scientific Thinkers program. The program is run by CEM professor Nandini Trivedi, Michelle McCombs and Erin Rinehart, with onsite coordination by Innis Elementary teacher Theresa Barber.

ANOTHER EXCITING BREAKFAST OF SCIENCE CHAMPIONS

CEM has participated in Breakfast of Science Champions (BOSC) since the Center's inception in 2008. BOSC is an interdisciplinary and cross-campus effort to support middle school students in Columbus City Schools in their exploration of science, math, and engineering. In a program designed especially for them, students spend a morning on campus and enjoy breakfast with faculty and graduate students from sciences, mathematics, and engineering to learn about career opportunities and attending college. Students then tour labs and participate in a variety of activities.

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SAVE THE DATE!

2017 OSU MATERIALS WEEK

MAY 9–12, 2017
COLUMBUS, OH

2017 OSU Materials Week – the annual showcase of materials-allied research at The Ohio State University and beyond – will be held **May 9–12, 2017** at the Blackwell Inn and Conference Center on Ohio State's Columbus campus.

JOIN US! Our 9th annual conference features a keynote address, student poster sessions, and technical and cross cutting sessions focusing on the latest advances in the full spectrum of materials innovation:

- Materials and Manufacturing for Sustainability
- Materials Innovation
- Materials and Nanostructures for Magnetic Skyrmions
- Integrated Design of Materials
- Nanoengineered Materials for Medical Applications
- Innovations in Advanced Microscopy
- Wide Bandgap Semiconductors

For more information:
go.osu.edu/2017OSUMaterialsWeek

WINTER 2017

Innovations in Materals Research is a free publication from The Institute for Materials Research at The Ohio State University.

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