Volume 5 Issue 2 Spring 2013

Innovations in Materials Research

Newsletter of the OSU Institute for Materials Research

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Innovations in Biomaterials: Identifying Misconceptions about Antibody Structure

Stephen C. Lee, Associate Professor of Biomedical Engineering, and his colleagues have overturned a long-held belief in the senor community regarding antibody properties, that immunoHFET/FET biosensors could not be used in physiological environments. This research finding was seeded by IMR funding and eventually led to NSF support, several publications, and the founding of a new company. In collaboration with Professors Wu Lu and Len Brillson from Electrical and Computer Engineering and Professor Gregg Hadley of the School of Biological Sciences' Department of Microbial Infection and Immunity, the Lee group engineers biomolecules (proteins, nucleic acids) for incorporation into devices. Previous work includes the development of novel protein engineering techniques (affinity selection of circularly permuted proteins), bioconjugation chemistries, molecular cloning systems (bacmid, marketed by Gibco-BRL) and biochemically targeted (via annexin V) delivery of contrast agents to sites of cardiovascular disease.

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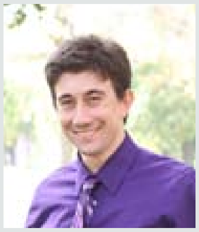
Faculty Spotlight: Josh Goldberger, Chemistry



Josh Goldberger is in his third year as an Assistant Professor in the department of Chemistry and Biochemistry at The Ohio State University. He originally received his B.S. in Chemistry from OSU before earning his Ph.D. at University of California, Berkeley as an NSF Graduate Fellow and conducting research at Northwestern University as an NIH-NRSA postdoctoral fellow. Dr. Goldberger has received many awards throughout his career including an MRS Graduate Student Finalist Award in 2003, and an IUPAC Prize for Young Chemists in 2007.

The major focus of Dr. Goldberger's materials chemistry lab is to design new materials that synergistically unite and organize inorganic and organic chemistry for applications in energy conversion and medicine. The research lab is multidisciplinary, combining synthetic organic, inorganic, and solid-state chemistry techniques, with insight and property measurements from the condensed-matter physics, materials science, and biomedical communities. Similar to how carbon can be sculpted into low-dimensional allotropes such as fullerenes, nanotubes, and graphene, one of the major premises of his research program is that the framework connectivity of atoms for any crystalline or molecular solid can be constrained along specific axes to produce stable single-atom, -polyhedron, or -molecule thick dimensionally-reduced derivatives with fundamentally different properties. Such materials would have a cross-cutting impact, and the Goldberger group is investigating materials for use in optoelectronic, thermoelectric, and medical diagnostic applications.

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IMR Institute for Materials Research

THE OHIO STATE UNIVERSITY

Director's Note

Dear Colleagues,

With the changing landscape of research funding, the need to make true innovations happen has rarely been more obvious. Fortunately, Ohio State's materials research community is poised to meet this challenge, given the extraordinary breadth and depth of our research activities and outstanding industry connections. Moving basic discoveries up through the technology development chain toward industrial impact and commercial realization in areas critical to advance society will be even more essential in the future, and The Ohio State University Institute for Materials Research and its members have been doing just that. We've highlighted several important successes by our faculty members, students and staff in this newsletter, further evidence of OSU's strength in materials.

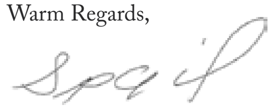
In this issue of *Innovations in Materials Research*, we are featuring innovations in the biomaterials and biosensing area led by Professor Stephen Lee in Biomedical Engineering with a team of professors in Electrical and Computer Engineering. Their development of what Prof. Lee calls an immunoHFET that is based on a gallium nitride transistor, was seeded by an IMR Interdisciplinary Materials Research Grant (IMRG) in 2007, leading to seminal papers being published, attraction of significant federal funding and ultimately the creation of a startup company to commercialize these innovative devices. Impactful innovation is hard work and done from the bottom up, and we are extremely proud of this interdisciplinary team and their success. We also feature Professor Josh Goldberger in this issue, who is working to advance the field of materials chemistry targeting energy and medical applications. Professor Goldberger, who joined OSU only three years ago, has made important advances in the synthesis of 2-dimensional materials for future energy applications, and both 0- and 1-dimenstional biocompatible materials targeting future medical diagnostics and therapies. These two examples alone already demonstrate the kind of breadth we are fortunate to have in our research community.

Of course, there are other great examples of innovators in this issue of the IMR newsletter – Professor Jessica Winters was named the 2012 Inventor of the Year by Tech Columbus at its annual Innovation Awards dinner, while Professor Joseph Heremans was elected to the National Academy of Engineering for his work on energy transfer and conversion devices that are applied in automobiles. And innovation is not just limited to research - our NSF-supported Nanoscale Science and Engineering Center launched an amazing web-based educational project through a collaboration with Edheads that, in the past year, has involved more than half a million viewers of all ages who have participated in educational activities related to nanotechnology and biotechnology.

We also share a number of other exciting announcements, including brief introductions of four new IMR members, the announcement of an internal postdoctoral fellowship program being sponsored by the Center for Exploration of Novel Complex Materials (ENCOMM), member highlights, updates to our core research facilities, and other newsworthy items and events too lengthy to list in this space!

Last but definitely not least, please mark your calendars for the 2013 OSU Materials Week conference and associated events, to be held May 7-10, 2013 with a special kickoff event during the afternoon of May 7 at the brand new Center for Electron Microscopy and Analysis (CEMAS), the newest major core facility within IMR jointly supported by the College of Engineering. I hope to see as many of you as possible at this important event. More information is inside this issue.

Warm Regards,



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

2013 OSU Materials Week – Mark Your Calendars!

Mark your calendars! 2013 OSU Materials Week is coming May 7 – 10, 2013!

This year's conference will kick off on **Tuesday, May 7** on West Campus with our first annual **IMR Keynote Address**, given by Stephen J. Pennycook of Oak Ridge National Laboratory, and a welcome reception at the new Center for Electron Microscopy and Analysis (CEMAS). Opening remarks start at 3:00 PM with Dr. Pennycook's presentation beginning at 3:45 PM.

Materials Week General Sessions run **Wednesday, May 8th - Friday, May 10th** at the Ohio Union on Ohio State's Columbus campus, including two cross-cutting sessions, six focus sessions, and two evening student poster session receptions. Highlighted schedule below:

Wednesday, May 8th

- Cross-cutting Session on **Microscopy**, featuring a presentation by Emmanuelle A. Marquis, University of Michigan.
- **Nano-engineering of hybrid materials** (external speakers include Chengde Mao, Purdue University, and Donald Leo, Virginia Tech.)
- **Nanoscale oxide and nitride optoelectronics and electronics** (external speakers include Jeremy Levy, University of Pittsburgh and Andy Armstrong, Sandia National Laboratories)
- Student Poster Session/Reception

Thursday, May 9th

- Cross-cutting Session on **Integrated Computational Materials Engineering**
- **Materials Design and Catalysis** (external speakers include Jeff Miller, Argonne National Laboratory and Krishna Rajan, Iowa State University)
- **Nano-Engineering and Nano-Fluidics for Sequencing Technology** (external speakers include Walter Reisner, McGill University and Paul Bohn, University of Notre Dame)
- Student Poster Session/Reception

Friday, May 10th

- **New Physics and Device Applications in 2D materials** (with Dr. Jie Shan, Case Western Reserve University)
- **Spin-Lattice Interactions** (featuring Burkard Hillebrands, Technische Universität Kaiserslautern)

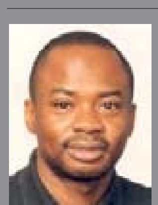
For registration information and a complete list of all activities and speakers, visit IMR's website at imr.osu.edu

About OSU Materials Week

Since 2008, the annual OSU Materials Week conference has showcased materials-allied research at The Ohio State University and beyond, including plenary, technical, and poster sessions covering the broad spectrum of materials topics, from graphene to devices to bio-inspired materials. This event is hosted annually by the Ohio State University **Institute for Materials Research**, the gateway to materials-allied research at OSU, and the **Center for Emergent Materials**, OSU's NSF Materials Research Science and Engineering Center (MRSEC). Our last conference welcomed about 450 materials researchers including OSU faculty, staff, and students and representatives from 13 other universities, 36 industry collaborators, and national labs and state entities, and featured 42 presentations by international authorities on Carbon-Based Materials and Biological Materials: From the Nano to Macro Scale, 2-D Materials Beyond Graphene, Materials Design and Catalysis, Thermal Spintronics, and Terahertz (THz) Materials. The technical programs for all past Materials Week conferences can be found on IMR's webpage at: http://imr.osu.edu/seminarsandevents/materials-week/

Welcome New IMR Members

This semester we welcome four new members to the OSU Institute for Materials Research. They include faculty new to The Ohio State University, and those who have been with the university for some time but have newly joined IMR. Below is a brief description of the areas of focus of their research.



Thaddeus Ezeji is an Assistant Professor of Animal Sciences and Ohio State Agricultural and Development Center (OARDC) in the College of Food, Agricultural, and Environmental Sciences. Dr. Ezeji's research focuses on the pretreatment of lignocellulosic biomass and conversion into biofuels and chemicals, the development of superior microbial strains for efficient metabolism of lignocellulosic hydrolysates, and the design of advanced fermentation systems. Additionally, Dr. Ezeji's laboratory conducts research activities on probiotics, metabolomics, genetic and metabolic engineering of solventogenic (butanologenic) Clostridium species. In collaboration with several faculty, Dr. Ezeji is involved in outreach programs that address emerging issues from Ohio's expanding bioenergy sector. He was previously a post doctoral researcher and Research Assistant Professor at the University of Illinois, Urbana-Champaign.

Lisa Hall is an Assistant Professor and holds the HC Slip Slider Professorship in the department of Chemical and Biomolecular Engineering. Her research applies statistical mechanical theory and molecular dynamics (MD) simulations to investigate structural, thermodynamic, and dynamic phenomena in soft materials. A focus is polymeric systems containing ions or nanoparticles in which the interactions and structure on the monomer to polymer radius of gyration scales are of great importance in determining the overall macroscopic behavior of the material.

Prasad Mokashi is an Assistant Professor in the department of Mechanical and Aerospace Engineering. His research interests are in computational solid mechanics including boundary element and finite element methods, interface problems, fracture mechanics, contact mechanics, wave motion, and nonlinear dynamics. Dr. Mokashi was awarded the 2008 and 2012 Charles Ellison MacQuigg Award for Outstanding Teaching from OSU's College of Engineering.

Vicki Wysocki, Ohio Eminent Scholar in Macromolecular Structure and Function and Professor in the department of Chemistry and Biochemistry, joined OSU in August 2012. Dr. Wysocki now directs the Campus Chemical Instrumentation Center, which provides state-of-the-art research facilities for the entire campus in three areas: Nuclear magnetic resonance, mass spectrometry and proteomics. Dr. Wysocki was professor and chair of the Department of Chemistry and Biochemistry at the University of Arizona. Her research specializes in finding new ways to study molecules that are critical to health and medicine, and her work is separated into three broad areas: (1) determination of peptide dissociation mechanisms as a means for improving programs used for automated sequencing of peptides and proteins, (2) biomarker discovery for foreign organism detection, and disease diagnosis using proteomics methods, and (3) implementation of surface-induced dissociation onto commercial time-of-flight instruments.

Innovations in Biomaterials: Identifying Misconceptions about Antibody Structure

(continued from page 1)

In 2007, the team received one of the first Interdisciplinary Materials Research Grant (IMRG) awards from the OSU Institute for Materials Research. IMRG grants were established to provide seed funding to support pioneering interdisciplinary research in materials-allied fields with the goal of generating highly competitive external grant proposals that target large, multi-investigator and center-level opportunities, and these internal awards are now incorporated into the broader OSU Materials Research Seed Grant Program. The project, titled "Interfacial engineering and scaling of hybrid biological-electrical biosensing architectures based on wide-bandgap semiconductor GaN," received IMR seed support for two years, and led to NSF support for development of immunoHFET biosensors for use in vivo.

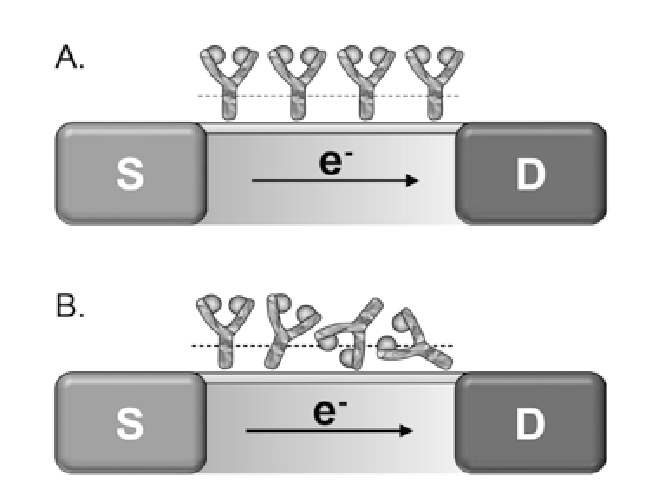


Figure 1. A) Antibodies (Y shapes) on immunoFET surface as depicted in classical representation [1-3]. Antibodies are attached to HFET surfaces via a polymeric linker (not shown) and analyte (circle) bound to antibody. Approximate Debye length position indicated by dashed line. Note uniform orientation of antibody molecules on immunoFET surface assumed in classical analysis, with antigen binding domains uniformly pointing 180° away from the sensing surface. B) A more realistic depiction of antibody alignment on an immunoFET. Note lack of consistent orientation of antibodies relative to FET surface, resulting in a distribution of proximities between bound analytes and sensor surface.

ImmunoHFET biosensors for use in physiological environments had previously been considered by biosensor experts to be fundamentally infeasible; however, this research team showed that that classical assessment was not valid, allowing them to file intellectual property applications and found a company (Sensetronics, LLC) to commercialize immunoHFET technology in medicine. Dr. Lee shares the following description of the research and its evolution over the last few years:

From our immunology expertise, we knew the classical assessment of immunoHFET/immunoFET feasibility depended on misconceptions regarding antibody biochemistry and structural dynamics. Antibody structure/dynamics properties (that differ dramatically from those assumed the classical assessment of immunoHFET/FETs) have been known for years and are universally accepted in immunology as canonical antibody properties. Moreover, these actual properties of antibodies invalidate the classical immunoFET/HFET infeasibility assessment and render immunoFET/HFETs eminently feasible protein sensing platforms.

ImmunoFET/HFETs thus represent a conveniently tunable sensing technology that can utilize any of an almost infinite diversity of distinct affinity elements to detect a similar diversity of distinct protein analytes. Sensing signals reflect net charges of analytes, providing differential signals for positively and negatively charged proteins, and, further, signal can be related to protein concentration. We are investigating modifications of the technology to allow detection of individual protein domains. If successful, this approach could lead to immunoFET/HFET-based protein structural analysis.

We have successfully detected by immunoHFET proteins over a wide range of masses and have detected both net negative and positively charged molecules. We can discriminate modified and unmodified proteins (gycosilated/unglycosilated proteins, lipid substituted/unsubstituted, unbiotinylated/ biotinylated proteins, etc.)

In principle, almost all polypeptides should be detectable by immunoHFET.

We have founded a company to commercialize immunoHFETs, Sensetronics, LLC. Sensetronics immunoFET technology is applicable to any circumstance in which protein-specific assays are required. Though current applications are in transplant biology, applications are feasible in any disease state (infectious, metabolic, etc.) wherein there is an antibody or other affinity element directed to a diagnostic protein.

Stephen C. Lee has been faculty member at The Ohio State University since 2001, and was one of the founding faculty members of OSU's Biomedical Engineering department, where he is currently an Associate Professor. Dr. Lee was educated at St. Ambrose College, the University Of Minnesota Department Of Microbiology (PhD, 1984) and the Department Of Genetics at Stanford University. For more information about Stephen Lee's research, visit http://engineering.osu.edu/content/stephen-lee

Figures in this article are from the publication: Patricia Casal, Xuejin Wen, Samit Gupta, Theodore Nicholson, Andrew Theiss, Yuji Wang, Leonard Brillson, Wu Lu, and Stephen C. Lee. 2012. ImmunoHFET feasibility in physiological salt environments. Journal of the Royal Society A 370: 2474-2488. doi:10.1098/rsta2011.0503,.

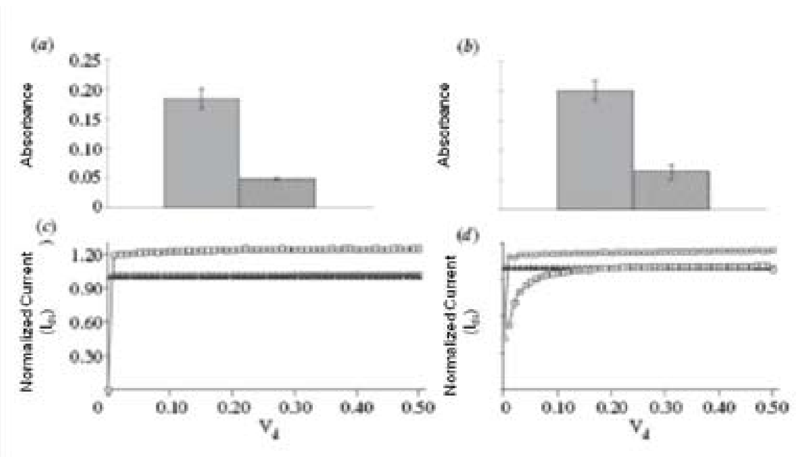


Figure 2. Specific detection of hu- (human) and mu- (murine) MIG by ELISA (A, B) and immunoHFET (C, D). ELISA was used to demonstrate selectivity of antibodies to huMIG and muMIG, respectively. Reactivities of (A) anti-hu MIG antibodies with huMIG and (B) anti-mu MIG antibodies with muMIG In ELISA are shown by gray bars. Reactivities of (A) anti-hu MIG with muMIG and (B) anti-mu MIG with huMIG are shown by cross-hatched bars. Responses of immunoHFETs with (C) antibodies to huMIG and (D) antibodies to muMIG decorating their respective sensing channels to PBS (solid triangle), PBS with 5 mg/ml huMIG (open square) and PBS with 5 mg/ml muMIG (open circle). Current changes associated with species matched MIG treatment reproduced within 10% (n=3).

ENCOMM Update: ENCOMM Evolves with Name Change, New Postdoctoral Fellowship Program and Associate Director

ENCOMM (the Center for Electronic & Magnetic Nanoscale Composite Multifunctional Materials) has officially changed its name to more accurately reflect our evolving community. ENCOMM is now the **Center for Exploration of Novel Complex Materials**.

The center recently initiated a new program to recruit top-quality young scientists to Ohio State, the ENCOMM Postdoctoral Fellowship. The 2013 ENCOMM Postdoctoral Fellowship was announced in early 2013 with an application deadline of March 1. The ideal candidate for the ENCOMM Postdoctoral Fellowship Program will display superb ability in materials research, show definite promise of becoming an outstanding leader in their field, and will be selected based on their research and academic accomplishments and the strength of their research proposal. The position provides a salary of $50,000 per year for up to 2 years, along with benefits and $20,000 in research funds, and the Post-doc will have as a research supervisor an OSU faculty member who is also an ENCOMM affiliate.

Finally, ENCOMM is pleased to announce the appointment of Prof. Roland Kawakami as the center's Associate Director. Dr. Kawakami joins the department of Physics this Fall, a move from University of California Riverside where he was an Associate Professor of Physics and Astronomy. His research focuses on spin in graphene, multifunctional oxide heterostructures and nanoscale magnetism, and semiconductor spintronics. Dr. Kawakami has an ongoing affiliation with Ohio State as an active member of the Center for Emergent Materials, the NSF Materials Research Science and Engineering Center (MRSEC) at OSU. Dr. Kawakami is a member of CEM's Interdisciplinary Research Group 1, "Towards Spin-Preserving, Heterogeneous Spin Networks." He has also been a speaker at past OSU Materials Week conferences, and was the guest presenter at January's Science Sunday Talk, an OSU forum to connect the public with scientists and recent developments in their fields.

For more information about ENCOMM, visit www.encomm.osu.edu or contact ENCOMM Program Assistant Amanda Zuurdeeg at zuurdeeg.@osu.edu.

Faculty Spotlight: Josh Goldberger, Chemistry

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Some materials that are under active investigation in the Golderberger lab include:

Si/Ge Graphane analogues

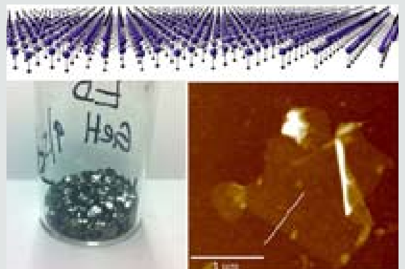


Figure 1. (Top) Atomic model of a single layer of germanane (GeH). (Bottom left) gram scale quantities of germanane. (Bottom Right) AFM image depicting an exfoliated GeH flake.

Silicon and germanium are the most technologically significant and ubiquitous electronic materials of our time. Recently the Goldberger group has created germanane, a hydrogen-terminated, two-dimensional germanium analogue of graphene. Germanane has a direct 1.6 eV band gap and is air stable (Figure 1). The terminal hydrogen can be substituted with other ligands to tailor the electronic structure, as well as enable high-specificity sensing applications. Converting Si and Ge into semiconductors with a direct and tunable gap would enable Si/Ge photovoltaics with significantly reduced active layer thicknesses and costs, and unlock previously unrealized applications such as light-emitting diodes, and lasing.

Dimensionally-Reduced Metal Chalcogenides

Layered metal chalcogenides are some of the most well-studied classes of 2D materials in the condensed matter research community due to the wealth of interesting phenomena and applications including charge density waves, superconductors, topological insulators, thermoelectrics, and battery materials. We have successful created TiS_2 (ethylenediamine), a one-dimensional derivative that is comprised of zigzag chains of edge sharing Ti–S octahedra, the first such dimensionally-reduced

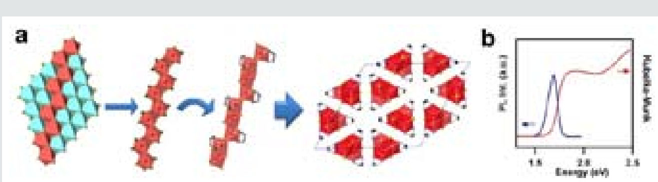


Figure 2. a) Dimensional reduction of a single layer of TiS_2 (left), in which a 1D chain of edge-sharing octahedra is extracted, the outer S atoms are replaced with a ligand to create TiS_2(etheylenediamine), which has a new crystal structure (right). b) Photoluminescence (blue) and absorbance (red) of TiS_2(ethylenediamine).

hybrid of this structure type (Figure 2). We have recently found that the band gap can be readily manipulated 1.2-1.7 eV using different anions and ligands. Furthermore, the 1D nature enables Li intercalation between the chains, yielding intriguing electronic and magnetic behavior.

Stimuli-Responsive Self-assembling 0D/1D Peptides

Creating biocompatible, self-assembling materials that reversibly transform in vivo into larger, more slowly diffusing objects in response to a specific physiological stimulus would serve as a novel mechanism for significantly enhancing the local concentration of diagnostic and therapeutic agents for specific diseases. For cancer, one such stimulus is pH as the extracellular vasculature of tumor tissue is slightly more acidic (pH=6.6-7.4) due to the enhanced glycolytic metabolism. We have developed a new class of self-assembling MRI-labelled peptide amphiphiles that transform from 0D spherical micelles into 1D nanofibers in this more acidic environment, and have established the design principles for fine-tuning the transition pH. Further efforts on this system with Dr. Michael Tweedle, Professor of Radiology, and other collaborators in the OSU Medical School are expected to lead to the first generation of pan-cancer pH-targeting MRI agents (Figure 3).

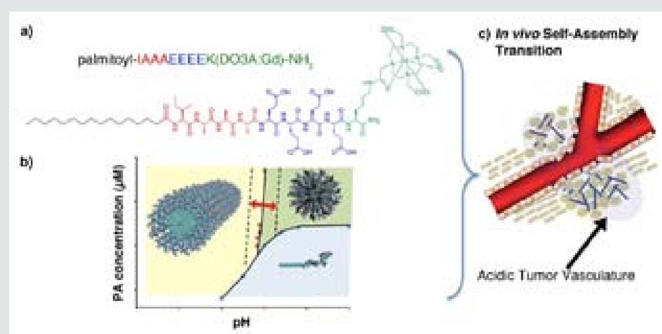


Figure 3. a) Peptide amphiphile structure. b) Concentration-pH self-assembly phase diagrams. c) Triggered self-assembly of drug delivery or imaging agent in acidic tumor tissue as an example application.

For more details on Dr. Goldberger's research and a list of publications go to: https://research.chemistry.ohio-state.edu/goldberger

NSF's Grant Proposal Guide Updates Impact All NSF Proposals

Effective **January 14, 2013**, the National Science Foundation has updated its *Proposal & Award Policies and Procedures Guide* (PAPPG), (NSF 13-1), which includes the *Grant Proposal Guide* (GPG) and the *Award & Administration Guide* (AAG). Changes include revisions to the merit review criteria based on recommendations of the National Science Board's report, "National Science Foundation's Merit Review Criteria: Review and Revisions."

NSF's changes will impact the preparation of NSF proposals. Faculty submitting letters of intent, pre-proposals and/or proposals to NSF are encouraged to take some time to familiarize themselves with the changes when developing their submissions, and should speak with their research administrators well in advance of submission to make sure NSF's changes are incorporated properly in their materials.

changes to Grants Policy Guide Effective January 14

Summary of Changes

The OSU Office of Research website has compiled some notable changes to NSF's GPG:

- **Biographical Sketches:** The Publications section has been renamed Products. Products may include, but are not limited to, publications, data sets, software, patents and copyrights.
- **Budget:** If salary is not being requested for senior personnel, their names must be removed from Section A of the budget. These senior personnel should still be listed on the cover sheet and their roles on the project described in the Facilities, Equipment and other Resources section of the proposal (see below).
- **Facilities, Equipment and Other Resources:** Proposers must now include an aggregated description of the internal and external resources (both physical and personnel) that the organization and its collaborators will provide to the project, should it be funded. The information must be provided in this section, rather than in other parts of the proposal (e.g., budget justification, project description). It should be narrative in nature and must not include any quantifiable financial information. If there are no facilities, equipment or other resources information related to the proposal, a statement should be included in this section.
- **Project Description:** Broader impacts must be described in a separate section within the narrative instead of being included as an integral part of the narrative. In addition, Results from Prior NSF Support has been redefined to include current NSF funding, whether or not the support was directly related to the proposal or salary support was provided.
- **Project Summary:** The headings for Overview, Intellectual Merit and Broader are no longer required since FastLane has been modified to display three separate text boxes where the information should be provided. Note that proposals not containing all three elements of the Project Summary will be returned without review.
- **References Cited:** If there are no references cited, a statement to that effect should be included in this section.
- **Review Criteria:** This section has been replaced by an expanded Merit Review Principles and Criteria section.
- **Indirect Costs**: NSF has elected to use grantee institutions' predetermined overhead rates in most instances. NSF program staff is not authorized to suggest or request that PIs seek reduction or waivers of indirect cost.

For more information, refer to the *NSF Proposal and Award Policies and Procedures Guide (January 2013), Document 13-001*, at NSF's website: www.nsf.gov

NSEC Update

Images from Edheads' website showing animated versions of OSU professors Andre Palmer and Jessica Winter.

The following update was provided by the Center for Affordable Nanoengineering of Polymeric Biomedical Devices (CANPBD), a National Science Foundation Nanoscale Science and Engineering Center (NSEC) program at The Ohio State University. The primary goal of the CANPBD is to develop polymer-based, low-cost nanomaterials and nanoengineering technology to produce advanced medical diagnostic devices, cell-based devices, and multifunctional polymer-nanoparticle-biomolecule nanostructures for next-generation medical and pharmaceutical applications.
For more information about CANPBD, visit their website: http://nsec.osu.edu/.

Outreach On a Massive Scale: Making Nanotechnology and Biotechnology Understandable to Young Scientists

Through a collaboration with Edheads (www.edheads.org), an award-winning, fun, distinctive and highly successful 501(c) (3) educational web development company, the NSF-supported CANPBD Center at Ohio State has been able to explain the benefits and excitement of nanotechnology to many thousands of potential future scientists. CANPBD's collaboration with Edheads teaches curious minds of all ages about nanotechnology and biotechnology through unique, educational Web experiences designed to make hard-to-teach concepts understandable. The hallmarks of the Flash-based Edheads activities are a focus on real-world applications, and involve the viewer in interactive problem-solving. The online activities motivate young participants to consider careers in science and engineering and the response to this web-based education project has been very enthusiastic.

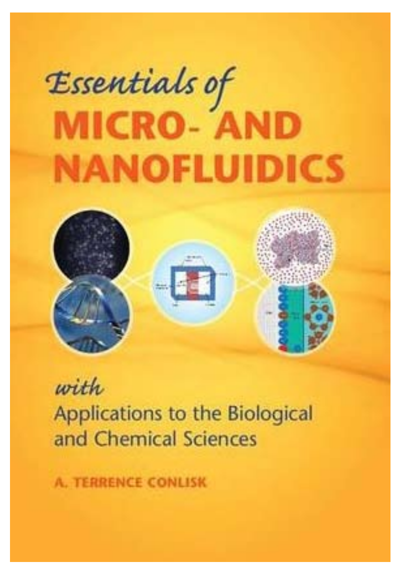
The Edheads project has made a major impact on the education of young people about science - the "Nanoparticles and Brain Tumors" activity was launched online in December 2011 and in the year since the launch, over half a million different viewers participated in the activity. A cell phone design activity produced in collaboration with the College of Engineering at Ohio State has involved over 10.9 million users since June 2009.

Edheads also created career animations based on professionals working in related fields, including two animations associated with a new Sickle Cell DNA activity featuring Andre Palmer, CANPBD faculty, and Matt Pastore, Genetic Counselor. The content covers some of the basic science needed to work in nanoengineering, while another section of the Edheads web site called Career Choices, introduces participants to a diverse set of actual professionals through text and pictures.

The CANPBD project and its collaboration with Edheads was funded by NSF Award Number 0914790, Center for Affordable Nanoengineering of Polymeric Biomedical Devices.

NSEC Member/MAE Professor Authors Book and Creates OSU Course in Microfluidics and Nanofluidics

Building on the success of an OSU course developed over the last ten years, NSEC member and Professor of Mechanical and Aerospace Engineering Terry Conlisk has authored a new textbook, Essentials of Mico- and Nanofluidics with Applications to the Biological and Chemical Sciences. The book, published by Cambridge University Press, introduces students to the basic physical principles to analyze fluid flow in micro and nano-size devices. This is the first book that unifies the thermal sciences with electrostatics and electrokinetics and colloid science, electrochemistry, and molecular biology. Conlisk also teaches an interdisciplinary course on this topic during Spring Semester with Sharya Prakash, Assistant Professor of Mechanical and Aerospace Engineering and Derek Hansford, Associate Professor of Biomedical Engineering, Introduction to Microfluidics and Nanofluidics (ME 6515/MBE 5663). Conlisk explains the rationale for the creation of the course and book, saying, "Most, if not, all problems in the twenty-first century are interdisciplinary in nature, yet there are few textbooks which address the topics required for investigating problems that cut across disciplines in engineering, the physical sciences and mathematics. This is especially true in the study of microscale and nanoscale fluid transport, the knowledge of which is essential in the research and design of biomedical and non-biomedical devices."



The OSU microfluidics and nanofluidics course includes hands-on labs and uses a project driven approach to the theoretical and experimental understanding of microscale and nanoscale fluid phenomena. The primary target audience of the course is the advanced undergraduate and beginning graduate mechanical, chemical, materials science and chemical engineering student; however, over the years the course has been populated by students in physics and chemistry as well. Nearly 100 students have taken the course since its inception in Autumn quarter 2003, with a typical class size of 10-15 students. In the move to semesters at OSU this year, a laboratory was added and the course is now a three hour semester course.

Applications specifically discussed in the textbook and the course include DNA transport and analysis, biochemical sensing, and the use of an implantable nanopore membrane to mimic the filtration function of the kidney and batteries. Other biomedical applications include Lab-on-a-Chip systems in which a diagnostic procedure involving several processes (``the laboratory") are integrated in one small device (``the chip"); these devices are a subset of a much larger class of systems called Microelectromechanical Systems (MEMS). Process level applications include controlled drug delivery, cell isolation, biofiltration processes, biomolecule separation processes, water purification and desalination, and fuel cells.

For more information on this OSU course or the textbook, contact Professor Conlisk at conlisk.1@osu.edu.

IMR Member News


Jim Beatty, Chair and Professor of Physics, and **Ralf Bundschuh**, Professor of Physics, have been elected American Physical Society Fellows. Beatty has been recognized for his contributions to cosmic ray astrophysics, while Bundschuh was honored for his contributions to quantitative understanding of biophysical properties of nucleic acids and use of physical approaches in biological sequence analysis.

Joseph Heremans, Ohio Eminent Scholar in Nanotechnology and Professor of Mechanical and Aerospace Engineering, has been named to the National Academy of Engineering (NAE) for his discoveries in thermal energy transfer and conversion to electricity and for the commercial devices employed in automobiles. Heremans studies the quantum-mechanical properties of materials in order to understand the link between heat, magnetism, and electric currents at the atomic level.

Ratnasingham Sooryakumar, Professor of Physics, and PhD candidate Aaron Chen in collaboration with scientists from the University of Illinois, KTM, Sweden and A*STAR, Singapore, recently published a paper that made the inside cover of the peer reviewed journal, Lab on a Chip. The article, entitled Ultra-localized single cell electroporation using silicon nanowires, discusses a method that allows for single cell manipulation and analysis using magnetic beads and external magnetic fields. In their study, individual cancer cells were positioned on a silicon nanowire and nanoribbon biological field effect transistors. A current sent across the transistor channel and the bulk substrate results in rapid and simple single cell lysis by disrupting the cell membrane. Analysis of the released cellular components can further the understanding of intracellular processes and the role of individual cell function within a larger cell population. This method has potential applications in medical diagnostics, proteome analysis and developmental biology studies.

Aaron Chen was also recently notified he was a recipient of the 2012 PhD Dissertation Research Award presented by the American Physical Society Topical Group on Magnetism and its Applications. This award recognizes outstanding dissertation research in magnetism. Chen will receive a cash prize and will deliver an invited talk at the 2013 American Physical Society March Meeting in Baltimore.

Jessica Winter, Associate Professor of Chemical and Biomolecular Engineering, was named 2012 Inventor of the Year by Tech Columbus at its annual Innovation Awards dinner celebrating central Ohio's top innovations and innovators. Dr. Winter is a founder and interim CEO of Core Quantum Technologies (CQT), whose technologies are based on her work in nanoparticle materials for biomedical applications. Dr. Winter and Core Quantum Technologies were featured in the Fall 2012 Innovations in Materials Research newsletter.

Materials Facilities Updates

In each issue of our newsletter, IMR provides updates on our three core materials research facilities, the NanoSystems Laboratory (NSL), Center for Chemical and Biophysical Dynamics (CCBD), and Nanotech West Laboratory. 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

Dr. John Carlin Named Associate Director of Nanotech West Laboratory

Dr. John Carlin has been named Associate Director of the Nanotech West Laboratory, effective November 1, 2012. As an IMR Member of Technical Staff at Nanotech West since 2007, Dr. Carlin has made valuable contributions to the advancement of IMR and Nanotech at many levels, including developing and leading the III-V metalorganic chemical vapor deposition (MOCVD) laboratory and the atomic layer deposition (ALD) facility, both of which anchor several major programs. Dr. Carlin has also been central to a number of research programs in the photovoltaic and other semiconductor device areas, notably in his role as a Co-Principal Investigator on a $1.5M Department of Energy program in photovoltaics and on a $1M award from the Ohio Department of Development, as a key member of the Wright Center for Photovoltaic Innovation and Commercialization (PVIC), and by providing critical support through his tireless work in the Nanotech device fabrication cleanroom. In his new role as Associate Director of Nanotech West, Dr. Carlin is responsible for leadership and technical oversight for the day-to-day operation of the micro- nano-fabrication cleanroom and associated laboratories, lab staff and students, and along with Nanotech West Director, Dr. Bob Davis, is responsible for the overall management of an efficient and successful operation. Congratulations to John on this important advancement!

Nanotech Celebrates 2012 Record Year

Calendar year 2012 closed with yet another record year of activity at Nanotech West! The facility's user activity was up over 20% of its 2011 levels by several measures. Non-OSU usage, which is dominated by Ohio small companies, continues to represent approximately 40% of NTW user fee income on a monthly basis and represents approximately 20-25% of actual lab activity.

Recent Equipment Donation from Lake Shore Cryotronics

The Nanotech West Lab recently received a generous donation of equipment from LakeShore Cryotronics in Westerville, Ohio - a Plasma-Therm electron cyclotron resonance (ECR) based plasma enhanced chemical vapor deposition (PECVD) system. Also included in the donation were additional pieces of equipment including a polarizing microscope, a laminar flow hood, and gas detection systems. Some of this equipment has been or will be relocated to other labs on campus that can best use it.

Expanding Research Space

Nanotech West has added approximately 900 square feet of space, Room 117 in the Science Village Building, to its laboratory space. Once renovated, the space will be utilized for light equipment such as characterization and inspection. Nanotech West would like to thank the Ohio State Office of Research for renting the additional space on its behalf.

ICP-RIE in Fourth Year at Nanotech

The Nanotech West Plasma-Therm SLR 770 inductively-coupled plasma reactive ion etcher (ICP-RIE), shown here with Laboratory Services Coordinator Derek Ditmer, will celebrate its fourth year of use at the Lab.

In early 2013, the Plasma-Therm SLR 770 inductively-coupled plasma reactive ion etcher (ICP-RIE) will celebrate its fourth year in the Nanotech West cleanroom. This workhorse tool (designated as ETC04, or "etcher 4", in the online reservation system) has served numerous fabrication projects at the Lab ranging from high-speed gallium nitride transistors to photovoltaics, from electro-optics to microelectromechanical systems (MEMS), and more. ICP-RIE is a high-density plasma technology that is widely used in the semiconductor industry due to various advantages over other plasma etch techniques in high etch rates, semiconductor surface damage reduction, and scalability to large wafer sizes. The tool began its journey to Ohio State at the IBM East Fishkill, NY facility and then went to OSemi Inc. in Red Wing, MN in late 2008 for refurbishment and a change to its current base 100 mm (4") wafer handling configuration. The tool is load-locked and is currently equipped with CF_4, CHF_3, Cl_2, BCl_3, Ar, and O_2 gases, and He gas for wafer backside cooling. The ICP-RIE instrument was purchased through the Ohio Wright Center for Photovoltaics Innovation and Commercialization (PVIC), funded by the Ohio Third Frontier Program.

Center for Chemical and Biophysical Dynamics (CCBD) – ccbd.chemistry.ohio-state.edu

Recent Equipment Upgrades and Repairs

An upgrade to the femtosecond mid IR spectrometer has been completed successfully to restore the output specifications of the Legend Elite 1 kHz Ti:Sapph regenerative amplifier. Replacing several aging optical elements of the laser for optics of a new generation resulted in output characteristics to the level of a brand-new laser with efficiency increased by 25%. Replacing several optical elements in the excitation leg of the setup increased the available excitation energy by 150%. These upgrades increased the overall sensitivity of the instrument to ca. 50 μOD and allowed one to observe transient signals from compounds with low transient dipole moments unavailable before, an approximately 100% overall increase in sensitivity in the spectral region between 4 and 12 μm with ca. 200 fs time resolution. The critical upgrades assured the success of experiments conducted in the lab by visiting scientists from Poland and Brazil in January and February 2013.

Work continued to couple CCBD lasers in the nanosecond time domain with the Thermo Scientific Velos Pro Linear Ion Trap Mass Spectrometer. The nanosecond laser was repaired to restore its output power to necessary specifications. The next step is planned to design and build a nonlinear frequency converter to generate nanosecond pulses in the mid IR region (ca. 3 μm). As a side result of the repair, the functionality of the nanosecond mid IR (4-12 μm) transient absorption spectrometer has been restored.

In collaboration with the IT group in the Department of Chemistry, CCBD has initiated a project to design and implement measures to ensure continuous use of old generation research instruments currently running on obsolete operating systems (Windows 95, 98) despite the unavoidable termination of support of older systems by their manufacturers. This project will involve virtual emulation of the older operating systems on new generation computers and the implementation of the communication hardware coupling USB and IP communication protocols to old hardware that recently became available on the market. Staff plan to upgrade CCBD's nanosecond and picosecond spectrometers first, followed by the upgrade of all femtosecond spectrometers.

Stricter Lab Access and Change of Room Location

An increase in the number of CCBD users resulted in a necessity to implement user access to the CCBD femtosecond lab (room 0140 Newman & Wolfrom Lab) through an electronic lock and BASIS access and record system. Together with the plans to implement a unified Facilities Operating and Management computer access system, these measures will facilitate access, safety, and record keeping for CCBD users. The new access system will be introduced in March 2013. Recent new faculty hires in the Department of Chemistry required us to vacate room 0118 Newman & Wolfrom Lab. As a result, CCBD is currently searching for a good home for its nanosecond IR transient absorption spectrometer and the time correlated photon counting setup.

NanoSystems Laboratory (NSL) – ensl.osu.edu

NSL Testing Site of New Integrated THz Frequency System

Integrated THz Frequency System for Material Characterization created by LakeShore Cryotronics (Westerville, OH) in collaboration with the OSU Center for Emergent Materials (NSF MRSEC). This instrument is now installed at NSL.

NanoSystems Laboratory (NSL) would like to announce the arrival of a new integrated THz frequency system for material characterization created by LakeShore Cryotronics (Westerville, OH) as a part of the joint research program between LakeShore and the OSU Center for Emergent Materials (NSF MRSEC) funded by the Ohio Third Frontier program. The instrument installed at NSL is an "alpha" system of a commercial product line that is undergoing extensive testing at NSL with the goal of improving the design of the instrument. The system incorporates a fiber-based optical platform for continuous wave (CW) THz spectroscopy with the capability for amplitude and phase detection ranging from 100 GHz to 1.8 THz with the spectral resolution under 100 MHz. The integrated cryostat and insert allows variable temperature operation from 4° K to 300° K. The built-in superconducting solenoid can deliver a magnetic field as high as 9 T. It is expected that the instrument will become a commercial product in 2013. Applications of the instrument include, but are not limited to, measurements of optical conductivity at THz frequencies, detection of cyclotron resonance and measurements of THz spectra of solid state molecular materials. Although at present the instrument is not open to a broad user community, it can be used by special arrangement. Users interested in using it should contact NSL Lab Manager Dr. Denis Pelekhov at pelekhov.1@osu.edu

IMR Sponsors SpinCat V Conference

The fifth annual Spin Caloritronics workshop will be held May 12-15, 2013 on the Ohio State University campus. This workshop is co-chaired by OSU Professors Roberto Myers (MSE/ECE) and Joseph P. Heremans (MAE), and will be the first to be held in the United States. The Spin Caloritronics workshop is dedicated to the analysis of the effects of heat gradients on spin and magnetism in solids, a field that originated in 2008 and has since grown exponentially.

Spin Caloritronics is a new technology that promises to result in all solid-state heat to electricity conversion technologies. Like thermoelectrics, it could be used to convert the world's waste heat into useful energy with possible transformational implications for solving the world's energy crisis. The field is in its infancy, and much of the fundamental science is yet to be quantitatively described, which is the purpose of the workshop. Work in this area by OSU researchers is recognized as pioneering, and made the cover of Nature in July 2012 and was featured in Nature Materials and Physical Review Letters, top journals in materials science and physics.

The meeting brings together 30 invited speakers from all over the world to discuss the coupling and interactions between their fields in the context of spin caloritronics effects. The opportunity for OSU's graduate students to learn from the experts is unique; students and postdocs will be asked to present posters.

For more information about the conference, visit http://imr.osu.edu/spincatv/

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