Materials Science and Engineering

Chris Van de Walle

Professor, Materials Department

University of California, Santa Barbara

Tuesday, September 30, 2014

Tech L361, 4:00pm

Effects of High Doping in Transparent Conductors

Basic information about transparent conductors, particularly about doping and how it affects electronic and optical properties, is often lacking. First-principles calculations are now capable of accurately predicting quantities that are directly relevant for applications. In oxides that can be highly doped, the large carrier concentrations significantly affect optical transparency. While direct absorption (either across the gap or to higher-lying conduction bands) is usually not a problem, indirect processes assisted by electron-phonon scattering create absorption, sometimes with unexpected wavelength dependence. First-principles evaluations of free-carrier absorption provide insight into the factors that limit this key criterion for transparent conducting oxides. The presence of large concentrations of electrons in the conduction band also affects the absorption edge, not only because of conduction-band filling but also through band-gap renormalization. I will discuss these processes and how we can treat them consistently and in quantitative detail.

Biography:

Chris Van de Walle is the inaugural recipient of the Herbert Kroemer Endowed Chair in Materials Science at the University of California, Santa Barbara. Van de Walle develops and employs first-principles computational techniques to model the structure and behavior of materials. He has performed extensive studies of semiconductor interfaces (including the development of a widely used model for band offsets) and of defects and impurities in semiconductors, with particular emphasis on doping problems. In recent years he has been focusing his attention on wide-band-gap semiconductors, nitrides, oxides, on the behavior of hydrogen in materials, and on spin centers for quantum computing. He co-leads IRG-2, “Correlated Electronics”, in the UCSB MRSEC, and his group is actively engaged in studies of efficiency limits in light emitters, novel channel materials for CMOS, transparent conducting oxides, and hydrogen storage materials. He has published over 350 research papers, holds 23 patents, has given 150 invited and plenary talks at international conferences, and is included in the 2014 “Highly Cited Researchers” list (www.highlycited.com). Professor Van de Walle has chaired three conferences, and was Program Chair for the 27th International Conference on the Physics of Semiconductors in 2004. He is a Fellow of the APS, AVS, AAAS, MRS, and IEEE, as well as the recipient of a Humboldt Award for Senior US Scientist, the David Adler Award from the APS, and the Medard W. Welch Award from the AVS.

Before joining the UCSB Materials Department in 2004, Professor Van de Walle was a Principal Scientist in the Electronic Materials Laboratory at the Xerox Palo Alto Research Center (PARC). He received his Ph.D. in Electrical Engineering from Stanford University in 1986. He was a postdoctoral scientist at the IBM T. J. Watson Research Center in Yorktown Heights, New York (1986-1988), a Senior Member of Research Staff at Philips Laboratories in Briarcliff Manor, New York (1988-1991), and an Adjunct Professor of Materials Science at Columbia University (1991).

Geoffrey Beach

Associate Professor, Department of Materials Science and Engineering
MIT

Tuesday, October 7, 2014
Tech L361, 4:00pm

Spin-Orbitronics: Interfacial Design of Spintronic Materials and Devices

There is great interest in electrically manipulating the magnetization in nanoscale materials for high-performance memory and logic device applications. In this talk I will describe recently-discovered mechanisms, based on symmetry breaking and spin-orbit coupling at interfaces, whereby the magnetization can be controlled using very low currents[1,2] or by a gate voltage alone.[3-5] I will focus on ultrathin transition metal ferromagnets sandwiched between an oxide and a nonmagnetic heavy metal, in which magnetic, electronic and ionic effects at the interface can be exploited in new and unexpected ways.

I first focus on the heavy-metal/ferromagnetic interface, where spin-orbit coupling influences not only spin transport, but the nature of magnetism itself in the ferromagnet. In nonmagnetic heavy metals, spin-orbit coupling leads to a left-right scattering asymmetry such that spin "up" and spin "down" electrons pile up on either side of a material when a charge current flows through it. I will show how this spin Hall effect can be used to create pure spin currents at the interface that can drive magnetization switching and domain wall motion in an adjacent ferromagnetic film.[1,2] In these same materials, broken inversion symmetry can lift the chiral degeneracy and generate new topological spin textures such as spin-spirals and skyrmions. We show for the first time that chiral ferromagnetism can persist at room temperature and can be engineered simply by appropriately designing interfaces between magnetic and nonmagnetic materials.[2]

I will then turn to the ferromagnet/oxide interface[3-6] and describe our discovery of a new class of "magneto-ionic" materials,[5,6] in which a gate voltage can be used to electrochemically switch the interfacial oxidation state to realize unprecedented control over magnetic properties. Here we use Pt/Co/$Gd_2O_{3-\delta}$ ultrathin film stacks, where $Gd_2O_{3-\delta}$ serves as an efficient oxygen ion conductor. I show that the magnetization in the thin Co layer can be switched between perpendicular and in-plane orientations, or quenched entirely, by driving O^{2-} towards or away from the Co/GdOx interface with a small gate voltage.[6] I then show that magneto-ionic gates can be used to locally tune magnetic properties and create a magnetic analog of field-effect transistors.[5]

Finally, I will describe emerging nanomagnetic devices that utilize these and other effects for memory,[3,4] logic,[5] and biosensing,[7] and assess the progress and outlook for a variety of applications.

Biography: Geoffrey Beach is an Associate Professor of Materials Science and Engineering at MIT. He received a B.S. in Physics from Caltech, a Ph.D. in Physics from the University of California, San Diego, and conducted postdoctoral work at the University of Texas at Austin. At MIT, Prof. Beach has established the Laboratory for Nanomagnetism and Spin Dynamics, which designs advanced materials for spin-based memory, logic, and biomedical applications. His work has been recognized with numerous awards including most recently a Deshpande Center Award for Technological Innovation, the MIT Junior Bose Award for Excellence in Teaching, the MIT Class of 1958 Institute Chaired Professorship, and the Department of Energy (DoE) Early Career Award.

1. S. Emori, D. Bono, and G. S. D. Beach, *Appl. Phys. Lett.* 101, 042405 (2012).
2. S. Emori, U. Bauer, S.-M. Ahn, E. Martinez, and G. S. D. Beach, *Nature Materials* 12, 611 (2013).
3. U. Bauer, M. Przybylski, J. Kirschner, and G. S. D. Beach, *Nano Lett.* 12, 1437 (2012).
4. U. Bauer, S. Emori, and G. S. D. Beach, *Appl. Phys. Lett.* 100, 192408; ibid **101**, 172403 (2012).
5. U. Bauer, S. Emori, and G. S. D. Beach, *Nature Nanotechnology* 8, 411 (2013).
6. U. Bauer, L. Yao, S. Emori, H. L. Tuller, S. van Dijken, and G. S. D. Beach, *under review*; arXiv:1409.1843 (2014).
7. E. Rapoport, D. Montana, and G.S.D. Beach, *Lab Chip.* 12, 4433-4440 (2012).

Carelyn E. Campbell
NIST – Materials Science and Engineering Division

Tuesday, October 28, 2014
4:00pm, Tech L361

The Materials Genome Initiative and the "Data Revolution"

As announced in 2011, the goal of the Materials Genome Initiative is to reduce the time and cost of material development and deployment by fifty percent. To reach this goal, a materials data infrastructure is evolving that includes the integration of a variety of workflow and data curation tools, repositories and registries. Central to this data infrastructure and the materials design process are phase-based property data (e.g. phase transformation temperatures, diffusivities, molar volumes, elastic coefficients and thermal expansion coefficients). These data sets are diverse in type, semi-structured, and often missing essential metadata and thus, present significant challenges to curate, share and transform. NIST is developing a variety of tools to address these challenges, including a materials-based digital repository and a web-based curation tool, the Materials Data Curator (MDC). The NIST digital materials repository is a customized version of the DSpace software, an open-source digital repository software that enables users to curate and share a wide variety of digital content including text, images and video. The web-based MDC allows users to store data in a non-relational database, use semantic-based technologies and integrate with a variety of workflow tools. The curation of a set of experimental diffusion data and a set of simulation data using the MDC will be demonstrated. Successful implementation of these and other data curation tools and repositories will enable more efficient materials design methods and new opportunities to integrate data science tools with materials science.

Biography: Carelyn Campbell is the leader of the Thermodynamics and Kinetics group in the Materials Science and Engineering Division in the Material Measurement Laboratory at the National Institute of Standards and Technology (NIST). Her research is focused on the development of a materials data infrastructure for phase-based property data and on diffusion in multicomponent multiphase systems. Since 2003, she has sponsored the annual NIST Diffusion Workshop series, which brings together experimentalists and theorists to improve the development of diffusion mobility databases and the prediction of diffusion controlled microstructure evolution in multicomponent multiphase systems. She received both her BS and PhD in Materials Science and Engineering from Northwestern University. She began her tenure at NIST in 1997, as a National Research Council Postdoctoral Fellow. In 2010, she received a Bronze Medal from the Department of Commerce for superior federal service in leading the NIST Diffusion Workshop series.

Ibrahim Karaman

Professor and Chair, Department of Materials Science and Engineering
Texas A&M University

Tuesday, November 4, 2014
Tech L361, 4:00pm

Unusual Functionalities in Martensitically Transforming Materials

Reversible martensite phase transformation, which readily occurs in shape memory alloys (SMAs), enables easily-controlled switching between significantly differing crystal structures due to the small energy differences between the transforming phases. We have achieved a number of new and unique functionalities in these materials near phase stability limits by engineering the microstructure, texture, and level of structural disorder, and their interactions with the reversible martensitic phase transformation. For example, alloys with tunable thermal expansion coefficients were created from polycrystalline SMAs through texturing and selection of appropriate stress-induced martensite variants by thermo-mechanical processing. Strain glass and spin glass behaviors were observed in the same magnetic SMA by controlling the martensitic transformation and its frustration through changing structural disorder. Grain refinement could be easily achieved by activating stress-induced martensitic transformation and creating reversible deformation twins in martensite. Grain boundary engineering is possible through the reversible transformation / deformation twins, which help to obtain low energy grain boundaries in nanostructured austenite. Finally, the effective elastic modulus of SMAs could be easily manipulated by varying the stress level at which stress-induced transformation occurs through controlling the dislocation density, grain size, and precipitation size and volume fraction of the alloy. These examples show that reversible martensitic phase transformation can be used as an engineering tool to precisely tailor the properties of materials, and functions as a versatile and powerful method to create “designer” materials for various applications.

Biography: Ibrahim Karaman is the Chevron Professor and Department Head of Materials Science and Engineering at Texas A&M University. He received his Ph.D. from University of Illinois at Urbana-Champaign in Mechanical Engineering in 2000. He joined the faculty of Department of Mechanical Engineering at Texas A&M University in 2000. He was promoted to the rank of Professor in 2011. He has served as the Chair of the Interdisciplinary Graduate Program in Materials Science and Engineering (MSEN) from 2010 to 2013. The MSEN program became a new department in 2013, where Dr. Karaman serves as the head. His main research interests are processing-microstructure-mechanical/functional property relationships in metallic materials and composites including 1) ultrafine and nanocrystalline materials, and 2) conventional, high temperature and magnetic shape memory alloys; micro-mechanical constitutive modeling of crystal plasticity; twinning and martensitic phase transformation. Dr. Karaman received several national and international awards including the NSF CAREER Award, ONR Young Investigator Award, The Robert Lansing Hardy Award from The Minerals, Metals and Materials Society (TMS), an Honorable Mention for the Early Career Faculty Fellow Award from TMS, and Gary Anderson Early Achievement Award from ASME and AIAA. He is an author or co-author over 190 refereed journal articles.

McCormick

Northwestern Engineering

Materials Science and Engineering

Marcus L. Young
Assistant Professor
Materials Science and Engineering
University of North Texas

Tuesday, November 18, 2014
4:00pm, TECH L361

"Advanced Characterization Techniques for Archaeometallurgy"

Archaeometallurgy, the study of ancient metal artifacts, provides valuable insight into the ancient cultures that produced them. Scientific investigation of these artifacts can answer many questions pertaining to, for example, provenance and trade, manufacturing and fabrication technologies, corrosion processes and conservation treatments, and authenticity and dating. Since many of these artifacts are unique and irreplaceable, the ability to examine these artifacts non-destructively is paramount to the application of a particular analytical technique and the success of these studies. In this presentation, I will discuss two important and powerful analytical tools (synchrotron radiation and dual beam focused ion beam/scanning electron microscopy) which can be used to non-destructively study archaeometallurgical objects. In the first part of the presentation, dual beam FIB/SEM will be discussed. In the second part of the presentation, SR facilities and specific SR techniques such x-ray imaging and diffraction will be discussed. In both cases, individual archaeometallurgy case studies will be presented.

Biography: Dr. Marcus L. Young is an Assistant Professor in the Department of Materials Science and Engineering at the University of North Texas (UNT), joining the faculty following a position as a research metallurgist at ATI Wah Chang, a large metal supplier company. Dr. Young received a B.F.A. in Sculpture and a B.F.A. in Ceramics from UNT and was the sole proprietor of a ceramics business before returning to school, where he received a B.S. in Metallurgical and Materials Science Engineering from Colorado School of Mines and a PhD in Materials Science Engineering from Northwestern University (NU). Dr. Young's PhD research was supported by Argonne National Laboratory (ANL), where he spent a significant time working at the Advanced Photon Source (APS). Following his education, Dr. Young worked as an Andrew W. Mellon Foundation Post-doctoral Research Fellow with the Art Institute of Chicago and NU and then as an Alexander von Humboldt Foundation Post-doctoral Research Fellow at Ruhr University in Bochum, Germany. At UNT, Dr. Young's research group is focused on the development, processing, and characterization of structural metallic materials, specifically shape memory alloys, and their porous and composite counterparts. In addition, Dr. Young's research group is focused on examining modern and ancient art historical objects with the Dallas Museum of Art as well as several other local and national museums.

Deji Akinwande

Assistant Professor, Department of Electrical and Computer Engineering
University of Texas at Austin

Tuesday, November 25, 2014
Tech L361, 4:00pm

Adventures with Buckled Atomic Sheets: The Case of Phosphorene and Silicene

Buckled atomic sheets such as phosphorene and silicene promise interesting anisotropic phenomena and strongly coupled multi-physics. Experimental properties and ageing effect are among the biggest topics. Here, we report key results of critical importance for device studies and understanding including phosphorene devices featuring: i) record mobility (μ) ~1560cm2/V.s about an order of magnitude higher than other 2D semiconductors, ii) ambipolar current saturation that is more desirable for optoelectronics than graphene because of its sizeable direct bandgap, and iii) the first demonstration of flexible devices and circuits. Experimental results on silicene represents the first device investigation that is enabled by advanced materials growth and a unique sandwich transfer process, and confirm the graphene-like Dirac transport. In addition, the common air-stability issue of great concern is investigated with microwave impedance microscopy (MIM) revealing that ordinary methods such as Optical and AFM are generally blind as an evaluation technique. Silicene and phosphorene materials show long-term air-stability with engineered protection. Collectively, the record mobility of phosphorene makes it the most compelling 2D semiconductor, while silicene's allotropic affinity with bulk Si and its low-T growth suggests a more direct path for semiconductor technology integration.

BIO:
Dr. Deji Akinwande received the PhD degree in Electrical Engineering from Stanford University in 2009, where he conducted research on the synthesis, device physics, and circuit applications of carbon nanotubes and graphene. His Master's research in Applied Physics at Case Western Reserve University pioneered the design and development of near-field microwave probe tips for nondestructive imaging and studies of materials.

He is currently an Assistant Professor with the University of Texas at Austin. The current focus of his research explores materials and electronic systems based on 2D atomic layers. He is a co-inventor of a high-frequency chip-to-chip interconnect and an electrically small antenna for bio-electronics. Prof. Akinwande has been honored with the inaugural IEEE Nano Geim and Novoselov Graphene Prize, the NSF CAREER award, the Army and DTRA Young Investigator awards, the 3M Nontenured Faculty Award, and was a past recipient of fellowships from the Ford Foundation, Alfred P. Sloan Foundation, and Stanford DARE Initiative. He is one of the directors of the NASCENT ERC center at UT Austin. He recently co-authored a textbook on carbon nanotubes and graphene device physics by Cambridge University Press, 2011. His work on flexible graphene systems was selected as among the "best of 2012" by the nanotechweb online technology news portal and has been featured on MIT's technology review and other technical media outlets.

Dr. Supratik Guha
Director of Physical Sciences, IBM Research

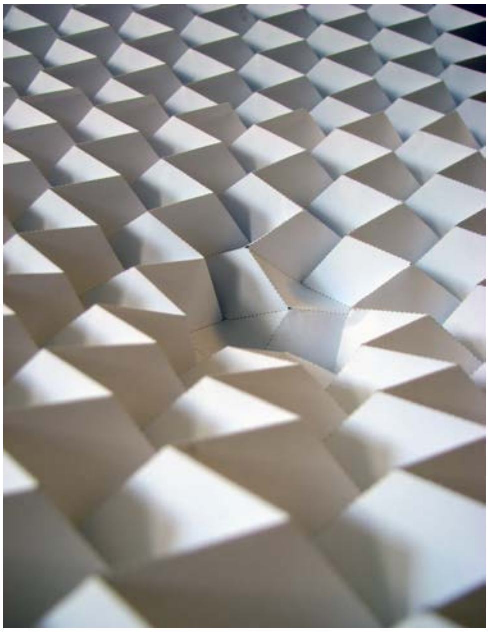
Tuesday, January 13, 2015
4:00pm, Tech L361

"Earth abundant vacuum deposited kesterite thin film solar cells"

For solar cells to be cheap and available in quantities to meet demands of ~ 50 GWp/year (for photovoltaics to make a significant dent in worldwide electricity production), it is desirable that they be made of materials that are earth abundant, stable, preferably non-toxic, and viable in polycrystalline form (to obviate the need for expensive single crystal substrates). Among the new materials being investigated, the kesterite compound copper zinc tin sulfide (CZTS) is an attractive solar cell absorber material that meets these criteria, provided the efficiencies of the cells can be increased to beyond its current value of ~9%. If one is willing to add some Se (CZTSSe) and tolerate some non-toxicity, efficiencies of ~ 12-12.5% may be achieved. These numbers however need to be >~15% for for pre-manufacturing activities in CZTS or CZTSSe to begin, and likely >~18% for them to be successful candidates for manufactured products in the future. Using examples from vacuum deposited CZTS, I will describe some of the materials issues that limits current electrical performance, the most significant among them being an open circuit voltage that is quite low. I will describe the role that microstructure and phase stability in this material plays, and the effect that Na addition has on grain growth and photovoltaic properties. In order to identify the role of extended defects and grain boundaries on performance, we have also begun a study of epitaxial CZTS grown on near lattice matched silicon substrates by molecular beam epitaxy, and these results will be discussed. Finally, I will show some of our early results in the successful demonstration of monolithic tandem kesterite-perovskite solar cells.

Biography:

Supratik Guha is presently the Director of Physical Sciences at IBM Research, where he has been since 1995. During his time at IBM he initiated and led the high dielectric constant (high-k) oxide materials research at IBM and was responsible for some of the key materials and processes that led to IBM's high-k metal gate CMOS technology. His current research interests are in new semiconductors and oxides for logic, and energy conversion applications. Supratik received his Ph.D. in Materials Science from the University of Southern California in 1991, and his B. Tech from the Indian Institute of Technology, Kharagpur (India) in 1985. He is also currently an adjunct professor of materials science at Columbia University. He is a fellow of the American Physical Society and the Materials Research Society.



Itai Cohen

Associate Professor, Department of Physics
Cornell University

Tuesday, January 20, 2015
Tech L361, 4:00pm

Bringing Physics into the Fold: Origami-Inspired Mechanical Meta-materials

Tessellated patterns, realistic animals, and curved polygonal shapes are all examples of the beautiful and amazing sculptures that can now be made using Origami, the art of paper folding. This art form has experienced tremendous growth with the advent of mathematical techniques that allow the basic structure of any new sculpture to be plotted out before any folding occurs, and laser cutter technologies that have made it easier to create folds in a variety of materials. In addition to their static properties, Origami sculptures can be designed to have a wide variety of mechanical properties making them responsive and tunable. In this talk I will describe our efforts to bring together artists, materials scientists, engineers, mathematicians, and yes, physicists to make meta-materials base on origami principles. Our teams are interested in making structures with a broad range properties including, tunable mechanical stiffness, mechanical cloaking capabilities, and topological constraints that can be utilized to design switches. The materials we work with range from paper models, to thermally responsive gel sheets, and even graphene. Collectively, we strive to design material platforms that can be used as building blocks for the nano and micro scale mechanical devices of the future.

BIO:
Professor Itai Cohen is obsessed with motion on various length scales. At Cornell, his research has focused on investigating the behavior of microscopic and nanoscopic particles suspended in a fluid, exploring the mechanics of materials ranging from biological tissues to origami inspired metamaterials, and discovering the mechanisms used by insects during flapping flight. Understanding the out-of-equilibrium behavior of these systems and their non-linear response to applied forces remains one of the biggest challenges in Physics.

Dr. Carol Hirschmugl, Professor
University of Wisconsin Milwaukee

Tuesday, February 3, 2015
4:00pm, Tech L361

“Simultaneous 3D Detection of Organics with Infrared Spectromicrotomography ”

The holy grail of chemical imaging is to provide spatially and temporally resolved information about heterogeneous samples on relevant scales. Synchrotron-based Fourier Transform infrared imaging[1] combines rapid, non-destructive chemical detection with morphology at the micrometer scale, to provide value added results to standard analytical methods. Hyperspectral cubes of (x,y, z, Abs ((lamdba please use symbol font))) are obtained employing spectromicrotomography[2], a label free approach, it inherently evaluates a broad array of wide organic materials, with minimal sample preparation and modification. Examples presented here (polymer composites, single cells and colonies of cells) demonstrate the broad applicability of this approach to detect complex chemical information of intact samples.

Biography:

Dr. Carol Hirschmugl received her B.S. in Physics from State University of New York at StonyBrook in 1987 and her Applied Physics Ph.D. from Yale University in 1994. She then received an Alexander von Humboldt grant to do research at Fritz Haber Institut, Berlin, from 1994-1996. In 1996 she was awarded the University of Califoria's Presidential Postdoctoral Fellowship to work at Lawrence Berkeley National Laboratory. Since 1997, Hirschmugl has been at the University of Wisconsin-Milwaukee, where she is a professor in the Physics Department and the Director of the Laboratory for Dynamics and Structure at Surfaces.

Professor Hirschmugl held visiting scientist positions at ANKA, FZK (Karlsruhe, Germany) in 2004 and at ESRG (Grenoble, France) in 2005. She mentored seven REU students and one RET High school teacher during the past 4 years. Hirschmugl's awards include three from the National Science Foundation and the Research Corporation Research Innovation award. Her research is currently supported by a UWM Research Growth Initiative award and a grant from the Southeastern Wisconsin Energy Technology Research Center.

James Hone

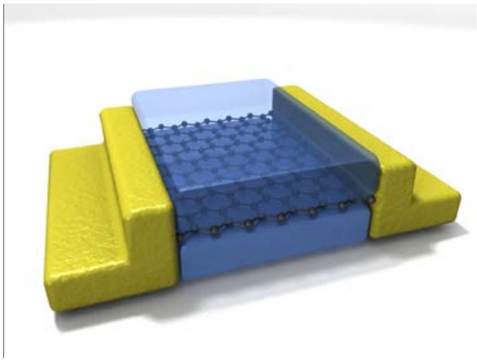
Professor, Department of Mechanical Engineering
Columbia University

Tuesday, February 17, 2015
Tech L361, 4:00pm

"Fabrication, Properties, and Applications of van der Waals Heterostructures"

Two-dimensional materials such as graphene offer a wide range of outstanding properties but are highly sensitive to disorder from the environment. We have developed techniques to stack 2D materials on top of each other to create 'van der Waals Heterostructures' with nearly perfect interfaces. Moreover, we can achieve high-quality contacts to the one-dimensional edge of buried layers. This talk will first describe the techniques used to create such heterostructures. Next, four application areas will be described: 1. Near-ideal performance achieved in graphene through encapsulation in insulating boron nitride (BN); 2. Applications in plasmonics, photonics, and light emission; 3. Greatly improved measurements of the electrical transport in semiconducting MoS_2 through BN-encapsulation; 4. Measurements of other 2D materials.

BIO:
James Hone is currently Wang Fong-Jen Professor of Mechanical Engineering at Columbia University. He received his PhD in experimental condensed matter physics from UC Berkeley in 1998, and did postdoctoral work at the University of Pennsylvania and Caltech, where he was a Millikan Fellow. He joined the Columbia faculty in 2003. His current research interests include synthesis, characterization, manipulation, and applications graphene, and other 2D materials; nanomechanical devices; and nano-biology.



Oleg Shpyrko

Associate Professor, Department of Physics
University of California, San Diego

Tuesday, March 10, 2015
Tech L361, 4:00pm

"X-ray Nanovision"

Attempts to produce focusing x-ray optics date back to the days of Roentgen, however, it was not until the past decade that X-ray Microscopy has finally been able to achieve sub-100 nm resolution. In my talk I will introduce a novel x-ray microscopy technique, which relies on coherent properties of x-ray beams, and eliminates the need for focusing optics altogether, replacing it with a computational algorithm. We have applied this technique to image magnetic stripe domains in GdFe multilayer films, as well as to image the distribution of lattice strain in nanostructures. I will also discuss recent results of in-operando imaging of lithium ion diffusion and dislocation dynamics in lithium ion energy storage devices. I will discuss applications of these novel x-ray imaging methods in context of new generation of fully coherent x-ray sources.

BIO:
Oleg Shpyrko received his Ph.D. from Harvard University in 2004. After working as a postdoctoral fellow at Center for Nanoscale Materials at Argonne National Laboratory, in 2007 he moved to University of California, San Diego where he is currently an Associate Professor of Physics. Since joining UCSD, Shpyrko has been a recipient of NSF CAREER award, Hellman Fellowship and Rosalind Franklin Award. His group at UCSD is actively involved in application of synchrotron scattering and imaging techniques to problems ranging from structure and dynamics of polymers, liquid surfaces and nanoparticles and nanowires to studies of magnetic, orbital and charge-ordered materials

Nigel Browning

Laboratory Fellow and Chemical Imaging Initiative Lead
Pacific Northwest National Laboratory (PNNL)

Tuesday, April 14, 2015
Tech L361, 4:00pm

"In-Situ (S)TEM/DTEM: From High Spatial Resolution to High Temporal Resolution"

The last few years have seen a paradigm change in (scanning) transmission electron microscopy ((S)TEM) with unprecedented improvements in spatial, spectroscopic and temporal resolution being realized by aberration correctors, monochromators and pulsed photoemission sources. Spatial resolution now extends to the sub-angstrom level, spectroscopic resolution into the sub-100meV regime and temporal resolution for single shot imaging is now on the nanosecond timescale (stoboscopic imaging extends this even further to femtoseconds). The challenge now in performing experiments in an (S)TEM is to implement the in-situ capabilities that will allow both engineering and biological systems to be studied under realistic environmental conditions. Performing experiments using in-situ stages or full environmental microscopes presents numerous challenges to the traditional means of analyzing samples in an electron microscope – we are now dealing with the variability of dynamic process rather than a more straightforward static structure. In this presentation, I will discuss the recent developments in the design and implementation of in-situ stages being pursued at the Pacific Northwest National laboratory (PNNL). Examples of the use of these capabilities for the direct imaging of interfaces and defects, to identify the fundamental processes involved in nucleation and growth of nanostructures from solution, and to investigate the electrochemical processes taking place in next generation battery systems will be presented. As the in-situ stages have been designed to be incorporated into both high spatial resolution aberration corrected (S)TEM as well as into high temporal resolution Dynamic TEM (DTEM), the potential for future experiments to study fast dynamics, including those in live biological structures, will also be discussed.

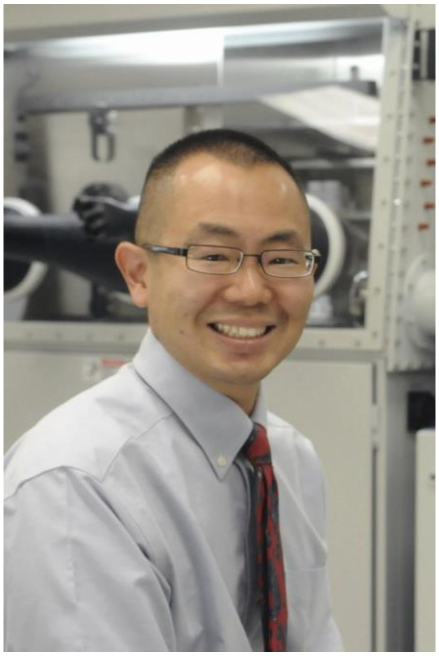
Nigel Browning is currently a Laboratory Fellow and Chemical Imaging Initiative Lead at Pacific Northwest National Laboratory (PNNL). After receiving his undergraduate degree in Physics from the University of Reading, U.K. and his Ph. D. in Physics from the University of Cambridge, U.K., he joined Oak Ridge National Laboratory (ORNL) as a postdoctoral research associate in 1992. In 1995, he took a faculty position in the Department of Physics at the University of Illinois at Chicago (UIC), then moved to the Chemical Engineering and Materials Science Department at the University of California-Davis (UCD) in 2002. He also held a joint appointment in the National Center for Electron Microscopy (NCEM) at Lawrence Berkeley National Laboratory (LBNL) which he moved to Lawrence Livermore National Laboratory (LLNL) in 2005. In 2009, he also joined the Department of Molecular and Cellular Biology at UCD.

Nigel has over 20 years of experience in the development of new methods in electron microscopy for high spatial, temporal and spectroscopic resolution analysis of engineering and biological structures. His research has been supported by DOE, NSF, NIH, DOD and by industry, leading to research projects for over 30 graduate students and 29 postdoctoral research fellows. He is a Fellow of the American Association for the Advancement of Science (AAAS) and the Microscopy Society of America (MSA). He received the Burton Award from the MSA in 2002, the Coble Award from the American Ceramic Society in 2003 for the development of atomic resolution methods in scanning transmission electron microscopy (STEM) and is co-recipient of R&D 100 and Nano 50 Awards in 2008 and a Microscopy Today Innovation Award in 2010 for the development of the dynamic transmission electron microscope (DTEM). He has over 350 publications and has given over 200 invited presentations on the development and application of advanced TEM methods.

McCormick

Northwestern Engineering

Materials Science and Engineering



Dillon Fong

Scientist, Material Science Division
Argonne National Library, Argonne, IL, USA

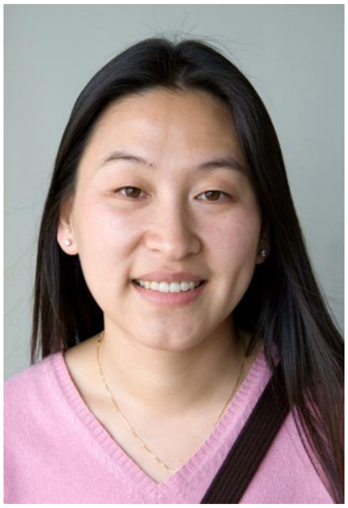
Tuesday, April 21, 2015
4:00pm, Tech L361

"In Situ Synchrotron X-Ray Studies of Epitaxial Oxide Heterostructures"

The surfaces and interfaces of complex oxide heterostructures have attracted much recent attention in the condensed matter community due to the appearance of unexpected properties. We employ in situ synchrotron x-ray techniques at the Advanced Photon Source to investigate the synthesis of such interfaces and heterostructures as well as their behavior in fluid environments and under applied potential. I will describe our results and discuss the importance of using in situ probes in developing new oxide materials for future electronic and energy applications

Biography:
Dillon Fong is a staff scientist in the Materials Science Division at Argonne National Laboratory. His research focuses on the use of *in situ* synchrotron x-ray techniques to investigate the behavior of materials in complex and dynamic environments. He won the 2009 Presidential Early Career Award for Scientists and Engineers, the 2011 Chair of Excellence from the Fondation Nanosciences (France), and the 2013 Argonne National Laboratory Distinguished Performance Award.

Dillon received his PhD (2001) in Applied Physics from Harvard University and his BS in Materials Science & Engineering from Northwestern University.



Ting Xu

Department of Material Sciences and Engineering,
Department of Chemistry,
University of California, Berkeley
Materials Sciences Division, Lawrence Berkeley National Laboratory

Tuesday, May 5, 2015
4:00pm, Tech L361

"Toward Using Protein/Peptide as Material Building Block"

The scientific community has been striving for decades to generate biomimetic materials to access many of the beneficial properties seen in Nature. However, there has been limited success in obtaining structural control, catalytic activity, molecular transport, and modulated responsiveness to small perturbation. Proteins, nature's "own" building blocks, have many unique features unmatched by any synthetic organic or inorganic analogs. Rather than developing biomimetic protein-like building blocks, using natural proteins to construct functional materials will clearly change the paradigm of materials science. I will present our explorations to design, synthesize and characterize protein/peptide-based functional materials. Specifically, I will discuss how our fundamental studies in peptide/protein-polymer conjugates led to functional materials in several areas, including 3-helix micelles as long circulating stable nanocarriers, and protein stabilization in non-biological environment.

Biography:

Dr. Ting Xu received her Ph.D from the Department of Polymer Science and Engineering from the University of Massachusetts, Amherst in 2004. She did her postdoctoral training jointly between the University of Pennsylvania and the Cold Neutron for Biology and Technology (CNBT) team at National Institute of Science and Technology from 2004-2006. She jointed University of California, Berkeley in both the Department of Material Sciences and Engineering and Department of Chemistry in January 2007. Researches in Xu's group take advantage of the recent developments in de novo protein design and peptidomimetics, polymer science and nanoparticles synthesis and manipulation; and use natural building blocks such as peptides and proteins in concert with the self-assembly of block copolymers, conjugated molecule and nanoparticles as platforms to generate nanostructured functional materials. Her research group focuses on a fundamental understanding of multiple length self-assemblies in multi-component systems and aims to generate hierarchically structured nanomaterials with built-in biological, electrical and magnetic functionalities. Prof. Xu has over 60 peer-reviewed journal articles, 5 book chapters and several patents. She is the recipient of 2007 DuPont Science and Technology Grant; 2008 3M Nontenured Faculty Award; 2008 DuPont Young Professor Award; 2009 Office of Naval Research Young Investigator Award; 2010 Li Ka Shing Woman Research Award; 2011 Camille-Dreyfus Scholar-Teacher Award; and 2011 ACS Arthur K. Doolittle Award. She was named as one of "Brilliant 10" by Popular Science Magazine in 2009.

Peng Yin

Associate Professor
Department of Systems Biology
Harvard University

Tuesday, May 12, 2015
Tech L361, 4:00pm

"Molecular programming with DNA/RNA"

I will discuss my lab's research on engineering digitally programmable DNA/RNA nanostructures and their applications in imaging, sensing, and nanofabrication.

We recently invented a general framework for programming the self-assembly of short synthetic nucleic acid strands into prescribed target shapes or demonstrating their prescribed dynamic behavior. Using short DNA strands, we demonstrated the modular construction of sophisticated nanostructures. Using reconfigurable DNA hairpins, we demonstrated diverse, dynamic behavior.

By interfacing these nucleic acid nanostructures with functional modules, we are introducing digital programmability into diverse applications. (1) Barcoding and imaging life with DNA. Using programmable fluorescent DNA probes, we developed a highly multiplexed (10×), precisely quantitative (>90% precision), and ultra-high resolution (sub-5 nm) optical imaging method. (2) Probing and programming life with DNA/RNA. We constructed unprecedented robust and ultra-specific DNA probes for detecting single base changes in a single-stranded DNA/RNA target. We developed RNA nano-devices as de-novo-designed synthetic gene regulators with unprecedented wide dynamic range and orthogonality, and demonstrated their utility in living cells and on paper-based in vitro systems. (3) DNA-directed nano-foundries. We developed diverse strategies for producing inorganic materials with arbitrarily prescribed 2D (e.g. using graphene, silicon dioxides and 3D shapes (e.g. using silver, gold).

See his lab's work at http://molecular-systems.net.

Biography: Peng Yin is an Associate Professor of Systems Biology at Harvard Medical School and a Core Faculty Member at Wyss Institute for Biologically Inspired Engineering at Harvard University. He directs the Molecular Systems Lab at Harvard. His research interests lie at the interface of information science, molecular engineering, and biology. The current focus is to engineer information directed self-assembly of nucleic acid (DNA/RNA) structures and devices, and to exploit such systems to do useful molecular work. Such de novo designed systems are composed of small synthetic DNA/RNA monomers capable of conditional configuration change and can be programmed to self-assemble, move, and compute. They can serve as programmable controllers for the spatial and temporal arrangements of diverse functional molecules (e.g. fluorophores, proteins), with a wide range of applications in nano-fabrication, imaging, sensing, diagnostics, and therapeutics.
He is a recipient of a 2010 NIH Director's New Innovator Award, a 2011 NSF CAREER Award, a 2011 DARPA Young Faculty Award, a 2011 ONR Young Investigator Program Award, a 2013 NIH Director's Transformative Research Award, a 2013 NSF Expedition in Computing Award, a 2014 ACS Synthetic Biology Young Investigator Award, and a 2014 Finalist for Blavatnik National Award for Young Scientists.

McCormick

Northwestern Engineering

Materials Science and Engineering

Northwestern University MRSEC

Joshua Goldberger

Assistant Professor, Department of Chemistry and Biochemistry
Ohio State University

June 2, 2015
Tech L361, 4:00pm

"Atomic-Scale Derivatives of Solid-State Materials"

Abstract Similar to how carbon can be sculpted into low-dimensional allotropes such as fullerenes, nanotubes, and graphene, one of the major themes of our research program is that the framework connectivity of atoms for *any* crystalline solid can be ligand-terminated along specific axes to produce stable, crystalline van der Waals materials comprised of single or few atom thick fragments. These new atomic-scale materials can have completely different and transformative physical properties compared to the original material. Here, we will describe our recent success in the creation of hydrogen and organic-terminated group IV (Si, Ge, Sn) 2D graphane analogues. We will discuss how the optical, electronic, and thermal properties of these materials can be systematically controlled by substituting either the surface ligand or via alloying the framework with other elements. Additionally, since every atom in these materials is a "surface atom", we will show how the optical, electronic, and thermal properties of these materials can be manipulated by altering the identity of the surface bound ligands. These atomic-scale materials represent an intriguing and unexplored regime in materials design in which both surface functionalization and solid-state chemistry can be uniquely exploited to design properties and phenomena.

Biography: Josh Goldberger received his B.S. in chemistry from The Ohio State University in 2001. He then received his Ph.D. in chemistry from the University of California at Berkeley under Professor Peidong Yang in 2006, as an NSF graduate fellow. He completed his postdoctoral research with Professor Sam Stupp at Northwestern University as part of the Chemistry and Materials Science Departments as well as the Institute for BioNanotechnology in Medicine, as an NIH-NRSA postdoctoral fellow (2007-2010).
Goldberger has received awards including a MRS Graduate Student Finalist Award in 2003, an IUPAC Prize for Young Chemists in 2007, and a Camille Dreyfus Teacher-Scholar Award in 2015. He joined The Ohio State University Chemistry and Biochemistry Department in August of 2010.

Co-Sponsored by Materials Research Science and Engineering Center (MRSEC)