Innovations in Materials Research

Newsletter of the OSU Institute for Materials Research

Volume 6
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Spring 2014

Faculty Spotlight: Carlos Castro, Mechanical and Aerospace Engineering

Carlos Castro joined The Ohio State University as an Assistant Professor of Mechanical and Aerospace Engineering in April 2011. He received his Bachelors and Masters degrees from Ohio State, then earned a Ph.D. in Mechanical Engineering from Massachusetts Institute of Technology and was awarded an Alexander von Humboldt Post-doctoral Fellowship working at the Technische Universität München before returning to OSU as a faculty member. He currently directs the Nanoengineering and Biodesign Lab with more than 10 members including graduate and undergraduate students and post-doctoral researchers. Dr. Castro was recently awarded an NSF CAREER award to fund his research, which will shed light on cellular function and guide the design of biomedical devices for applications such as cell sorting or biosensing. Dr. Castro's lab focuses on the development of novel tools and approaches to study biological systems at multiple lengthscales, ranging from the single molecule level up to millimeter scale complex biological systems. A major focus is the development of nanoscale devices using programmed self-assembly of DNA. Dr. Castro is also co-lead of a Proto-IRG seeded by the Center for Emergent Materials, an NSF MRSEC program at Ohio State. In addition to the two focus areas below, Castro's research includes DNA-based nanomachine design, developing novel approaches to single molecule force spectroscopy using DNA nanotechnology to study protein-DNA interactions, and establishing novel methods to probe biophysical and biochemical characteristics of immune cell signaling

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OSU Team Develops Nanowire "Shag Carpet" to Improve Bone Growth

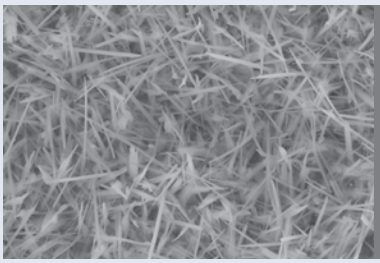

Figure 1: SEM micrograph showing typical nanostructured surface resulting from the oxidation of Ti-6Al-4V at 700°C for 8 hours in 500 sccm of laboratory grade Ar containing 10s of ppm of oxygen. Fiber diameters are 10s of nm.

An OSU research team has developed a new coating for medical implants that may help broken bones and joint replacements heal faster, and an economical assembly to facilitate the process. Researchers found that bone cells grow and reproduce faster on a textured surface than they do on a smooth one. They further discovered that a nanowire "carpet," a shag carpet-type model made up of tiny metal oxide wires, helped bone growth increase by nearly 80 percent. The multidisciplinary team included faculty Sheikh Akbar and Suliman Dregia from Materials Science and Engineering, and Derek Hansford in Biomedical Engineering. This research was partially seeded in its early stages by an IMR Facility Grant and further supported by the National Science Foundation.

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The Ohio State University

IMR
Institute For Materials Research

Director's Note

Dear Colleagues,

Spring is here and much is already blooming in the IMR world at Ohio State! Perhaps the largest growth of the season to date is the recent announcement by White House establishing the American Lightweight Materials Manufacturing Innovation Institute (ALMMII) as the third hub within the U.S. National Network for Manufacturing Innovation. The Ohio State team, led by Professor Glenn Daehn, with fellow co-founding team members - The Edison Welding Institute (EWI) and The University of Michigan, will be working with a consortium of more than 50 companies and universities. With funding from the Department of Defense, this group has created a $148M hub that will be the world leader in the application of innovative lightweight metal production and component/subsystem manufacturing technologies. ALMMII builds from the Center for Design and Manufacturing Excellence (CDME), a strategic initiative being led by the College of Engineering and EWI, and leverages our strengths in Integrated Computational Materials Engineering (ICME), characterization, structural materials and joining.

Not only is this a recognition of some of our world-leading strengths, it is also perfectly timed with the University's recent announcement of the "Materials for a Sustainable World" Discovery Theme, an internal investment to move Ohio State from Excellence to Eminence by leveraging strengths to address some of the planet's most pressing technological, environmental and societal needs. IMR is hard at work cultivating a dynamic response to this terrific opportunity by working with a large number of departments, centers and external entities.

I invite you to look inside this most exciting edition and read about the innovative research led by Prof. Carlos Castro in Mechanical and Aerospace Engineering, who just received a prestigious NSF CAREER award related to the research described in our Faculty Spotlight section – congratulations Carlos! We are also showcasing a collaboration between Profs. Sheikh Akbar and Suliman Dregia (both in Materials Science and Engineering) and Prof. Derek Hansford in Biomedical Engineering, who have recently discovered and developed a metal oxide nanowire "carpet" that is being considered for biomedical applications in the area of bone growth and joint replacement. The Center for Emergent Materials (CEM), Ohio State's NSF MRSEC, is not only hard at work for their renewal, but CEM continues to expand their activities, and recently learned that they have made it to the finalist reverse site visit round! Our core materials facilities continue to enhance their capabilities and sustainability – the NanoSystems Laboratory, with cost sharing from many units including IMR, has announced the installation of a Helium Gas Liquefaction Plant that will provide liquid helium at reasonable costs to researchers for years to come. Nanotech West Laboratory is working to release a new, mobile-friendly website and its recent $2.5M Ohio Sensor and Semiconductor Innovation Platform (OSSIP) program has hired 2 new engineers to focus on a range of optoelectronic sensor technologies with OSSIP partner companies.

And finally, I hope to see you all May 6-9, 2014 for this year's OSU Materials Week Conference.

With warm regards,

Steven A. Ringel, Ph.D.
Neal A. Smith Chair Professor
Director, The Ohio State University Institute for Materials Research

IMR Expands International Connections

IMR Director Tours India Through Ohio State India Gateway

Shamala Nadendla, Larsen and Toubro Construction; Steven Ringel, IMR Director; Ratnesh Bhattacharya, Director, Ohio State India Gateway; and Anish Kalathil, Larsen and Toubro Construction

The Ohio State India Gateway serves as a catalyst to enhance our faculty's research and teaching interests; increase partnerships with international institutions and Ohio-based businesses abroad; attract international students; provide new study abroad opportunities; and reconnect with alumni. In February, IMR Director Steve Ringel, took advantage of the India Gateway mission and by working with its director, Ratnesh Bhattacharya, engaged in a very busy and productive series of meetings with industrial executives and academic leaders across India for the purpose of establishing meaningful linkages between the OSU materials community and Indian companies and universities. Meetings were held with OSU alumni in academia and industry in Chennai, Bangalore and Mumbai. Key companies visited included Larsen and Toubro, Kiran Energy Solar Power and several divisions of the Tata Group of companies, including Tata Solar, Tata Consulting Engineers, and Tata Advanced Materials. He also met with faculty members at the Indian Institute of Technology-Bombay, the Indian Institute of Technology-Madras and the Indian Institute of Science in Bangalore to discuss their research interests and strengths and opportunities for collaboration with IMR members. During his visits, Dr. Ringel gave several presentations on the strengths and breadth of the OSU materials community, discussed areas of mutual research and innovation interests, including opportunities and mechanisms for enabling meaningful collaborations in advanced materials, manufacturing, semiconductors, nanotechnology, solar energy, and industry-university multinational partnerships.

Ringel and Bhattacharya tour Larsen & Toubro Construction headquarters in Chennai

Based on the success of Dr. Ringel's visit, the Institute for Materials Research in turn hosted a delegation from leading Indian companies in the materials and energy sectors, who visited Ohio State's Columbus campus April 9 and 10. Leaders from these Indian companies toured research facilities and met leaders from the State, Columbus and the University o further discuss opportunities of mutual benefit to all parties.

IMR Director is Guest of Honor at First International Innovation Dinner in Cardiff

IMR Director Steve Ringel was one of two guests of honor to speak at the First International Innovation Dinner, hosted by IQE Inc., held in Cardiff, Wales on March 10. The dinner meeting, organized to discuss technology innovation and how innovation is being developed in various countries in Europe and the Americas in conjunction with major universities, was in part spurred on by the desire of companies within the European Union to explore partnership opportunities to align with various Horizon 2020 efforts being considered for funding by the European Union. Guests at the International Innovation dinner included business, technology, academic and finance leaders from across Europe, including representation from the highest offices of the European Commission, the Welsh government and the U.K. government.

2014 OSU Materials Week

May 6 – 9, 2014

Join us May 6-9 for the 6th annual showcase of materials-allied research at The Ohio State University and beyond. A wide range of technical sessions will feature cutting-edge materials research by leading scientists from academia, national laboratories and private industry, while a highlight of Materials Week will once again be the two student poster sessions featuring the latest research by OSU students. This event is presented by The Ohio State University Institute for Materials Research, the gateway to materials-allied research. Registration fees are $35 for current students and $45 for all others.

A continuously updated agenda with confirmed speakers and talk titles is available online: http://imr.osu.edu/seminarsandevents/materials-week/

Tuesday, May 6

IMR Keynote Address:

Real Materials under Real Conditions in Real Time: Studies with High Brightness, High Energy X-rays at the Advanced Photon Source - G. Brian Stephenson, Director, Advance Photon Source at Argonne National Labs

Welcome Reception

Wednesday, May 7

Cross Cutting Session:
Advances in In-Situ Characterization

Focus Sessions:
- Computational Design of Materials for Energy
- Materials in Medicine

Poster Session and Evening Reception

Thursday, May 8

Cross Cutting Session:
Computational Materials

Focus Sessions:
- Biopolymers and Polymers
- Oxides and Interfaces

Poster Session and Evening Reception

Friday, May 9

Focus Sessions:
- Lightweight Structures and Manufacturing
- Spin-Mediated Thermal Properties

Ohio Research Scholars Symposium (by invitation)

Poster Awards

Faculty Spotlight: Carlos Castro, Mechanical and Aerospace Engineering (continued from page 1)

Reverse Engineering Ant Neck Joint Material and Structural Design

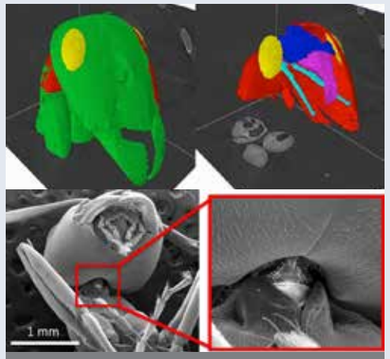

Figure 1: MicroCT (top) and scanning electron microscopy (bottom) were used to quantify the internal and external structure and the surface microstructures of the Allegheny Mound Ant. The structural design is critical to the optimized mechanical function of the neck joint.

Inspired by a natural marvel, Dr. Castro and his research group have studied the mechanical structure of the ant neck joint to learn what allows ants to carry objects many times their own weight. Castro was awarded an IMR Facility Grant in December 2011 to characterize the micromechanical structure-function relation of several species of ants. This work was supplemented by an NSF graduate research fellowship for former Master's student Vienny Nguyen, co-advised by MAE Associate Professor Blaine Lilly. The group hypothesized that the ant's ability to carry extremely large loads relative to its body mass was the result of a highly integrated system comprised of composite materials, internal muscle mechanisms, and surface microstructure. Using a combination of electron microscopy and micro-computed tomography (microCT imaging), they examined the exoskeleton and underlying tissues in the critical loadbearing regions where the head, thorax, and abdomen join (Figure 1).

While some exotic ant species, for example the African Weaver Ant, have been observed carrying ~1000 times their own weight, Castro initially estimated that a common local field ant, the Allegheny Mound Ant, may be able to carry a few hundred times their own weight. Surprisingly, their research determined that the neck joint of a ant can actually withstand forces up to 5,000 times the ant's weight. Castro believes this feat is possible due to two structural items noted in his research. First, electronic microscopy images revealed that each part of the head-neck-chest joint contained detailed surface and internal microstructures, which may minimize stress and optimize mechanical function through friction or bracing one moving part against the other. Second, the interface between the soft materials of the neck and the hard materials of the head has a graded and gradual transition between materials that may give it an enhanced performance. This research is now published in the Journal of Biomechanics and continued understanding of this ant neck joint could lead to advances in robotics and similar joints might enable future micro-robots to mimic the ant's weight-lifting ability on earth and in space. In addition, the lessons learned from the structural and material design might provide useful insight in optimizing joints between hard and soft components in composite material applications. Castro and his collaborators plan to further study how the ants move and observe their muscles closely through microCT imaging and computer simulations as the next steps in understanding the ant's mechanics.

Dynamic Mechanical Behavior of DNA Origami Nanostructures

Dr. Castro is a co-lead (along with Prof. Michael Poirier, Physics) of a Proto-IRG (Interdisciplinary Research Group) studying "Functional Dynamics of DNA-Based Nanostructures," funded by the Center for Emergent Materials and the OSU Materials Research Seed Grant Program. This multidisciplinary research project's goal is to enable the nanoengineering of mechanically dynamic hybrid material nanomachines. A fundamental challenge in nanotechnology is to construct nanoscale functional devices that are mechanically dynamic yet structurally well-defined. Biopolymers such as DNA and proteins overcome this structural contradiction by folding into structures that are held together by many k_BT-scale interactions so the nanostructure is simultaneously globally stable and locally dynamic. Recent advances in nanotechnology have enabled the fabrication of well-defined

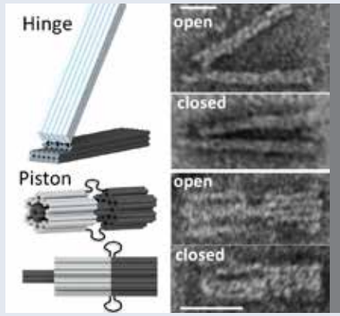

Figure 2: The nanoscale hinge (top) and piston (bottom), designed and fabricated in Dr. Castro's lab, enable rotational and linear motion, respectively. Both were designed by connecting stiff DNA origami components with flexible single-stranded DNA connections. Scale bars are 20 nm.

nanostructures from biopolymers, in particular DNA; however, the ability to control the structural dynamics of these nanostructures remains a challenge because the material parameters that govern the dynamics of designed DNA nanostructures are largely unexplored. This project is laying the foundation for functionally dynamic nanomachines by designing dynamic DNA nanostructures, integrating functional proteins and nanoparticles, and developing single molecule assays to measure the dynamics of these DNA-based nanomaterial systems. This team has had multiple successes thus far, leading to the request for full NSF funding as an IRG in the Center for Emergent Materials renewal proposal.

The underlying basis for the prototype nanomachines that the team will develop include a DNA origami hinge for rotational motion and a DNA origami piston for linear motion (Figure 2), both designed and fabricated in Dr. Castro's lab. The research team is developing robust approaches to integrate and exploit the dynamic properties of functional proteins and nanoparticles in the DNA nanostructures. For example, the team have successfully developed a scheme for integrating DNA-binding protein into the hinge that can function as a latch to regulate the conformation of the hinge. Other hybrid nanomachine systems will integrate functional nanoparticles (i.e. gold, magnetic, or fluorescent) to use as a basis for dynamic actuation or experimental readouts of motion. To better understand explore the mechanical dynamics of these systems, this seed project has developed single molecule force spectroscopy assays to measure the conformational dynamics of a DNA origami nanostructures sensor using magnetic tweezers.

The research on ant neck joint can be found in the January 2014 issue of *Journal of Biomechanics,* (Volume 47, issue 42, January 2014, doi:10.1016/j.jbiomech.2013.10.053). For more information on Carlos Castro's research, visit his group's website at http://mae.osu.edu/labs/nbl/

OSU Team Develops Nanowire "Shag Carpet" to Improve Bone Growth (continued from page 1)

Titanium dioxide (TiO_2) nanowires were grown by a simple thermal oxidation process, an affordable technique developed to create the wires as a means of coating Ti64-based devices to increase cell adhesion and proliferation. Dr. Akbar estimates that with this cost-effective process, just $100 worth of metal foil could make hundreds of samples. The team then used fluorescence microscopy and laser scanning cytometry (LSC) to monitor human osteosarcoma (HOS) cell proliferation and alkaline phosphatase activity on three different surfaces – HOS on bare titanium, nanostructured TiO_2 and non-nanostructured (smooth) TiO_2 . Cancer cells were used because they are particularly hardy and reproduce identically to healthy bone cells. The nanowire-coated samples showed increased cell adhesion and proliferation, 80% more compared to the non-nanostructured TiO_2 and Ti64 samples.

"What's really exciting about this technique is that we don't have to carve the nanowires from a solid piece of metal or alloy. We can grow them from scratch, by exploiting the physics and chemistry of the materials," explained Dr. Akbar, referring to this process as "nanostructures by material design." Researchers were able to grow the wires using a furnace heated to 1,300 degrees Fahrenheit to create fine filaments of titanium dioxide tens of thousands of times smaller than a human hair, which then grew a protective coating of aluminum oxide around itself. This "shag carpet"-like structure gave the bone cells something to easily adhere to.

Dr. Hansford indicated that the coating could have orthopedic medical applications such as hip and knee replacements, dental implants or broken bones, allowing healthy bone to form a strong bond with an implant faster. "Our hope is that this surface treatment will become a simple-to-implement modification to titanium implants to help them form a stronger interface with surrounding bone tissue," explained Hansford. "A stronger interface means that implants and bones will be better able to share mechanical loads, and we can better preserve healthy bone and soft tissue around the implant site."

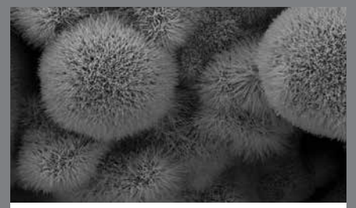

Figure 2: TiO_2 nanofibers grown β-Ti particles at 700°C for 8 hours in 500 sccm of laboratory grade Ar containing 10s of ppm of oxygen. Fiber diameters are 10s of nm.

While the research findings were first published in the July 2013 issue of *Ceramics International*, this exciting news was also covered locally and nationally, including the *Columbus Dispatch* and The American Ceramic Society website. A recently awarded IMR Facility Grant titled, "Nano-Textured Biomaterials for Enhanced Stem Cell Adhesion and Growth" allows Dr. Akbar and OSU graduate student Derek Miller to further investigate by studying stem cell behavior on these surfaces with Dr. Mahmood Khan in OSU's Cardiovascular Medicine division. Mesenchymal stem cells (MSCs) can differentiate into several specific types of tissue and organ cells, and are typically cultured on a flat surface before injection into the body. In this project, nano-textured surfaces will grow the MSCs in a 3D environment more similar to the body, likely increasing cell survival rate after injection. Increased cell adhesion to this textured surface should provide a firmer contact between a titanium implant and the surrounding environment and the optimal nano-textured morphology for cell growth and adhesion will be examined. Dr. Akbar is also working with researchers at the University of Malay (Kuala Lumpur, Malaysia) studying effects of joint cells (such as chondrocytes) on these surfaces, and that related research is currently in-press with the *Ceramics International* journal.

The research on nanowire carpets can be found in *Ceramics International* (Volume 39, Issue 5, July 2013, Pages 5949–5954, doi:10.1016/j.ceramint.2012.12.004). Dr. Akbar's related research with colleagues at the University of Malaya is currently "in press" with *Ceramics International* but available online (http://dx.doi.org/10.1016/j.ceramint.2014.01.032).

Ohio State Co-Founds High-Tech Manufacturing Institute

This article was originally featured in the university publication onCampus and on the Materials Science and Engineering department website, and is republished here with permission.

The Ohio State University, along with Columbus-based EWI and the University of Michigan, are co-founders of a consortium of universities, companies and nonprofits that will establish a $148 million high-tech manufacturing research institute. The American Lightweight Materials Manufacturing Innovation Institute (ALMMII) is expected to create 10,000 new jobs in the Midwest in the next five years in support of a rapidly expanding lightweight materials industry.

ALMMII was created in response to a solicitation from the U.S. Navy that focused on lightweight and modern metals. The technologies and materials developed by ALMMII will also be transitioned to commercial firms, including small and medium-sized businesses. ALMMII will help develop advanced lightweight materials and technology for use in everything from new hulls for Navy ships to lighter and safer automobiles that are more energy efficient. The institute will help train workers in using new technology involved with creating and using new lightweight materials.

The Department of Defense awarded the team $70 million for the new institute. The state of Ohio has committed $10 million, and the Ohio State College of Engineering has committed $5 million. The remainder of the $148 million for the institute will come from other team members. The White House officially announced the new institute in Washington, D.C.

"We are proud to be working with such an outstanding founding group in establishing this important national institute, which will bring together resources from industry, government and academia to enhance the region's competitiveness, create opportunities for students and generate economic growth," said Ohio State Interim President Joseph A. Alutto. Alutto acknowledged the importance of the support from Ohio leaders in making this award possible, particularly the $10 million commitment from the Kasich administration and the legislative passage of HCR 33 in support of this project.

Additionally, Alutto thanked Ohio's state and federal elected officials for their strong statewide, bipartisan support of the Ohio State-EWI application. U.S. Sen. Sherrod Brown and Reps. Joyce Beatty and Steve Stivers led letters in support of the proposal, signed by Sen. Rob Portman and Reps. Pat Tiberi, Tim Ryan, David Joyce, Bob Gibbs, Bill Johnson and Brad Wenstrup. Brown in particular has been a tireless advocate of advanced manufacturing, including introducing legislation to promote these centers, the Revitalize American Manufacturing and Innovation Act (S 1468). "American workers have the drive, the creativity and the determination to out-innovate the rest of the world," Brown said. "By developing innovative partnerships among the Department of Defense, research institutions like The Ohio State University and industry organizations like EWI, we ensure that American workers and businesses have the resources they need to develop the next generation of high-tech manufacturing industries. This type of investment helps rebuild our nation's manufacturing sector while creating new jobs and strengthening our middle class."

In addition to EWI (a nonprofit organization that helps develop and apply manufacturing technology), Ohio State and the University of Michigan, the team includes more than 50 other members. The institute will be based in metropolitan Detroit, but will draw heavily from Ohio State and EWI assets in Columbus. Researchers at Ohio State and EWI will be engaged in executing research projects in collaboration with the government and key industry partners, training the next generation of workers in lightweight manufacturing, and transitioning the results of their activities to commercial firms across the state and the region. The latter thrust is directly aligned with state and national goals of increasing competitiveness in advanced manufacturing and creating the high value jobs of tomorrow. ALMMII will capitalize on EWI and Ohio State facilities and assets including key faculty, students and project managers to execute its projects. Ohio State, EWI and the University of Michigan will all have seats on the ALMMII Board of Directors, and each organization will contribute a key employee to the ALMMII leadership team.

ALMMII is part of an integrated advanced manufacturing plan developed by Ohio State's College of Engineering that includes a new OSU-EWI initiative called the Center for Design and Manufacturing Excellence (CDME), said Dean David B. Williams. The college is also investing heavily in Ohio State's new discovery theme of Materials for a Sustainable World. The discovery themes are designed to leverage Ohio State's human talents and fiscal resources to address the technological, social and environmental stresses that define today's global world.

ALMMII, the CDME and the Materials for a Sustainable World discovery theme will work together as part of the overall advanced manufacturing initiative and should enable Ohio State to hire new faculty in pursuit of transformative, interdisciplinary research that impacts existing and emerging markets and firms, Williams said. "This collaborative effort in lightweight metals echoes Ohio State's commitment to manufacturing innovation, especially as it relates to transportation," said Williams. "The work we do will directly impact the automotive, aerospace and defense sectors, each of which is very important here in Ohio."

Ohio State's partners at EWI and the University of Michigan expressed their support and enthusiasm for the new institute. A vision of the institute is to prepare an eager work force and equip them with 21st century advanced manufacturing skills. Through the integration of the region's work force, education and economic development assets, the institute will enable the availability of job-ready employees and maximize the transition of emerging technologies to small, medium and large firms in the region and across the nation," said Lawrence Brown, executive director of the institute and director of government technology programs at EWI. U-M President Mary Sue Coleman concurred. "Through this initiative, our region will build on its core strengths to become the hub for lightweight materials nation's technology and manufacturing," Coleman said. "Companies from around the country will come here not only because of our technological capabilities, but also because we have the work force they need in their efforts to revitalize and transform domestic manufacturing." ALMMII is part of the National Network for Manufacturing Innovation. Previously announced institutes are located in Youngstown, Ohio, and Raleigh, N.C.

For more information on the American Lightweight Materials Manufacturing Innovation Institute, visit almmii.org

> **"This award intends to extend the use of Integrated Computational Materials Engineering (ICME) to bring new high performance light metal products from the idea stage to market. It will leverage OSU's strengths in ICME, characterization, structural materials and joining to both to reduce the weight of automobiles, aircraft and ships as well as bring new economic opportunities to the region."**
>
> — Glenn Daehn, Professor, Materials Science and Engineering and Director, Ohio Manufacturing Institute

IMR Member News

Carlos Castro, Mechanical and Aerospace Engineering, has earned a National Science Foundation Early CAREER Development award for his research proposal, titled "A Molecular Force Sensor for Single Molecule Studies of Cellular Force Application." The NSF CAREER award, which recognizes outstanding junior faculty, provides Castro with funding across five years in the amount of a $408,164 grant. As part of his work, Castro will develop, calibrate, and implement a nanoscale molecular force sensor that is capable of measuring cellular traction forces (CTF) of single membrane proteins and protein.

Liang-Shih (L.S.) Fan, Chemical and Biomolecular Engineering, was named 2013 Fellow of the National Academy of Inventors, which honors those who make outstanding contributions to the creation of outstanding inventions that have made a tangible impact on quality of life, economic development and the welfare of society. Fan holds 39 patents, and invented the leading clean-coal technology in the United States, called Coal-Direct Chemical Looping (CDCL), which chemically harnesses coal's energy and efficiently contains the carbon dioxide produced before it can be released into the atmosphere.

Hamish Fraser, Materials Science and Engineering, was elected Fellow in the Microscopy Society of America for his contributions to the microscopy and microanalysis of materials community.

Shaurya Prakash, Mechanical and Aerospace Engineering, has co-authored a textbook published by Elsevier. The textbook, titled *Nanofluidics and Microfluidics Systems and Applications*, includes chapters dealing with lab-on-a-chip systems, energy and environmental systems, and nanobiotechnology systems, and is being used in ME 6515, Introduction to Microfluidics and Nanofluidics – a course offered in the graduate-level mechanical engineering curriculum.

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Center for Emergent Materials Update

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. There are two IRGs at the Center for Emergent Materials focused on researching the quantum mechanical phenomenon called "spin" in order to understand and engineer functional nanostructures. For more information about CEM, visit their website: http://cem.osu.edu/.

CEM Enters Third and Final Stage for Renewal

Now in its sixth and final year of funding, the CEM shows no sign of slowing down as it ramps up activity as it competes for renewal. Center activity is expanding: this includes research output, education, outreach, industrial interactions and collaboration. In January, the CEM was invited to submit a proposal to the National Science Foundation that included four IRGs:

- Spin-orbit coupling in correlated materials: novel phases and phenomena
- Control of 2D electronic structure and 1D interfaces by surface functionalization of group IV graphane analogues
- Hybrid nanostructures with controllable structural dynamics
- Nonlinear interactions between spin flux and engineered magnetic textures

The proposal is currently under review, and we expect news from the NSF regarding a potential reverse site visit imminently.

Wide Ranging Research Advances

Since the fall newsletter the MRSEC has had an additional eight publications, now totaling 161 papers to-date for the center. The CEM is proud to report that "The effect of spin transport on spin lifetime in nanoscale systems," was published online to *Nature Nanotechnology* last week, and that international collaborations with IFW Dresden in Germany are still going strong, as evidenced by a joint publication in the *Journal of the American Chemical Society* ("Independent Ordering of Two Interpenetrating Magnetic Sublattices in the Double Perovskite Sr_2CoOsO_6").

In *Nature Nanotechnology,* the team demonstrated how information can flow through a diamond wire. OSU's Pam Frost Gorder (writing for website phys.org) likened the behavior of electrons in the diamond wire to sports spectators performing "the wave" at a sporting event. The research performed in this paper is important because it revealed that diamond transmits spin better than most previously tested metals. The work done on this project could change future studies of spintronics and technologies. Read more about the findings in *Nature Nanotechnology* here, or in Gorder's article on phys.org.

Recent highlights include:

- "The effect of spin transport on spin lifetime in nanoscale systems," J. Cardellino *et al., Nat. Nanotechnol.*, (2014).
- "S-I-S Josephson junction with a correlated insulator below its S-I transition," C. D. Porter *et al., Physica C*, (2014).
- "Realization of one-way electromagnetic modes at the interface between two dissimilar metals," M. Dixit *et al., Appl. Phys. Lett.*, (2014).
- "Tight-binding model for adatoms on graphene: Analytical density of states, spectral function, and induced magnetic moment," N. A. Pike *et al., Phys. Rev. B*, (2014).
- "Tunable gaps and enhanced mobilities in strain-engineered silicane," O. D. Restrepo *et al., J. Appl. Phys.*, (2014).
- "Heterojunction band offsets and dipole formation at $BaTiO_3/SrTiO_3$ interfaces," S. Balaz *et al., J. Appl. Phys.*, (2013).
- "An embedded atom method potential of beryllium," A. Agrawal *et al., Model. Simul. Mater. Sc.*, (2013).
- "Independent Ordering of Two Interpenetrating Magnetic Sublattices in the Double Perovskite Sr_2CoOsO_6," R. Morrow *et al., J. Am. Chem. Soc.*, (2013).

CEM Welcomes Two New Scientists

This winter, the CEM was privileged to welcome two talented researchers onto its team: Dr. Sarah Dunsiger and Dr. Ramasamy Pandian.

Sarah Dunsiger has recently joined the CEM from the Technical University of Munich. She is performing research at the Center for Emergent Materials within the Integrated Research Group "Spin Orbit Coupling in Correlated Materials". She has a background in transition metal and rare earth oxides, particularly pyrochlores and is using depth resolved spin resonance techniques like low energy muon spin relaxation and beta detected nuclear magnetic resonance to investigate the magnetic and electronic properties of artificial multifunctional materials. These studies are complemented by investigations of the bulk materials using inelastic neutron scattering. Sarah is particularly interested in the fundamental nature of the magnetic excitations of buried layers and interfaces, which typically deviate from those of the individual constituents. In practical devices such excitations constrain the characteristic spin decoherence timescales; in model magnetic systems an understanding of the excitations is critical to shed light on the underlying spin interactions. Sarah received her doctorate from the University of British Columbia in 2000 with a thesis on "Spin Relaxation in Geometrically Frustrated Pyrochlores."

R. Pandian is performing research with Professors P. Chris Hammel and Michael G. Poirier at the CEM. He uses innovative electron paramagnetic resonance (EPR) technique and EPR-active oxygen sensing spin probe materials for quantitative determination of oxygen concentration in biological systems. He is interested in synthesis and characterization of porphyrin and phthalocyanine paramagnetic materials, coupled with necessary insight and innovation in his approaches for various biological applications. He uses magnetic resonance and other physicochemical techniques for device characterization. Pandian is closely involved in development of nanoscale optical detection of magnetic resonance (ODMR) of oxygen-sensing paramagnetic nanoparticles for non-invasive detection of oxygen concentration within single living cells.

R. Pandian received his doctorate in Inorganic Chemistry from Indian Institute of Technology (IIT), Kanpur. He was Higher Education Research fellow at Israel Institute of Technology, Haifa, Israel; Japan Society for Promotion of Science (JSPS) fellow at Osaka University, Osaka, Japan; and Centre National De La Recherche Scientifique (CNRS) fellow at Pierre et Marie Curie Universite, Paris, France.

Inspiring the Next Generation of Scientific Thinkers

CEM Director Prof. Chris Hammel led a career talk for fourth grade students at Innis Elementary on March 25, 2014. He discussed the importance of magnetism in computing and then worked with the students to make simple motors and learn how their computer hard drive works.

Innis Elementary is a partner school for the Scientific Thinkers program (PI: CEM faculty member Nandini Trivedi). Through the Scientific Thinkers program, undergraduate and graduate students from OSU STEM fields work with first through fifth grade teachers at Innis elementary to develop and teach hands-on science lessons. This program provides the students experience communicating scientific information to those outside of their field. They also have an opportunity to reach out to the Columbus community and motivate the next generation of scientific thinkers.

For additional information about the program, please visit our website: http://osuscientificthinkers.wordpress.com/.

IMR Member News

(continued from page 1)

Claudia Turro, Chemistry and Biochemistry, is the 2014 recipient of the Susan M. Hartmann Mentoring and Leadership Award by OSU's College of Arts and Sciences. This award is presented to a leader who demonstrated outstanding mentoring to and leadership on behalf of women or other historically underrepresented groups at the university, who has generously and unselfishly served others in an effort to promote equity, fairness, and equal opportunities for all members of the university community.

John Volakis, Electrical and Computer Engineering, received the 2013 IEEE Rudolf Henning Distinguished Mentoring Award in recognition of his mentoring of students and young engineers to achieve successful careers in the areas of RF/microwave and wireless engineering.

Jessica Winter, Biomedical Engineering and Chemical & Biomolecular Engineering, was named one of *Columbus Business First* Magazine's "20 People to Know in Technology," as one of 20 individuals in central Ohio "who are front and center in their industries."

New IMR Member

This semester we welcome one new member to the OSU Institute for Materials Research. Below is a brief description of his area of focus of their research.

Rolando Valdes Aguilar is an Assistant Professor with the Condensed Matter Experiment group in Physics. His areas of interest include the study of emergent low energy degrees of freedom of complex correlated material systems using optical spectroscopies with femtosecond and picosecond time resolution. He joins us directly from a Postdoctoral Fellow position at Los Alamos National Laboratory, preceded by a Postdoctoral Fellow position at Johns Hopkins University. Prof. Valdes Aguilar received his Ph.D. from the University of Maryland with advisor Dennis Drew.

Materials Facilities Updates

In each issue of our newsletter, IMR provides relevant updates from our core materials research facilities - the NanoSystems Laboratory (NSL), Center for Chemical and Biophysical Dynamics (CCBD), Nanotech West Laboratory and the Center for Electron Microscopy and Analysis (CEMAS). 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.

Nanotech West Laboratory – nanotech.osu.edu

Ohio Sensor and Semiconductor Innovation Platform (OSSIP) Hires Two Engineers

A new Ohio Third Frontier Program, the Ohio Sensor and Semiconductor Innovation Platform (OSSIP) began in late 2013. As detailed in the Fall 2013 issue of *Innovations in Materials Research*, OSSIP is a $2.54M, three-year program with the goal of helping Ohio companies create new high-tech products and associated quality jobs. The initial two "clients" of OSSIP are L-3/Cincinnati Electronics of Mason, Ohio and Srico Inc. of Columbus. The partnership with L-3/CE will develop new high-definition infrared (IR) focal plane arrays, and the work with SRICO will develop new sensors based on electro-optic modulators (EOM) and EO materials. Specific goals of the program are that new products be commercially marketed within three years and that the program is sustainable with the initial and added industry clients. Specifically, OSSIP gives OSU the "bandwidth" to take on projects that formerly it could not do with the regular Nanotech West staff.

Nanotech West's engineers: John Carlin, Dave Hollingshead, Jay DeLombard and Aimee Price

Two Research Associate engineers were hired in February 2014 to serve as principal OSSIP engineers. Mr. Dave Hollingshead returns to Nanotech West where he worked as a student. He holds MS and BS degrees in Electrical Engineering from Ohio State and was employed by Replex Plastics where he primarily worked on low-concentration photovoltaics systems and other optical products. Mr. Jay DeLombard also returns to Ohio State, where he earned a BS degree in Physics. He spent several years at Lake Shore Cryotronics and has extensive experience in the fabrication, and with the equipment enabling such fabrication, of a wide range of electronic and electro-optical devices. These two new engineers are based at Nanotech West and will provide key support for the OSSIP project and its stakeholders.

Other Recent Nanotech West Highlights

- **E-beam celebrates 5th year at NTW** – The OSU Leica / Vistec EBPG 5000 electron beam nanolithography tool celebrated its fifth anniversary at Nanotech West. It was relocated from its former location in Dreese Lab to leverage major capital investments at Nanotech West by the Wright Center for Photovoltaics Innovation and Commercialization (PVIC), an Ohio Third Frontier Program. Along with the tool came now-Nanotech West Staff Member Ms. Aimee Price, a Senior Research Associate and an IMR Member of Technical Staff. The tool was originally purchased with State of Ohio funding, the result of a proposal led by Prof. Paul Berger of the OSU Electrical and Computer Engineering Department, and supports a spectrum of funded programs.

- **Freshman Tours** – In early March, approximately 40 OSU students toured Nanotech West as part of their Freshman Honors Engineering experience course. All had the chance to tour through the cleanroom and receive a short 40 minute classroom introduction to micro- and nanofabrication.

- **New Web Site** – During Spring of 2014 Nanotech West will release its updated web site. The new web site will be mobile-device friendly and will also be easier for Nanotech West staff to update and add content.

- **New Furnace Tube Order Placed** – An order for a new stand-alone furnace tube at Nanotech West was placed in early March, and will arrive sometime in May. This tube, 100 mm wafer capable, will enable Nanotech West to fill the need of many users for a variety of annealing processes, including those for which they purchase their own dedicated tubes. It will be located in Bay 4 to leverage the availability there of pure process gases.

- **Annual Safety Retraining** – The second annual NTW/NanoSystems Laboratory (NSL) Safety Retraining Program will occur in May. All current users in the Columbus area will be required to attend and special arrangements will be made for users outside of Columbus. Numerous 50 minute sessions will be given throughout the month in multiple locations on campus in collaboration with the IMR-affiliated NanoSystems Lab, which also requires its users to attend a session.

NanoSystems Laboratory (NSL) - ensl.osu.edu

New Organic Clean Room Facility

New NSL class 10,000 clean room space optimized for chemistry of air sensitive organic materials featuring multiple interconnected glove boxes with nitrogen or argon atmosphere. Other equipment includes, but not limited to, two thin film PVD chambers installed inside of glove boxes.

NanoSystems Laboratory has announced an expansion of its capabilities with an acquisition of an additional 1,600 ft^2 of class 10,000 clean room space optimized for the chemistry of air sensitive organic materials. The equipment for the clean room is donated by Distinguished University Professor Dr. Arthur J. Epstein (Department of Physics). It features four interconnected glove boxes with nitrogen or argon atmosphere available, with two thin film PVD chambers - one optimized for metal film deposition and the other for organic film deposition. The metal film deposition chamber is equipped with one e-beam, one sputter, and two thermal evaporation sources. The organic film deposition chamber is equipped with two OLED and two thermal evaporation sources. Additional equipment available within the glove boxes includes a spin coater, a vacuum oven, freezer storage, a solar simulator, a wiring station, and a test station for electrical measurements. The clean room also features a yellow room for substrate preparation, with a fume hood, an ultrasonic cleaner, a UV ozone cleaner, and an optical microscope. This new organic clean room is available to all users on a user fee basis upon completion of appropriate training and certification.

New Helium Gas Liquefaction Plant to be Installed in Physics Research Building

Experiments in many branches of physics, chemistry and engineering including, but not limited to, the studies of properties of new materials and electronic devices, require guaranteed availability of liquid helium which is used as a cryogen for cooling experimental equipment and samples. Over the past decade the price of liquid helium has grown significantly, putting multiple research programs at risk due to its prohibitive costs. In addition, there is a possibility of helium gas shortages in the future since it is a nonrenewable resource. In this light, NSL announces the beginning of a project aimed at the purchase and construction of a helium gas liquefaction plant and helium gas collection network to be installed in the Physics Research Building (PRB). This new facility will collect and reliquefy helium gas used in scientific experiments in the PRB, thus reducing the need to purchase liquid helium from external sources and reducing the overall cost of liquid helium to researchers. The liquefaction plant will be funded by OSU and maintained and operated by NSL, and the department of Physics will provide a technical staff member for plant operation.

To arrange use and training on the organic cleanroom or for further information on the helium liquefaction plant, please contact NSL Program Assistant Laura Heyeck (heyeck.2@osu.edu).

Institute For Materials Research

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2014 OSU MATERIALS WEEK

Blackwell Inn, Columbus, Ohio

MAY 06 TUE_09 FRI

For a full schedule of technical talks, poster sessions and other conference activities, go to page 2 of this issue or visit imr.osu.edu

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