

# IMR Quarterly

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## New Ohio Research Scholar Stretches the Boundaries of Natural Rubber

### Faculty Spotlight: Katrina Cornish

This summer Katrina Cornish joined The Ohio State University faculty at OARDC-Wooster as an Endowed Chair in Bio-based Emergent Materials. This key position is one of three Ohio Research Scholars at OSU founded by an Ohio Department of Development Ohio Research Scholars Program award, Technology-Enabling and Emergent Materials, with IMR Director Steven Ringel as the Principal Investigator.



Image provided by  
Ken Chamberlain OSU CommTech



Dr. Cornish is an expert in alternative natural rubber production, properties and products, and on natural rubber biosynthesis in general. Her research focuses on bioemergent materials including exploitation of opportunity feedstocks from agriculture and food processing wastes for value-added products and biofuels.

Dr. Cornish will hold a joint appointment with the Department of Horticulture and Crop Science and the Department of Food, Agricultural and Biological Engineering. In her new position, Cornish will lead a multidisciplinary team in the creation of innovative industrial materials from plant-based sources and associated biological, chemical and physical processes. She will also be charged with training new scientists and engineers for the emerging global bio-based economy. She will be based on the Wooster campus of the Ohio Agricultural Research and Development Center (OARDC) - which is the research arm of CFAES and the largest university agricultural bioscience research facility in the United States.

*For more information on Dr. Cornish's research see page 6.*

## Director's Note

Dear Colleagues,



The constant progress of research in the Ohio State materials community continues to be amazing. The past few months witnessed several exciting developments captured in this issue. The first of our Ohio Research Scholar Endowed Chairs in Advanced Materials,

Professor Katrina Cornish, was hired in the area of bio-based emergent materials, in a joint position between the Departments of Food, Agricultural and Biological Engineering and Horticulture and Crop Science. Dr. Cornish's unique, multidisciplinary focus incorporates biochemistry, synthesis, material analysis and horticulture science, and is a great demonstration of the range of activities we can achieve at Ohio State. At the other end of the materials spectrum, a team led by Professor Suresh Babu has been awarded a NSF I/UCRC in the area of materials joining entitled "Center for Integrative Materials Joining Science for Energy Applications." Two IMR groups won Multidisciplinary University Research Initiative grants from the Department of Defense, one led by Professor Joseph Heremans in the area of novel thermoelectric materials, and the other as part of a multi-university team that includes Professors Siddharth Rajan, one of the recent TIE Cluster hires in Electronic and Energy Materials, and Steven A. Ringel, in the area of novel dielectric materials for power and high speed electronics.

In other notable IMR member news, Professor P. Chris Hammel and colleagues recently published their invention and application of a new type of microscope based on ferromagnetic resonance imaging (FMRI), which enables imaging and spectroscopy of magnetic components at the nanoscale. Professor Len Brillson was named an ACI Fellow by the NSF Division of Materials Research, while Professor and IMR Associate Director Malcolm Chisholm received the Nyholm Prize of the Royal Society of Chemistry, demonstrating some of the recognition being bestowed upon the exceptional successes of our materials-affiliated faculty.

On the infrastructure front, several multi-user laboratories are currently putting into place major new capabilities awarded via two NSF Major Research Instrumentation (MRI) grants and TIE funds, including a newly awarded NSF-MRI to a team led by Professor P. Chris Hammel for acquisition of a high field physical property measurement system (PPMS) with an integrated cryogenic scanning probe. As a result, the ENCOMM Nanosystems Lab is

undergoing dramatic growth with the addition of a system for diamond deposition, and a system for electron-beam evaporation and sputtering of films along with the PPMS. At the Nanotech West Lab, an optical stepper for sub-micron photolithography was installed recently, along with some new electrical property measurement equipment, and its new III-V MOCVD system was officially accepted by IMR and OSU and is now open for use.

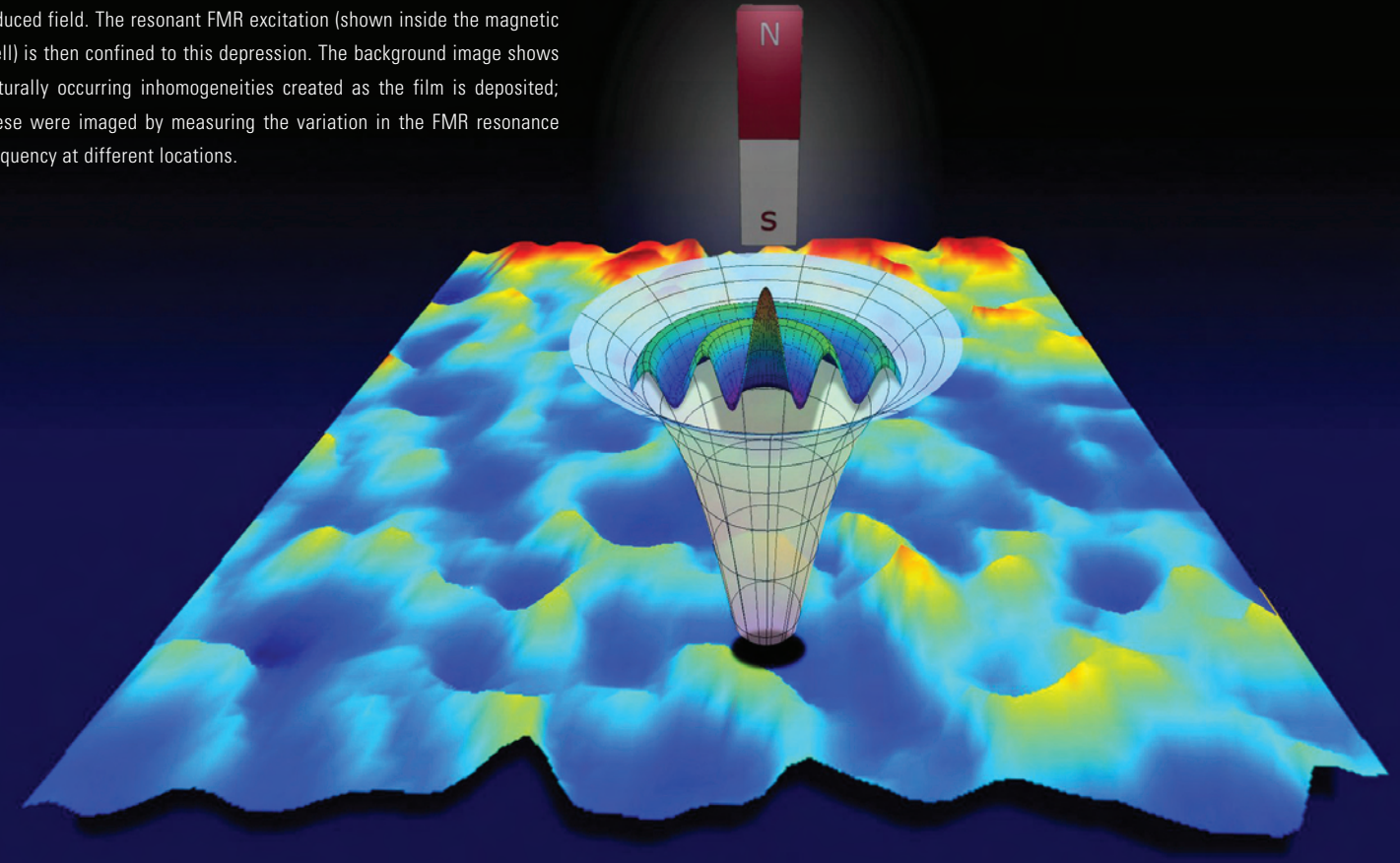
Our materials centers news updates feature the Center for Multifunctional Polymer Nanomaterials and Devices (CMPND) Wright Center, which is making great progress in its focus on public-private partnerships in the area of polymer nanotechnology, and we highlight two key efforts with private companies in this issue. The Center for Emergent Materials MRSEC announced the awarding of two Proto-IRG seed grants toward creating new IRGs in the CEM's future, and over the summer ran a very successful workshop on magnetic materials in collaboration with the Leibniz Institute for Solid State and Materials Research in Dresden, Germany. Finally, our third annual Materials Week event, held in September 2010, was a huge success, with 80 student posters showing off our best and brightest students, 10 best poster awardees presented by OSU President Gordon Gee, a total of 330 attendees, and invited presentations from a wide range of universities and industrial firms.

Inside this issue, I hope you will enjoy reading through the range of activities and accomplishments made by our great research community!

Warm Regards,

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

The figure illustrates a new method for using a tiny magnetic tip (represented by the bar magnet) mounted on a scanned microscale cantilever to confine the ferromagnetic resonance to a tiny region of a ferromagnetic film. This magnet creates a tiny magnetic field well in the ferromagnet—a region in which ferromagnetic resonance occurs at a reduced field. The resonant FMR excitation (shown inside the magnetic well) is then confined to this depression. The background image shows naturally occurring inhomogeneities created as the film is deposited; these were imaged by measuring the variation in the FMR resonance frequency at different locations.



## A New Microscope Allows a Look Inside Nanoscale Ferromagnets

The groundbreaking work of an OSU research team composed of Physics professors Chris Hammel and Fengyuan Yang, their students, and IMR Member of Technical Staff Denis Pelekhov was recently featured in the August issue of Nature. The group demonstrated a new microscope that can look inside the nanoscale ferromagnets needed for spin electronics and biomagnetic applications. This Ferromagnetic Resonance Imaging (FMRI) microscope works by scanning a highly localized magnetic resonance mode that is confined by a tiny magnetic tip. This microscope can image buried magnetic structures and distinguish various elements of complex nanoscale magnetic and magnetoelectronic devices.

Magnets provide non-volatile memory used in a variety of computing, information processing and control functions. Reducing these magnets to the nanoscale and incorporating them directly into logic and electronic devices holds the key to future improvements in functionality offering a route to entirely new approaches to computing while reducing energy

consumption. A key barrier to achieving such advances is the difficulty of imaging and characterizing nanomagnets buried in devices.

The unique ability of FMRI to see interactions and fields inside potentially buried ferromagnets and to measure their strength with spectroscopic precision heralds a powerful new tool for understanding a range of magnetic, spintronic and magnetoelectronic systems involving buried and surface nanomagnets.

For more details, the article is available online: "Nanoscale scanning probe ferromagnetic resonance imaging using localized modes," Inhee Lee, Yuri Obukhov, Gang Xiang, Adam Hauser, Fengyuan Yang, Palash Banerjee, Denis V. Pelekhov & P. Chris Hammel, Nature 466 845-848 (12 August 2010) doi:10.1038/nature09279 or <http://www.nature.com/nature/journal/v466/n7308/full/nature09279.html>

## IMR Members Win Two New MURI Awards

Two Ohio State research teams were awarded funding through this year's highly competitive Multidisciplinary University Research Initiative (MURI) program. The MURI program supports research by teams of investigators that intersect more than one traditional science and engineering discipline in order to accelerate both research progress and transition of research results to application. The Army Research Office (ARO), the Office of Naval Research (ONR) and the Air Force Office of Scientific Research (AFOSR) solicited proposals in 30 topics important to the U.S. Department of Defense. A total of 411 white papers were submitted, resulting in 32 awards announced for fiscal 2010, selected based on merit review by panels of experts.

A research team led by Ohio Eminent Scholar and OSU Mechanical and Aerospace Engineering professor Joseph Heremans was awarded one of these MURI programs. The solid state cooling research project, titled *Cryogenic Peltier Cooling*, will be conducted in collaboration with team members from five other universities in the U.S. and four overseas institutions. The goal of Heremans' MURI program is to develop small, compact all-solid-state heat pumps based on the thermoelectric or Peltier effect. While previous thermoelectric research by some of the co-principal investigators of this MURI has focused on ranges of 300K and up, this new project will seek to extend scientific progress to materials in the range of 150K down to 10K.

The research findings of Dr. Heremans and the MURI team could, among other advances, revolutionize the architecture of surveillance satellites and unmanned aerial vehicles from weight considerations. The initial call for research also noted that solid-state cooling advances could dramatically affect NASA's space needs. Small, 500kg surveillance satellites need cooling to 10K to run on-board solid-state sensors that operate over a wider range from x-ray wavelengths to the very far infrared. Thermoelectrics, for example, would revolutionize the architecture of surveillance satellites from weight and cost considerations. Solid-state cooling also can dramatically affect Department of Defense's terrestrial IR sensor programs, and NASA's and Department of Energy's space needs. Further advances in solid-state cooling will enable x-ray sensors and extremely sensitive bolometers for space situation awareness; enhance the reliability of electronic components; directly cool IR diode lasers; and increase the sensitivity and spectral range of UAV sensors.

A second MURI program - *Dielectric Enhancements for Innovative Electronics (DEFINE)* - was awarded to a team led by the University of California, Santa Barbara, along with six other universities, including an Ohio State effort led by Professors Steve Ringel, IMR Director, and Siddharth Rajan, both of the Department of Electrical and Computer Engineering. The overall focus of the DEFINE MURI is to comprehensively explore the science and technology of high-k and low-k dielectric materials on GaN-based semiconductors, with the objective of establishing a fully characterized, robust set of manufacturable and scalable dielectrics with desirable properties that would enable novel functionalities in GaN-based devices.

The approach combines experimental methods with ab initio calculations to explore interface formation, band engineering, defect science, and the chemistry and physics of engineered dielectric/III-nitride heterostructures, as they relate to controlling the electrostatics and charge states of this complex materials system. With the general problem of dielectric/III-V interfaces being a major and as-yet unanswered challenge, this project seeks to create new fundamental discoveries that impact both high speed and advanced power device technologies of the future. In this context, the primary goal of the Rajan-Ringel team is to explore ALD-deposited dielectric/GaN heterostructures and devices, focusing on the impact of polarization charge, surface orientation, dielectric composition and dielectric deposition method (ALD, MBE, MOCVD) on interface bandstructures, trap formation, and device transport properties. The OSU team will also serve as one of the two primary MBE growth sites and the primary electronic defect characterization site for the DEFINE team of investigators.

*Information from this article originally appeared in a Department of Mechanical and Aerospace Engineering publication by Nancy Speicher and on the website of the department of Electrical and Computer Engineering.*

## 2010 OSU Materials Week – Recap

Each September, IMR hosts Materials Week, an annual conference that showcases materials-allied research at The Ohio State University and beyond. In 2010, we were joined by the Center for Emergent Materials, OSU's NSF Materials Research Science and Engineering Center, in planning the conference.

This annual event brings together hundreds of researchers and covers the full spectrum of materials-allied research. 2010 OSU Materials Week was a great success and our largest conference yet, with over 330 participants representing OSU and 15 other universities, over a dozen industry collaborators, and several government labs. This year's Materials Week had a full schedule, with Plenary, Cross-Cutting, Technical, and Student Poster Sessions, including:

- Materials Science of Energy Storage
- Spintronics and Graphene
- Next Generation Photovoltaics, Advanced Characterization and Ultra-Fast Phenomena
- Materials, Entrepreneurship, and the Innovation Cycle
- Computational Materials Design
- Epitaxial Control of Novel Materials
- Biomaterials and Bio-Based Products
- Frontiers in Biomaterials

A highlight again this year was the student poster sessions, where 80 research posters were presented by OSU students and postdoctoral researchers. On Wednesday, September 15, ten award winners were announced at the Materials Week luncheon. OSU President Gordon Gee joined the group and presented plaques and Barnes and Noble gift cards to each of the ten winners, listed below. Congratulations to the ten students, their advisors, and colleagues on an excellent presentation of your research.

Joshua Askin, Materials Science and Engineering, Advisor: Wolfgang Windl  
Taeyoung Choi, Physics, Advisor: Jay Gupta  
David Daughton, Physics, Advisor: Jay Gupta  
Timothy Garcia, Mechanical and Aerospace Engineering, Advisor: Thomas Blue  
Andrew Gledhill, Material Science and Engineering, Advisor: Nitin Padture  
Qilin Gu, Electrical and Computer Engineering, Advisor: Steven Ringel  
Young Woo Jung, Physics, Advisor: P. Chris Hammel  
Rohan Mishra, Materials Science and Engineering, Advisor: Wolfgang Windl  
Digbijoy Nath, Electrical and Computer Engineering, Advisor: Siddharth Rajan  
Shreyas Rao, Chemical and Biomolecular Engineering, Advisor: Jessica Winter

This year's Materials Week student poster sessions/receptions were generously sponsored by several industry partners: Entrotech, Energy Focus, Polymer Ohio, Replex Plastics, and LakeShore Cryotronics.



## Materials Center Update: CMPND

The Center for Multifunctional Polymer Nanomaterials and Devices (CMNPD), a Wright Center of Innovation headquartered at The Ohio State University, leads a research and commercialization partnership in polymer nanotechnology. In this issue, CMPND provides a look at two of its Ohio industry partners – Lockheed Martin Mission Systems and Sensors in Akron, and Ovation Polymers Technology and Engineered Materials in Medina. Both of these CMPND updates highlight the success of private-public partnerships supported by the state of Ohio and CMPND.

### Lockheed Martin's Lighter-Than-Air Program Continues to Benefit Ohioans

The Ohio Department of Development (ODOD) recently awarded Lockheed Martin Mission Systems and Sensors in Akron a \$1 million grant for advanced materials development. The grant will support Lockheed Martin's effort to develop the next generation of lighter-than-air (LTA) vehicles for use in persistent surveillance, reconnaissance and communication applications.

Key technology advancements are required in the materials area to ensure the durability and integrity of the LTA vehicle's envelope, particularly the hull fabric. This grant is specifically directed toward establishing commercial production of light-weight, flexible film materials in Ohio that will provide the high modulus and reduced permeability required for the LTA vehicles. The superior and unique material properties will come from Ohio companies, working collaboratively with Lockheed Martin, as part of its local supply chain. As the use of LTA vehicles continue to grow, the market for the fabric will increase and create additional jobs in the state.

The project team includes Lockheed Martin, Akron Polymer Systems (APS), Chemsultants International located in Mentor, Ohio, and the University of Akron. Lockheed Martin will be the project lead and provide expertise in LTA technology. APS will provide its knowledge of condensation polymers. Chemsultants is a world leader in films and casting. UA includes experts in polymers and nanomaterials. Ohio's Center for Multifunctional Polymer Nanomaterials and Devices (CMPND) has a long history with these organizations, building collaborative relationships, assisting with grant preparation and providing leadership.

The proximity of suppliers benefits Lockheed Martin in terms of speed and communications, while providing an additional 10 near-term jobs to the northwest Ohio economy. Assuming the materials development and subsequent demonstration project is successful, Lockheed Martin's LTA development team is expected to employ an additional 120 workers by 2013. Further, the project will preserve 80 jobs in Ohio and create expanded opportunities in the state for such advanced flexible composites markets as medical packaging and instruments, space structures and inflatable ground structures.

Both the technologies and collaborations involved in the project build on a history of support and cooperation developed in earlier efforts. More specifically, this proposal is clearly an extension of groundwork put in place by collaborations with CMPND and the ODOD Research Commercialized Program (RCP) Polyimide project support. The Ohio Third Frontier Program that is funding this and other projects leverages private enterprise funds to create additional jobs for Ohioans.

### Ovation Raises Its Flag

A very special flag-raising took place in late August at Ovation Polymers Technology and Engineered Materials (OPTEM, Inc.) in Medina, Ohio, to commemorate its successes, the strong commitment to growth reflected by OPTEM staff and supporters, and to celebrate Ohio's national #1 ranking as "the place to be" for companies in the polymer industry. OPTEM, Inc.'s focus is on conductive polymeric materials, high-performance engineered polymers, and nanomaterials technology for applications in electronics/semiconductor/hard disk industry, energy sector, health science, and other Industrial sectors needing Innovative materials with extreme functional properties.

OPTEM's Board of Directors and its Chairman, Jim Petras, and the company president, Asis K. Banerjee, invited representatives of business, the State, and community groups to a morning of speaker presentations and a flag raising on August 27, 2010 to celebrate nearly six years of sustained business growth and increased employment for the Akron-Medina area of northeast Ohio. Banerjee began his introductory speech with sincere thanks to the Ohio Department of Development (ODOD) and others who lent extraordinary support to his company during the "economic tsunami" of 2008-09. During the ceremony, PolymerOhio CEO Wayne Earley said, "PolymerOhio has appreciated the opportunity to connect OPTEM to other Ohio organizations and to connect OPTEM to other Ohio organizations. We look at OPTEM not only as a growing Ohio company, but as a new Ohio resource that provide growth opportunities for other Ohio companies."

The ceremony ended with Dr. Sharell Mikesell - Co-Director of the Center for Multifunctional Polymer Nanomaterials and Devices (CMPND, a Wright Center of Innovation in Ohio) and Associate Vice President at The Ohio State University Industry Liaison Office (ILO) - raising the American flag. Medina Mayor Dennis Hanwell raised the state of Ohio flag and Bethany Dentler, Medina County Economic Development Director, raised the flag of Ovation Polymers. The invited guests had the opportunity to tour the facility and meet OPTEM staff.

From its start five years ago, OPTEM has grown to now include three dozen workers who research, develop, and produce unique polymer products that are not made elsewhere and bring reputation and respect to this operation in the Medina area. Along the way, OPTEM researchers have been responsible for 20 patent applications, six granted, including one patented material that has the highest thermal

conductivity rates in the marketplace. OPTEM products run the gamut from trays used in building computer parts to critical thermal management in LED lamps.

During the speeches, Dr. Mikesell noted that OPTEM's progress personifies innovation in Ohio. "Innovation distinguished a leader from a follower because a leader exchanges traditional thinking and focused on creating the future, doing new things, and knowing that his or her thinking might not be accepted at first. It takes repeated attempts, endless demonstrations, and monotonous rehearsals before innovation can be accepted. This takes courageous patience."



Mikesell said that in Ohio, the economic sectors of polymers, energy, and agriculture provide emerging market-driven opportunities at the intersection of these three core technologies. "Nanotechnology is a key enable for the future of Ohio's economy and such new technologies are exactly the kind of forward progress that is reflected in what OPTEM is doing."

For more information, visit Lockheed Martin at: <http://www.lockheedmartin.com/> or OPTEM's website: <http://ovationpolymers.net>

## Continued: New Ohio Research Scholar Stretches the Boundaries of Natural Rubber

The author of 145 scientific articles and patents, Cornish has also provided leadership for the development of new crop varieties, processing innovations, industrial and regulatory regulations and standards, clinical trials, and the creation of novel materials from hypoallergenic medical devices to termite-resistant building materials to biofuels. She has overseen several extramural research agreements with academia and the federal government in the United States, the European Union, Australia and southeast Asia.

Dr. Cornish worked with the US Department of Agriculture at its Western Regional Research Center in California from 1989 -2004, first as a Lead Scientist and later as the Acting Research Leader of the Crop Improvement and Utilization Unit. Prior to joining OSU, she served as the Senior Vice President of Research and Development of Yulex Corporation. Her inventions at USDA were licensed by Yulex and form the foundation of the US domestic rubber industry by commercializing rubber and other industrial products made from guayule, a plant native to the southwestern United States. At Yulex, Dr. Cornish oversaw the company's ongoing research, development, production, validation and regulatory programs for the commercialization of guayule latex for safe medical devices and specialty consumer products, including extramural programs.

"This position is vital to push the boundaries of bio-based materials research and create the interdisciplinary connections from which new scientific advances and bio-based technologies of the future can be achieved," said Steven Ringel. "Dr. Cornish's interdisciplinary background, along with her

Figure 1

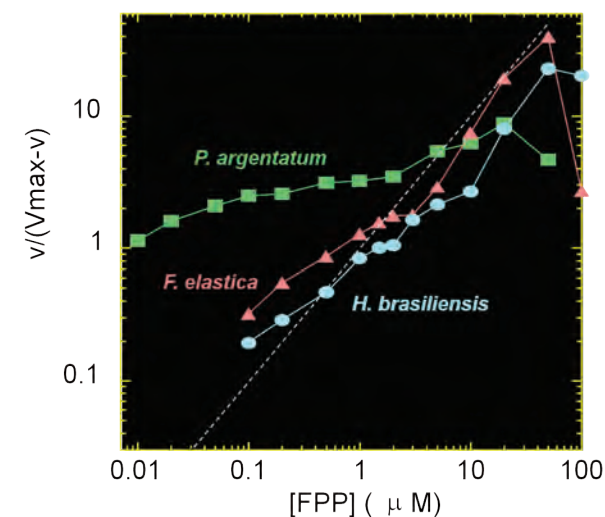
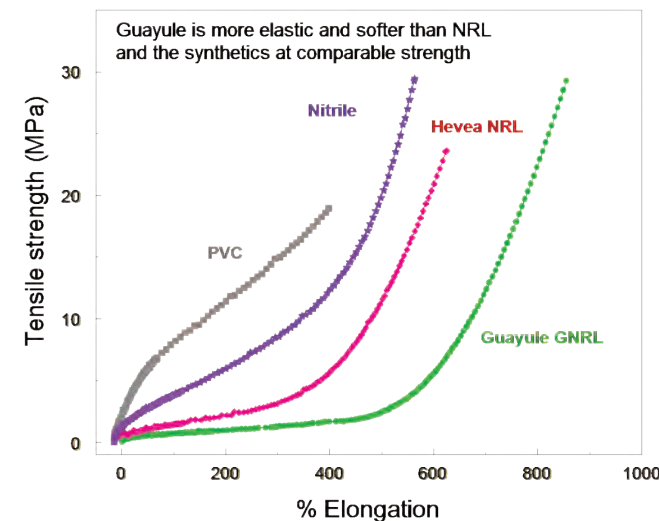


Figure 2



experience both as a world-leading scientist and successful entrepreneur, make her the ideal Ohio Research Scholar. We are looking forward to strengthening even further the connections between OARDC and OSU's main campus, as well as with the University of Akron and the University of Dayton."

### Research Highlights from Dr. Katrina Cornish

Natural rubber is a fascinating material - an elastomer unmatched by synthetic materials. We have shown that rubber is made by different plant species using essentially the same biochemical process but with species-specific differences that can be exploited commercially. For example, the rubber polymerizing enzyme in guayule (a desert shrub) is most active in the winter time, making large amounts of high quality, high molecular weight polymer. In the summertime, the rubber enzyme is a poor competitor for the monomer, which is essential for plant growth and development. However, the enzyme uniquely inhibits the rubber polymer chain transfer reaction over a wide range of initiator concentrations - so once a new molecule is initiated, it stays in the active site and slowly grows to full length (see Figure 1). Without this property, guayule would make short, poor quality polymers in the summer and not make uniformly high quality rubber. We have also found that magnesium ions, an essential cofactor, act as an activator. Rubber biosynthetic rate is very sensitive to magnesium concentration. The affinity of the enzyme for the monomer can increase up to 100X with only a 2X increase in magnesium with a concomitant increase in production rate.

Regulation of the concentrations of substrates and cofactor can produce polymers unknown in nature, such as molecular weight 50X higher than the normal high quality one million g/mol. Not only do the biochemical catalysts behave differently but the resultant rubber may perform differently indicating different market segments should be targeted (see Figure 2). Natural rubber outperforms synthetic materials, but guayule rubber is softer and stretchier than even Hevea natural rubber, making it an ideal material for gloves and balloons.

My research program is all about taking basic research to applied and then through the development and commercialization processes. We proved that guayule rubber does not contain any of the proteins involved in life-threatening Type I latex allergy and then scaled up the process. After overcoming a large number of commercialization barriers, guayule latex rubber now forms the base of the US domestic rubber industry in the south western states. We are working now to develop and commercialize rubber from the Russian Dandelion, a new crop plant for Ohio and to profitably use all parts of the plant. I am very interested in converting the inulin coproduced with the rubber into a butadiene - replacing an essential building block of petroleum-based synthetic polymers with a biobased, but identical, version.

For more information about Dr. Cornish's work, contact her at [cornish.19@osu.edu](mailto:cornish.19@osu.edu)

## OSU Wins I/UCRC Materials Joining Center

The National Science Foundation (NSF) recently awarded funding for the establishment of an Industry/University Cooperative Research Center (I/UCRC) at The Ohio State University, to be headed by Prof. Sudarsanam Suresh Babu, Associate Professor of Materials Science and Engineering. The new **I/UCRC Center for Integrative Materials Joining Science for Energy Applications** will operate in four universities - The Ohio State University, Colorado School of Mines, Lehigh University, and University of Wisconsin - and the integration of the interdisciplinary materials joining expertise from the faculty and students of these schools is crucial to the center's success. Many organizations including small businesses, non-profit organizations, government national laboratories, medium sized businesses and large-scale companies have also committed to participate in the Center and will play a crucial role in its operation.

The center was established to address the many instances where the application of new, high performance materials has been limited, or precluded by the inability to join them. A basic problem along the path from development to implementation is the lack of a structured, scientifically-based methodology for determining material "weldability." The concept of weldability occurs at the intersection of the joining process and the materials' reaction to the thermal and mechanical conditions that are imposed by the process. Considering the diverse need for materials in energy industries, it is critical to develop scientific methodologies to join these materials.

Thus, the Center for Integrative Materials Joining Science for Energy Applications was created with the following three synergistic missions:

- To close the gap between material development and weldability
- To establish scientifically-based methodologies for assessing material weldability/joinability that span the nm to mm scale
- To develop a new generation of materials joining engineers and scientists

The NSF Industry/University Cooperative Research Centers (I/UCRC) program develops long-term partnerships among industry, academia, and government. The centers are catalyzed by a small investment from the NSF and are primarily supported by industry center members, with NSF taking a supporting role in the development and evolution of the center. Each center is established to conduct research that is of interest to both the industry members and the center faculty.

Dr. Babu joined OSU faculty in October 2007 through a joint IMR-College of Engineering Cluster-Hire in Computational Aspects of Multi-scale Materials Modeling funded partially by the Targeted Investment in Excellence (TIE) program. Look for updates on this center's activities in future issues of IMR Quarterly newsletter.

For more information on the Center for Integrative Materials Joining Science for Energy Applications, contact Dr. Suresh Babu at [babu.13@osu.edu](mailto:babu.13@osu.edu) or visit the center's website at: [materialsjoining.osu.edu/](http://materialsjoining.osu.edu/)

# Facilities Updates

## ENSL News

The ENCOMM NanoSystems Laboratory will dramatically expand its research capabilities through the acquisition of three new pieces of equipment that will include a combined e-beam evaporation/sputtering system from Kurt J. Lesker, a 14 Tesla Physical Properties Measurement System (PPMS) from Quantum Design USA combined with a cryogenic Atomic Force/Magnetic Force microscope and a Diamond Chemical Vapor Deposition (CVD) System by Seki Technotron Corp. The instruments will be purchased with both external and university funds. In particular, two of the instruments have been funded by the National Science Foundation Major Research Instrumentation (NSF MRI) awards. The funds for the acquisition of the 14 T Quantum Design PPMS system have been awarded to a group of researchers lead by P. Chris Hammel with Nitin Padture, Patrick Woodward, Jessica Winter and Roberto Myers as Co-PIs. The funds for acquisition of the Diamond CVD system have been awarded to a group of researchers lead by Ezekiel Johnston-Halperin with Steven Ringel, Fengyuan Yang, Siddharth Rajan and Harris Kagan as Co-PIs. In both cases the matching funds for the NSF award have been obtained from internal OSU sources. The Kurt J. Lesker sputtering system is funded by the ENCOMM TIE funds. The primary features of the upcoming instruments are listed below.

### The Quantum Design USA 14 Tesla Physical Properties Measurement System (PPMS) with cryogenic Atomic Force/Magnetic Force microscope (AFM/MFM)

- 14 T superconducting solenoid with standard variable temperature operation of 1.9 K – 400 K
- AC Susceptibility/DC Magnetization Measurement with sensitivity of  $10^{-8}$  emu (AC);  $2.5 \times 10^{-5}$  emu (DC)
- Large bore Vibrating Sample Magnetometer (VSM) System with RMS Sensitivity of  $< 10^{-9}$  emu with 1 sec averaging and high temperature oven for variable temperature measurements in the range of 1.9 K – 1100 K
- AC/DC Transport Property Measurement System for measuring AC/DC Resistivity, Hall Effect, I-V Curve Tracing, and Critical Current
- Torque Magnetometry capability for measuring moments of very small anisotropic samples
- Sample rotation relative to magnetic field with a Horizontal Sample Rotator with a computer controlled stepper motor
- Reduced liquid helium consumption with PPMS External Helium Reliquefier System

- Cryogenic Atomic Force/Magnetic Force microscope (AFM/MFM) by ION-TOF USA, Inc. compatible with 14 T magnetic field and 2.8 K – 400 K temperature range operation. Microscope resolution at low temperature is 0.23 nm (lateral), 0.031 nm (vertical) and 15 nm in MFM mode

### The Seki Technotron Corp. AX5200M 1.5kW Microwave-Plasma Enhanced-Chemical Vapor Deposition system

- State-of-the-art deposition tool for synthesizing high quality polycrystalline and single crystal diamond films for research and production
- Process gases: H<sub>2</sub>, CH<sub>4</sub>, O<sub>2</sub> and N<sub>2</sub>

### The Kurt J. Lesker Co. Lab 18 Thin Film Deposition system

- Three 3" sputtering sources and one 6-pocket e-beam evaporator in the same deposition chamber
- RF and DC sputtering capabilities
- 2 process gases: Argon and Oxygen
- Substrate cleaning with RF plasma
- Sample substrate heating up to 1100° C during deposition
- Optimization for sputter deposition of magnetic metals and/or oxides followed by coating with a precious metal (gold, platinum) using e-beam deposition
- Rapid turn-around operation with a load lock
- Aggressive substrate cleaning and sample ion milling with a collimated Kauffman & Robinson KDC-40 ion source installed in the load lock



Seki Technotron Corp. AX5200M 1.5kW Microwave-Plasma Enhanced-Chemical Vapor Deposition system

## New Tools at Nanotech West Lab

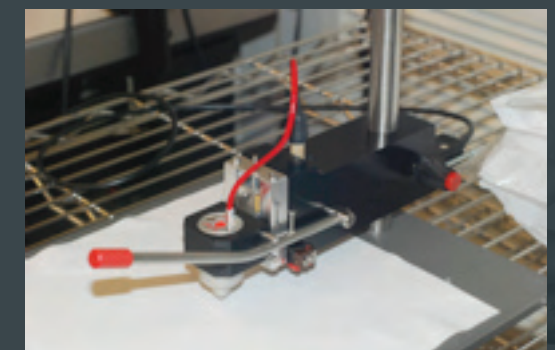
During October 2010, Nanotech West Lab finished the installation of a new **CHA SOLUTION™ System electron gun evaporator** which is located in Bay 4 of the class 100 cleanroom (first announced in the Spring/Summer 2010 issue of *IMR Quarterly*). The new e-gun evaporator features a six-pocket hearth and a programmable Inficon IC/5 deposition controller which will allow the semi-automatic deposition, with rate control, of a wide variety of materials. The system is pumped by a cryopump with auto-regeneration capability and has a base vacuum pressure in the upper-10-08 Torr range. The tool, designated EVP03, will have improved uptime, faster pumpdown rates, perform cleaner depositions, and will be easier to use than other evaporators at Nanotech West. Training for users will begin in late October. The purchase was funded by the Wright Center for Photovoltaics Innovation and Commercialization (PVIC), in turn funded by the Ohio Department of Development through the Third Frontier Program.

Also, during October, Nanotech West Lab received a **Jandel® four-point probe measurement system** consisting of a Jandel® Multiheight probe (MHP) and RM3-AR autoranging electronics unit. The instrument will be very useful in characterizing the sheet and bulk electrical resistivity of a wide variety of materials for application in photovoltaics, electronics, and materials science. This acquisition was also funded by PVIC.

Two major capital installations at Nanotech West also passed significant milestones in October. The **Aixtron® 3x2" close-coupled showerhead metalorganic chemical vapor deposition (MOCVD)** tool finished acceptance and signoff and started its first user growth runs. An antimonide source for the tool was ordered in September and will complement the In, Ga, As, Al, and P sources by late 2010. Also, the **GCA 6300-series i-line optical stepper**, donated to OSU by the Air Force Research Laboratory Sensors Directorate, finished installation in Bay 2; with operation and maintenance training completed in October by the install vendor. The system, which is capable of photolithography down to ~0.70 microns, will likely be available to users at the very beginning of November. More news on this tool will be available in a future issue of *IMR Quarterly*.



Nanotech West Lab staff member Paul Steffen and the new 6 pocket CHA SOLUTION™ System electron gun evaporation system in Bay 4 of the cleanroom.



Jandel® multiheight probe four point probe head.

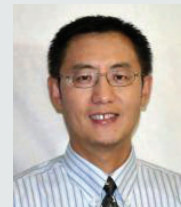
## IMR Member News



**Bharat Bhushan**, Ohio Eminent Scholar and the Howard D. Winbigler Professor in the Department of Mechanical and Aerospace Engineering, was awarded a National Science Foundation grant of \$300,000 in support of the project entitled "Mechanically Reliable Surfaces for Superhydrophobicity." Professor Bhushan also authored the article, titled, "Biomimetics -- Turning Nature's Successes into Gold" which appeared in the August 2010 issue of NANO Magazine. The article appears on page 20 of the printed publication, but is also available for online viewing. Go to: <http://www.nanomagazine.co.uk> and search the title of the article.



**Len Brillson**, Professor in the department of Electric and Computer Engineering, has been selected as a American Competitiveness and innovation (ACI) Fellow for 2010 by the NSF Division of Materials Research. An ACI Fellowship citation states that Brillson was selected "for establishing the optical signature of a leading defect in ZnO, opening the way to monitor and study processes that promote p-type conductivity, a major current objective in semiconductor optoelectronics. He is also recognized for his outstanding efforts in student mentoring and broadening participation of underrepresented groups in science" He was also recognized for his outstanding efforts in student mentoring and broadening participation of underrepresented groups in science by creating research opportunities for high school girls.



**Lei (Raymond) Cao**, Assistant Professor in the Department of Mechanical and Aerospace Engineering has received funding through a three-year, \$450,000 faculty development grant from the U.S. Nuclear Regulatory Commission received by OSU's Nuclear Engineering Program. Ohio State will also provide matching funds of \$150,000 over a three-year period. This award will be used to assist Cao in integrating his innovative research into the core competitiveness of the OSU Nuclear Engineering Program in advanced instrumentation, control, and reactor safety. It will also benefit the OSU Research Reactor since the new research program to be developed will involve more utilization of the reactor to strengthen nuclear engineering research and education. The objectives of his research are to develop novel radiation detectors for meeting safeguard mission requirements for both nuclear safety and the control of nuclear materials in fuel cycles which are critical in meeting domestic and global energy needs.



**Malcolm Chisholm**, Distinguished University Professor, and Chemistry Department Chair has been selected to receive the Nyholm Prize of the Royal Society of Chemistry. The prize is awarded every two years to an inorganic chemist and consists of a medal, certificate and £5000 which will be presented at an awards dinner on November 12th, at the Birmingham Hilton Metropole Hotel, UK.



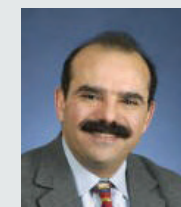
**Terrence Conlisk Jr.**, Professor in the Department of Mechanical and Aerospace Engineering, along with Georgia Tech Professor Minami Yoda, have awarded \$429,000 grant by the Army Research Office for a research project titled "Transport of Multivalent Mixtures in Micro- and Nanochannels." The objective of the research is to learn how to control complex fluid mixtures like contaminated water or saliva for separating out desired components.



**Prabir K Dutta**, Professor of Chemistry, received the highest faculty honor of being named a Distinguished University professor. Recipients will receive a one time cash award of \$30,000 from the Office of Academic Affairs to support their academic work and will become members of the President's and Provost's Advisory Council.



**P. Chris Hammel** of Physics, **Roberto Myers** of Materials Science and Engineering, **Denis Pelekhov** of Physics and IMR, **Jessica Winter** of Chemical and Biomolecular Engineering, **Patrick Woodward** of Chemistry, and **Nitin Padture** of Materials Science and Engineering as co- PIs have just received a NSF grant of \$504,129 towards "Acquisition of a High Field Physical Properties Measurement System with Cryogenic AFM/MFM." Hammel is the principal investigator on this NSF grant. OSU provides a cost share of \$216,055 through cash contributions from the Office of Research, College of Arts & Sciences, College of Engineering, and departments of Chemistry, Chem. & Biomol. Engr., Mater. Sci. & Engr., and Physics. This \$720,184 facility, which will be housed in the ENCOMM NanoSystems Laboratory, will enhance greatly OSU's materials research capabilities in the broad area of magnetoelectronics. See the NSF website for details: <http://www.nsf.gov/awardsearch/showAward.do?AwardNumber=1040296>



**John Volakis**, Professor and Director of the ElectroScience Laboratory received the 2010 Clara M. and Peter L. Scott Faculty Award. This is the highest honor given out by the College of Engineering to a faculty member. This award is given based on excellence in teaching and the qualitative aspects of teaching with emphasis on effective innovation, and for outstanding fundamental or applied research contributions (in scope and/or originality) in one or more areas of endeavor.

# Materials Center Update: CEM

## CEM Awards Two Proto-IRG Seed Grants

In early 2010 the Center for Emergent Materials (CEM) revised the mission of the Seed Funding Program from funding small single investigator projects to team projects aimed at nucleating future IRGs (Interdisciplinary Research Groups). With this strategic redesign, and additional resources committed from the Institute for Materials Research (IMR) and the Center for Electronic/Magnetic Nanoscale Composite Multifunctional Materials (ENCOMM), CEM released a call last April for Proto-IRG Seed Funding Proposals (see IMR Quarterly Winter 2010 issue for more information).

The CEM is currently comprised of two IRGs. The idea behind incubating Proto-IRGs at this stage is to stimulate interdisciplinary research with the potential to develop into full-scale IRGs at the time of the CEM's renewal proposal to NSF (2013). Ultimately, the CEM will hold an internal open competition to downselect a total of 4 to 5 IRGs that will form the renewal proposal of the CEM.

Two proposals were awarded CEM Proto-IRG Seed Funding with a total investment of \$200,000 in direct costs over twelve months. Below are the abstracts describing these two new research initiatives.

### “Thermal Spintronics: Engineering Spin Currents and Dissipation”

PI: Roberto Myers, Dept. of Materials Science and Engineering

Co-PI: Joseph Heremans, Dept of Mechanical and Aerospace Engineering

Co-PI: Ezekiel Johnston-Halperin, Dept of Physics

Thermal spintronics is a relatively new area that brings together the research fields of thermal transport and spintronics. Myers' Proto-IRG group will develop new tools for thermal spintronics to address the most challenging and timely issues related to spin currents and spin injection in semiconductors. This work is largely stimulated by the recent measurement at Ohio State of the spin-Seebeck effect in a semiconductor [Ref. Jaworski et al., Nature Materials 2010]. Briefly, when a thermal gradient was applied to a piece of magnetically doped GaAs, Myers and Heremans observed a redistribution of electron spins. This property stems from a conversion of thermal energy into a distribution of spins, and can provide a thermal means of transferring spins between magnetic and non-magnetic materials. Following from this effect, the proto-IRG team will tackle a new set of materials and measurements involving the conversion of the spin to temperature, or vice versa. One idea is to use high sensitivity free-standing membrane based calorimeters to search for and measure temperature changes (heating or cooling) associated with spin injection and spin currents. Another area involves development of new materials, magnetically doped wide band gap semiconductors, to generate spin currents.

### “Magnetic Resonance Studies of Chromatin Structure and Dynamics”

PI: Michael Poirier, Dept. of Physics

Co-PI: Christopher Jaroniec, Dept of Chemistry

Co-PI: P. Christopher Hammel, Dept. of Physics

The human genome contains about 1 meter of DNA that is compacted by hundreds of millions of protein molecules into less than a 10 nm diameter sphere, the cell nucleus. This genome compaction results in a DNA-protein polymer fiber called chromatin, whose structural and dynamical material properties are directly linked to genome expression, replication and repair. However, the mechanisms by which chromatin material properties control gene expression and replication and facilitate DNA repair are unknown. Poirier's group proposes to determine the structural and dynamical material properties of chromatin with ensemble and single molecule magnetic resonance measurements. This project will provide a foundation for understanding the influence of our genome material properties on its expression, replication and repair.

## Novel Magnetic Materials Workshop in Dresden, Germany



The CEM and the Leibniz Institute for Solid State and Materials Research (IFW Dresden) co-hosted a 3-day workshop to advance promising research partnerships. The CEM delegation included 12 faculty, 10 graduate students, and 1 post doctoral researcher, and the group traveled to Dresden for three days of talks, facility tours, social activities, and a joint poster session. An estimated 75 individuals attended the sessions that included 17 individual presentations and 40 posters. A follow-up visit bringing IFW participants to Ohio is being considered for 2011.



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