Recent Advances and Challenges in Ni-Base Superalloy Technologies

As one of the most important classes of high-temperature structural materials, Ni-base superalloys are critical to the continued development of high-performance turbine engines for propulsion and power generation. In order to accommodate the increases in engine operating temperatures required for improved performance and efficiency, innovative alloying concepts and processing approaches have been developed to enhance the mechanical properties of Ni-base superalloys. These technological advances can largely be attributed to the development of physics-based computational models and novel characterization tools that provide an improved fundamental understanding of the intrinsic mechanisms governing their characteristic behavior. This talk will discuss some of the advances and challenges associated with developing engineering solutions to overcome these intrinsic limitations and extend the temperature capability of polycrystalline Ni-base superalloys.

Biography: Dr. Sammy Tin is a Professor of Materials Engineering in the Department of Aerospace, Materials and Mechanical Engineering at the Illinois Institute of Technology. Professor Tin’s research has focused on the composition – processing – microstructure – mechanical properties - performance relationships in polycrystalline and single crystal Ni-base superalloys. Prof. Tin is an internationally recognized expert in the field of superalloy creep, fatigue, oxidation and solidification.

Professor Tin serves on the Editorial Committee for Materials Science and Engineering A and Metallurgical and Materials Transactions A. He was the recipient of the 2004 Rolls-Royce Mark Shipton Patent Award, the 2006 IOM3 Cook/Ablett Award and the 2007 ASM Marcus A. Grossmann Award. He has also served as the Chair of the TMS High Temperature Alloys Committee and is currently on the Programming Committee of the 2016 International Conference on Superalloys. Prof. Tin has five patent applications and authored over 90 manuscripts in referred journals and conference proceedings.
The Behavior of Electrons at Nanoscale Interfaces within Colloidal Quantum Dots

Quantum-confined semiconductor nanocrystals, or "quantum dots", are excellent model systems for studies of interfacial chemistry and photophysics. We will discuss methods for quantitative characterization of the chemical structure of the inorganic-organic interfaces within these colloidal materials, and map this chemistry to electronic structure and dynamics relevant to generation of photocurrent and to photocatalysis.

**Biography:** Emily Weiss is a Professor and the Irving M. Klotz Research Professor in the Department of Chemistry at Northwestern University. Emily earned her PhD from Northwestern in 2005, advised by Mark Ratner and Michael Wasielewski. Her graduate work focused on magnetic superexchange interactions of radical ion pairs created by electron transfer within organic donor-acceptor systems. Emily did postdoctoral research at Harvard under George M. Whitesides from 2005-2008 as a Petroleum Research Fund Postdoctoral Energy Fellow, and started her independent career at Northwestern in Fall 2008. Emily's group studies electronic processes at organic-inorganic interfaces within colloidal semiconductor and metal nanoparticles. The objectives of this research are to understand the mechanisms of conversion of energy from one class to another (light, heat, chemical potential, electrical potential) at interfaces, to understand the behavior of quantum confined systems far from equilibrium, and to design and synthesize nanostructures that are new combinations of organic and inorganic components.
Steve McIntosh
Associate Professor
Department of Chemical and Biomolecular Engineering
Lehigh University

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

Functional Materials for Energy Systems: From Ionic Transport to Biomineralization
The McIntosh group focuses on the development of functional materials in energy systems. As opposed to structural materials, functional materials interact with their environment to provide a useful function, be it ionic transport and catalysis in a fuel cell, or light harvesting in a solar cell. In this talk, McIntosh will focus on two specific areas: the use of in-situ powder neutron diffraction techniques to probe ionic transport in materials for solid oxide fuel cells, and biomineralization as a route to the green synthesis of semiconductor quantum dots.

The promise of direct and efficient conversion of chemical to electrical energy makes fuel cell development an area of great technological interest. Solid Oxide Fuel Cells (SOFCs) are one of the most promising technologies to meet this goal. However, the current high operating temperature (typically > 700 °C) is a barrier to wide-scale adoption of the technology. A significant barrier to progress is a lack of experimental techniques that can probe the materials properties under working conditions. In-situ neutron diffraction can reveal information relating to phase transition, order-disorder phenomenon, and the number, location and anisotropic displacement of oxygen vacancies in crystalline oxides over a wide variety of operating conditions. Analysis of this data enables visualization of preferred transport pathways in the material. We couple this with measurements of outer surface composition and surface kinetics to interpret the performance of fuel cell electrodes.

Biomineralization is the process by which living organisms form minerals. The majority of prior biomineralization studies have focused on the production of structural materials, such as bone and shells, similar to those found in nature. The McIntosh group is part of a collaborative effort to utilize biomineralization to produce functional materials. Results will be presented demonstrating the efficacy of this approach for the size controlled green synthesis of semiconductor quantum dots of a range of compositions.

Biography: Steven McIntosh is the Class of ‘61 Associate Professor of Chemical and Biomolecular Engineering at Lehigh University. He received his Bachelor of Engineering from the University of Edinburgh, Scotland, and his MS and PhD in Chemical Engineering from the University of Pennsylvania. He spent a postdoctoral period in the Inorganic Materials Science group of Prof. Henny Bouwmeester at the University of Twente, NL. Dr. McIntosh was an assistant professor at the University of Virginia from 2006 to 2010, prior to joining the faculty at Lehigh University in Fall 2010. He was awarded a Marie Curie Intra-European Postdoctoral Fellowship from the European Union in 2004 and received a National Science Foundation CAREER award in 2007. He is an associate editor for RSC Advances and editor for the RSC Specialist Periodical Reports Electrochemistry.
Nanostructured block copolymers enable the design of membranes with optimized transporting channels for a variety of applications. This presentation addresses the use of these membranes to transport lithium ions in polymeric lithium battery electrolytes, and to separate biofuels such as ethanol and butanol from dilute fermentation broths where they are produced. Previous studies of electrolytes showed an inverse correlation between ionic conductivity and shear modulus: increasing conductivity invariably resulted in a decrease in the shear modulus. Similarly, previous studies of alcohol-selective membranes showed an inverse correlation between alcohol separation factor (ratio of alcohol concentration in the exiting stream to that of the incoming stream) and total flux: increasing the separation factor invariably resulted in a decrease in total flux. Block copolymer membranes do not suffer from these inverse correlations. Practical implications of our discoveries for enabling safe rechargeable batteries and second generation biofuels will be discussed. A large fraction of energy and materials that we use today are derived from industries that consume non-renewable resources. The two projects described here may enable a gradual transition toward a more sustainable approach.

Biography
Nitash P. Balsara is a chemical engineer with a bachelor's degree from the Indian Institute of Technology in Kanpur, India in 1982, a master's degree from Clarkson University in Potsdam, New York in 1984, and a PhD from Rensselaer Polytechnic Institute in Troy, New York in 1988. From 1989-1991, he was a post-doctoral researcher, first at the Department of Chemical Engineering and Materials Science at the University of Minnesota, and then at Exxon Research and Engineering Company in Annandale, New Jersey. In 1992 he joined the faculty of Department of Chemical Engineering at Polytechnic University in Brooklyn, New York. He was promoted to associate professor in 1996 and professor in 1998. In 2000 he accepted the job that he currently holds: a joint appointment as professor of Chemical Engineering at the University of California, Berkeley, and faculty scientist at Lawrence Berkeley National Laboratory.
Inside Out: Visualizing phase transformations and light-matter interactions within individual nanoparticles

In Pixar's Inside Out, Joy proclaims, “Do you ever look at someone and wonder, what is going on inside?” My group asks the same question about nanomaterials whose function plays a critical role in energy, biology, and information-relevant processes. In this presentation, I will describe new techniques that enable visualization of nanoparticle phase transitions in reactive environments as well as light-matter interactions with near-atomic-scale resolution. First, we directly monitor hydrogen absorption and desorption in individual palladium nanocrystals. Our approach is based on in-situ electron energy-loss spectroscopy in an environmental transmission electron microscope. By probing hydrogen-induced shifts of the palladium plasmon resonance, we find that hydrogen loading and unloading isotherms are characterized by abrupt phase transitions and macroscopic hysteresis gaps. These results suggest that alpha and beta phases do not coexist in single-crystalline nanoparticles, in striking contrast with ensemble measurements of Pd nanoparticles. Then, we introduce a novel tomographic technique, cathodoluminescence spectroscopic tomography, to probe optical properties in three dimensions with nanometer-scale spatial and spectral resolution. Particular attention is given to reconstructing a 3D metamaterial resonator supporting broadband electric and magnetic resonances at optical frequencies. Our tomograms allow us to locate regions of efficient cathodoluminescence across visible and near-infrared wavelengths, with contributions from material luminescence and radiative decay of electromagnetic eigenmodes. The experimental signal can further be correlated with the radiative local density of optical states in particular regions of the reconstruction. Our results provide a general framework for visualizing chemical reactions and light-matter interactions with nanometer-scale resolution and in three-dimensions.

Biography: Jennifer Dionne is an assistant professor in the department of Materials Science and Engineering at Stanford University. Jen received B.S. degrees in Physics and Electrical & Systems Engineering from Washington University in St. Louis in 2003, and a Ph.D. degree in Applied Physics from the California Institute of Technology in 2009, advised by Prof. Harry Atwater. She joined Stanford in 2010 following a postdoctoral research fellowship at the University of CA, Berkeley and Lawrence Berkeley National Laboratory, working with Prof. Paul Alivisatos. Jen’s research develops new nano and optical materials for applications ranging from high-efficiency solar energy conversion to bioimaging and manipulation. This research has led to demonstration of negative refraction at visible wavelengths, development of a subwavelength silicon electro-optic modulator, development of quantum plasmonic materials, design of new optical tweezers for nano-specimen trapping, and demonstration of a metamaterial fluid. She was recently awarded the Sloan Foundation Fellowship (2015), the Presidential Early Career Award for Scientists and Engineers (2014), and the inaugural Kavli Nanoscience Early Career Lectureship (2013). She was also named one of Technology Review's TR35 - 35 international innovators under 35 tackling important problems in transformative ways (2011).
Exploring the Behavior and Application of Reactive Materials

Reactive materials are being developed and commercialized for a variety of applications ranging from local heat sources for bonding to dispersed heat sources for bio-agent defeat. In all cases the reactive materials are fabricated into an unstable state from which large amounts of energy can be released. This is true for materials that enable formation reactions, reduction-oxidation reactions, and simple combustion reactions. In the first part of the presentation we will review some of the factors that control the initiation and propagation of formation reactions in Ni:Al multilayer foils, and we will compare results from novel in situ studies of phase transformations (XRD and DTEM) with MD simulations. We will also explore current commercial applications in the field of joining, using both formation and reduction-oxidation reactions. In the second part of the presentation we will review the impact of chemistry and geometry on the initiation and combustion of reactive foils and particles, and we will evaluate their use for defeating bio-agents such as Anthrax.

Biography: Timothy P. Weihs is a Professor in the Department of Materials Science and Engineering at the Johns Hopkins University where his research focuses on reactive materials and the mechanical properties of structural materials and biomaterials. His formal education includes a BA degree from Dartmouth College, an ME degree from Thayer School of Engineering, and a PhD in Materials Science and Engineering from Stanford University. Following a NATO Postdoctoral Fellowship in the Department of Materials at Oxford University and a second postdoctoral position in the Chemistry and Materials Science Department at Lawrence Livermore National Laboratory (LLNL), he joined the faculty in the Department of Materials Science and Engineering at Johns Hopkins University in 1995.

In 2002, Professor Weihs took a three-year leave of absence from Johns Hopkins University and Co-founded Reactive NanoTechnologies (RNT). After growing the company to the point of first commercial sales as CEO, Professor Weihs returned to active duty at Hopkins to focus on the research areas noted above. However, he remains an active consultant for Indium Corporation that purchased and now produces the NanoFoil® product in 2009. His awards include an NSF Career Award, a 3M Young Faculty Fellowship, an R&D 100 Award, an Innovator of the Year Award, and the TMS Application to Practice Award.
Grain boundaries play a decisive role in determining the processing, microstructure and properties of engineering materials. One important aspect of grain boundaries that has not been fully appreciated until more recently is that they can undergo rapid and discontinuous changes in structure and chemistry (and hence properties) at certain values of thermodynamic and interfacial parameters. These phase-like changes in the state of grain boundaries are referred to as grain boundary complexion transitions, to differentiate them from bulk phase changes. More precisely defined a grain boundary complexion is interfacial material or strata that is in thermodynamic equilibrium with the abutting phase(s). This talk will first introduce the general concept of grain boundary complexions and complexion transitions and then proceed to show how it can be utilized to control the microstructure and performance of inorganic materials.

**Biography:**

Martin P. Harmer is the Alcoa Foundation Distinguished Professor of Materials Science and Engineering and the Senior Faculty Advisor for Research Initiatives at Lehigh University. He studied ceramics at Leeds University in England from 1972 to 1980 where he obtained a first class honors B.Sc. degree and a Ph.D. in ceramics. He also earned a higher doctorate (Doctor of Science) degree in ceramics from Leeds in 1995. He directed the Center for Advanced Materials and Nanotechnology at Lehigh for 22 years before assuming his current position as Senior Faculty Advisor for Research. He has supervised more than 60 Ph.D. students and 25 post-doctoral researchers and published over 250 papers. His research has focused on understanding the fundamental mechanisms of interfacial transport and microstructure development in structural and electronic ceramics. His work has led to fundamental discoveries about the nature of grain boundaries including a breakthrough experimental discovery that grain boundaries exhibit phase-like behavior called grain boundary complexion, which has provided new explanations for longstanding problems in material science, such as the origin of abnormal growth and the cause of liquid-metal embrittlement. He is an ISI highly cited researcher and a Distinguished Life Member and Fellow of the American Ceramic Society (ACerS). He has received several other awards from ACerS including the W. David Kingery Award, the Robert B. Sosman Memorial Lecture Award, the Richard M. Fulrath Award, the Ross Coffin Purdy Award and the Rowland B. Snow Award. He is a member of the World Academy of Ceramics and the European Academy of Sciences. He is a recipient of the George C. Kuczynski Prize for Sintering, the Humboldt Prize for Senior Scientists from the Alexander Von Humboldt Foundation, and was a first round recipient of the NSF Presidential Young Investigator Award. He has been an Editor of Acta Materialia since 2007.
Bridging the Gap: Layered Black Phosphorus for Electronics and Optoelectronics

Black phosphorus recently emerged as a promising new 2D material due to its widely tunable and direct bandgap, high carrier mobility and remarkable in-plane anisotropic electrical, optical and phonon properties. It serendipitously bridges the zero-gap graphene and the relatively large-bandgap transition metal dichalcogenides such as molybdenum disulfide (MoS$_2$). In this talk, I will first cover the basic properties of few-layer and thin-film black phosphorus, followed by a discussion of recent observation of highly anisotropic robust excitons in monolayer black phosphorus. Finally I will present a few potential applications of black phosphorus such as radio-frequency transistors and wideband photodetectors.

Biography: Fengnian Xia received the B.S. degree with highest honor in electronics engineering from Tsinghua University, Beijing, China, in 1998 and M.A. and Ph.D. degrees in electrical engineering from Princeton University, Princeton, NJ, USA in 2001 and 2005, respectively. He joined IBM Thomas J. Watson research center in Yorktown Heights, NY, USA as a postdoc in March 2005, and was a Research Staff Member before he started at Yale University as an assistant professor in September 2013. His current research focuses on nanophotonics and nanoelectronics using emerging materials such as graphene, transition metal dichalcogenides, and black phosphorus. He is also actively pursuing carrier transport and light-matter interaction research in dimensional systems.

He received an IBM corporate award, three IBM research division level awards, and numerous IBM invention achievement awards. In 2011, Dr. Xia was selected by MIT technology review magazine as a top young innovator under the age of 35. He received the 2015 Young Investigator Award from the Office of Naval Research (ONR-YIP).

References
Graphics, images and figures — visual representations of scientific data and concepts — are critical components of science and engineering research. They communicate in ways that words cannot. They can clarify or strengthen an argument and spur interest into the research process.

But it is important to remember that a visual representation of a scientific concept or data is a representation and not the thing itself — some interpretation or translation is always involved. And just as in writing a journal article, one must carefully plan a figure or photograph; to decide what to say, and in what order to say it. The process requires clear thinking and the ability to communicate.

Communication, however, is a two-way enterprise. The viewer must first choose to look. This talk will include examples of my own attempts in creating various representations; some more successful than others. I will discuss the iterative process of getting from "here" to "there," in order to create representations that are more than good enough.

**Biography:**

Frankel is a fellow of the American Association for the Advancement of Science, was awarded a Guggenheim Fellowship and held the following positions: Senior Research Fellow in Harvard University’s Faculty of Arts and Sciences, Visiting Scholar at Harvard Medical School’s Department of Systems Biology, and the Chancellor’s Distinguished Visiting Fellow in the Arts and Sciences at UC Irvine. She received the Distinguished Alumna Award at Brooklyn College, CUNY, the Lennart Nilsson Award for Scientific Photography, the Progress Award from the Photographic Society of America, and grants from the National Science Foundation, the National Endowment for the Arts, the Alfred P. Sloan Foundation, the Camille and Henry Dreyfus Foundation, and the Graham Foundation for Advanced Studies in the Fine Arts. She was a Loeb Fellow at Harvard University’s Graduate School of Design.

Working in collaboration with scientists and engineers, Felice Frankel’s images have been published in over 200 journal articles and/or covers. She most recently developed and instructed the first online MOOC addressing science and engineering photography. “Making Science and Engineering Pictures, A Practical Guide to Presenting Your Work.” (course 0.111x)

Felice has been profiled in the New York Times, Wired, LIFE Magazine, the Boston Globe, the Washington Post, the Chronicle of Higher Education, National Public Radio’s All Things Considered, Science Friday, the Christian Science Monitor and various European publications. She exhibits throughout the United States and in Europe. Her limited edition photographs are included in a number of corporate and private collections and were part of MOMA’s exhibition, “Design and the Elastic Mind”.

“More than Pretty Pictures: Representations that communicate and clarify your thinking.”
Form, Color, and Function: Understanding the Appearance of Art through Computational Imaging and Materials Analysis

How do you quantify the appearance of a work of art? Simply, take its picture.

New ways of engaging with cultural heritage objects have been made possible with advances in computation and imaging that allow scientists to analyze art non-invasively, historians to better address its function and context, and the general public to explore and interact with art objects in ways never before possible. In this talk, I demonstrate how the Northwestern University / Art Institute of Chicago Center for Scientific Studies in the Arts (NU-ACCESS) has been adapted these methods of computational imaging (e.g., photometric stereo, hyperspectral imaging, super-resolution X-ray fluorescence imaging, and other techniques) to reduce artworks into their basic components of form, color, and visual content. These data provide a better understanding of how artists worked, how these objects were used, and how they have aged over time. Case studies will be presented that show how multiple wavelengths of light illuminated from all directions onto Roman portrait paintings (2nd C. AD) and works by Paul Gauguin (1848-1903) are helping us re-evaluate how the artists created these paintings and drawings. Finally, I will demonstrate how collection of these data is facilitating material classification through the creation of image-based databases and libraries.

Biography: Marc Walton is the Senior Scientist at the Northwestern University / Art Institute of Chicago Center for Scientific Studies in the Arts (NU-ACCESS) and holds an appointment as a Research Associate Professor of Materials Science and Engineering at Northwestern University. Trained in Chemistry and Art History at Clark University, he earned a D.Phil. from the University of Oxford following an MA in art history and a diploma in the conservation of works of art from the Institute of Fine Arts, New York University. Marc worked at the Los Angeles County Museum of Art for two years prior to joining the Getty Conservation Institute in 2005, where he was an associate scientist responsible for the scientific study of antiquities at the J. Paul Getty Museum. He established and ran the analytical laboratory at the Getty Villa site for eight years. His research has focused primarily on trade and manufacture of ancient objects as well as the development of new computation imaging techniques for the analysis of art.
This talk will discuss the use of microfluidic devices to precisely control the flow and mixing of fluids to make drops, and will explore a variety of uses of these drops. These drops can be used to create new materials that are difficult to synthesize with any other method. These materials have great potential for use for encapsulation and release. I will also show how the exquisite control afforded by microfluidic devices provides enabling technology to use droplets as microreactors to perform reactions at remarkably high rates using very small quantities of fluids.

**Biography**

Weitz received his PhD in physics from Harvard University and then joined Exxon Research and Engineering Company, where he worked for nearly 18 years. He then became a professor of physics at the University of Pennsylvania and moved to Harvard at the end of the last millennium as professor of physics and applied physics. He leads a group studying soft matter science with a focus on materials science, biophysics and microfluidics. He is director of Harvard’s Materials Research Science and Engineering Center, funded by the National Science Foundation. Several startup companies have come from his lab to commercialize research concepts.
In the last decades, colossal effective permittivity (CEP, $\varepsilon_r > 10^{4-5}$) has been reported in a number of electronic ceramics. To date, there are several oxide systems that exhibit this phenomenon. Examples include, CaCu$_3$Ti$_4$O$_{12}$ (CCTO), BaTiO$_3$, K$_{0.3}$MoO$_3$, Bi$_{1-x}$La$_x$NiO$_3$, and more recently co-doped TiO$_2$. In this colloquium presentation, the phenomenon of colossal effective permittivity will be reviewed by focusing on a few of these compounds, to describe our current understanding on the different mechanisms responsible for the observed permittivity (i.e. surface barrier-, grain boundary-, internal barrier-layer capacitor, polaron hopping, etc.). Moreover, recognizing that CEP, is primarily the result of extrinsic and “quenched” intrinsic defects, the effects of composition (precursors, dopants, impurities, etc.), processing (fast firing, reducing atmosphere, etc), and sample preparation (polishing, electroding, annealing) will also be discussed. Further, an attempt to summarize best practices in terms of dielectric characterization that most accurately allow the investigation of the nature of CEP will be made in order to provide a common ground for future research in the field. Finally, an overview of the potential electronics application space for CEP materials will be discussed.

Biography:
Dr. Juan Claudio Nino, is a Professor in the Materials Science and Engineering Department at University of Florida (UF) in Gainesville, FL. He obtained his bachelor’s degree in Mechanical Engineering in 1997 at Los Andes University (Bogotá, COLOMBIA). He was a Lecturer at the Colombian Engineering School before joining The Pennsylvania State University in 1998, where he completed his doctoral degree in Materials Science and Engineering in 2002. After a postdoctoral appointment focusing on ferroelectric thin films at the Materials Research Institute (State College, PA), he joined UF in Fall 2003 as an Assistant Professor. Since, he has established the Nino Research Group (NRG) with main focus of the investigation of fundamental relationships governing energy-related materials towards enhancing their efficiency, performance, and sustainability. NRG’s research investigates ceramics, polymers, bio-inspired materials, and their composites. With over 100 publications in the field and four patents, current research focus includes optimization and development of materials for: (a) electrolytes and cathodes for ionic and protonic conduction devices, (b) high frequency and high temperature dielectrics, ferroelectrics and piezoelectrics, (c) porous ceramics and composite foams, and (d) semiconductors and scintillators for radiation detection. He is a recipient of the CAREER award by the US National Science Foundation. In 2009 he received the J Bruce Wagner Jr Young Investigator Award from the Electrochemical Society. In 2014 he received the Fulbright US Scholar Innovation and Technology Award from the US Department of State. He is an Associate Editor for the Journal of the American Ceramics Society, and a Coordinating Editor for the Journal of Electroceramics.
Advances in solid-state devices have been enabled by the introduction of new materials platforms and their subsequent improvements in carrier concentration, mobility and breakdown voltages. To this end, the exploration of interfaces, where a novel functionality or phenomenon is generated at the interface of two materials that is not present in either of the bulk forms of the constituent materials, is promising. With recent developments in complex oxide thin film deposition techniques, novel ground states at perovskite oxide interfaces have been studied intensively in order to understand the role of mismatches in bands, valences, and interaction lengths. The most well-known example of such emergent phenomena at complex oxide interfaces has been the discovery of metallic behavior at the interface of two band insulators LaAlO$_3$ and SrTiO$_3$. We have recently discovered that low dimensional metallic behavior at the interface of a Mott insulator LaTiO$_3$ and a band insulator SrTiO$_3$ is characterized by quantum oscillations and strong in-plane anisotropic magnetoresistance. Our previous work showed that metallicity can be induced in the bulk of a LaTiO$_3$ film grown on a SrTiO$_3$ substrate. Once the LaTiO$_3$ film thickness is decreased down to 3 unit cells, we observe metallicity associated with the interface. This metallicity is characterized by Shubnikov de Haas oscillations that appear around 1T but unexpectedly disappear by 4T. The frequency of oscillations of $3.7 \pm 0.7$ corresponds to a small cross sectional orbit of $0.015 \pm 0.003\%$ of the first Brillouin zone. The area of the pocket in the Fermi surface causing the oscillations is so small that by 4T the system reaches the quantum limit in which all of the electrons in that pocket are in the lowest Landau level, thus explaining the disappearance of the oscillations by 4T. A Berry’s phase of $\pi$ is deduced from the Shubnikov de Haas oscillations and can be attributed to a large Rashba coupling. This is consistent with the observed in-plane anisotropic magnetoresistance as both its size and magnetic field dependence have been theoretically predicted for a system with a very strong Rashba effect. Such a large Rashba coupling suggests that such a Mott/band insulator interface may be an excellent candidate for spintronics.

**Biography:**
Yuri Suzuki received an A.B. in physics magna cum laude with high honors from Harvard University in 1989 followed by a Ph.D. in Applied Physics from Stanford University in 1995. During her graduate career, she performed research on high temperature superconductivity and complex oxide thin films with NSF and ARCS Foundation fellowships. As a postdoctoral member of technical staff at AT&T Bell Labs (1994-1996), she moved into the field of magnetism. She then assumed an assistant professor position at Cornell University in the Department of Materials Science and Engineering (1997) and was later promoted to associate professor (2001). She moved to UC Berkeley in 2003 as an associate professor and was later promoted to professor in 2008. She is currently in the Department of Applied Physics at Stanford where she moved to in 2012. She has been recognized with an NSF Career Award, ONR Young Investigator Award, Packard Foundation Fellowship, Robert Lansing Hardy Award of TMS, Maria Goeppert-Mayer Award of the American Physical Society, American Competitiveness and Innovation Fellowship of the National Science Foundation, Fellowship in the American Physical Society and the DoD National Security Science & Engineering Faculty Fellowship.
Many nanomaterials (e.g. graphene, metallic nanowires, and ceramic nanospheres) exhibit extraordinary strength, ductility and flaw tolerance. These nanoscale size effects can be transmitted to the bulk by arranging nanostructures in 3D hierarchical architectures with optimized structural topologies, but these nano-architected structures are challenging to construct using conventional manufacturing techniques.

We present the use of two-photon lithography to fabricate 3D copper lattices made up of micronsized beams connected at solid nodes in the octet geometry. Mechanical testing reveals that the porous Cu lattice has higher strength than monolithic copper with the same volume and microstructure. This counterintuitive behavior results from size-dependent strength enhancement within lattice beams coupled to the strong and lightweight structural geometry.

We also explore the use of self-assembly to form mechanically robust nanocomposites from solution-processed nanoscale building blocks. Polystyrene grafted Au nanoparticles are self-assembled at a fluid interface to form ordered, superlattice thin films with sub-10 nm features. The mechanical properties of superlattice thin films depends critically on polystyrene molecular weight and grafting density, and the degree of lattice disorder.

Biography:
Xun Wendy Gu is a postdoctoral scholar with Prof. Paul Alivisatos at UC Berkeley. She is interested in the size-dependent mechanical properties of architected nanomaterials such as metallic and polymeric nano-lattices, pillars, and semiconducting quantum dots. Her current work focuses on the use of colloidal synthesis and self-assembly to make structurally robust nanocomposites, and semiconductor quantum dots for use as luminescent stress sensors in biological systems and structural polymers. Wendy received her PhD at the California Institute of Technology, where she worked with Prof. Julia Greer on the strength, deformation and fracture of lithographed metallic nanostructures. Before starting graduate school, Wendy was a Fulbright Scholar with Prof. Ernesto Joselevich at the Weizmann Institute of Science in Israel. Wendy received a B.S. in Chemical Engineering from UC Berkeley in 2009.
“Engineering Optoelectronic Point Defects in Nanoscale Materials” Designing point defects within nanoscale materials remains an active area for both basic and applied research. This seminar will present recent results with engineering specific point defects in both 1) nanodiamond (NV\(^{−}\), Si-V\(^{−}\)) and 2) yttrium-lithium-fluoride nanocrystals (Yb\(^{3+}\), Er\(^{3+}\)). In the first half of the seminar high-pressure, high-temperature processing in a laser-heated diamond anvil cell [PNAS (2011), v.108 p.8550] will be presented as a promising strategy for engineering both the nitrogen-vacancy center and silicon di-vacancy center within nanocrystalline diamond materials. In the second half of the seminar recent results [PNAS (2015), v.112, p.15024] will be presented showing that it is possible to cool colloidal dispersions of yttrium-lithium-fluoride nanocrystals (YLiF\(_4\) or YLF) in liquid water based on anti-Stokes photoluminescence from Yb\(^{3+}\) point defects. Solid-state laser-refrigeration materials have been developed in the last 10 years that are capable of cooling to cryogenic temperatures without mechanical vibrations to enable a range of advanced optoelectronic sensing applications. However, to date it has remained an open question whether solid-state laser refrigeration materials can also be used to refrigerate condensed phases such as liquid water. We use single-beam laser trapping experiments to show that the temperature of water surrounding individual YLF crystals decreases by nearly 20°C from room temperature based on interferometric measurements of a particle's Brownian motion, suggesting a range of potential applications for solid-state laser-refrigeration at nanometer length scales.

**Biography:**

Peter Pauzauskie received BS degrees in chemical engineering, chemistry, and mathematics from Kansas State University in 2002 after pursuing undergraduate research in the chemistry laboratory of Prof. Ken Klabunde where he focused on understanding complex surface reactions between magnesium oxide nanocrystals and methyl iodide molecules. After being recognized with the Barry M. Goldwater Scholarship and the National Science Foundation’s Graduate Research Fellowship he pursued a Ph.D. in physical chemistry with Prof. Peidong Yang at the University of California, Berkeley where his dissertation focused on the synthesis, characterization, and optoelectronic integration of inorganic nanowires. After graduating in 2007 he started a post-doc in the Chemical Sciences Division of the Lawrence Livermore National Laboratory as a DOE Lawrence Fellow under the direction of Dr. Joe H. Satcher, Jr. where he focused on novel diamond- and graphene- based carbon aerogel materials. Since 2010 Prof. Pauzauskie has served as an assistant professor in the Materials Science & Engineering department at the University of Washington.
Heat Under the Microscope: 
Uncovering the Microscopic Processes that Govern Thermal Transport

Thermal transport is a ubiquitous process that incorporates a wide range of physics and plays an essential role in nearly every technological application, ranging from space power generation to consumer electronics. In many solids, heat is carried by phonons, or quanta of lattice vibrations. Compared to other energy carriers such as electrons or photons, the microscopic transport properties of thermal phonons remain remarkably poorly understood, with much of our understanding still based on semi-empirical studies from over fifty years ago. In this talk, I will describe our efforts to uncover the microscopic processes that govern thermal transport by phonons. In particular, I will describe how our advances in computation and experiment have enabled the first direct measurements of thermal phonon transmission coefficients at solid interfaces. I will demonstrate how these insights are advancing applications ranging from thermoelectric waste heat recovery to radio astronomy.

Bio:
Austin Minnich is an Assistant Professor of Mechanical Engineering and Applied Physics at the California Institute of Technology. He received his Bachelor’s degree from UC Berkeley in 2006 and his PhD from MIT in 2011, after which he started his position at Caltech. He is the recipient of a 2013 NSF CAREER Award and a 2015 ONR Young Investigator Award. His research interests focus on understanding the fundamental processes governing heat transport and using these insights to advance technologies for space exploration, consumer electronics, and energy conversion.
Ionic liquids (IL’s) have been suggested for applications as diverse as solubilizing cellulose, antimicrobial treatments, and electrolytes in batteries due to their molten salt properties. We have recently discovered that a polymerized cation (such as imidazolium) is an excellent host for any associated anion. As a result, polymerized ionic liquids are not just solid counterparts to IL’s, but are excellent vectors for the inclusion of a massive variety of functionalities ranging from multi-valent ions for batteries to magnetic anions. Moreover, PIL block copolymers allow orthogonal control over mechanical and morphological properties, ultimately leading to a conceptual framework for processable, tunable, multifunctional materials. In this talk, I will discuss a class of protic polymerized ionic liquids (PILs) based on imidazolium cations which exhibit high ionic conductivities in the solid state. Further, the scaling of conductivity with IL loading, domain spacing, and temperature will be explored and polyelectrolyte block copolymers.

Biography:
Rachel A. Segalman received her B.S. from the University of Texas at Austin and Ph.D from the University of California, Santa Barbara. She was a postdoctoral fellow at the Universite Louis Pasteur before joining the faculty of UC Berkeley in 2004 where she was recently the Acting Division Director for Materials Sciences at Lawrence Berkeley Laboratories. In the summer of 2014, she moved to UC Santa Barbara to be the Kramer Professor of Chemical Engineering and Materials and became Department Chair of Chemical Engineering in 2015. Segalman’s group works on controlling the structure and thermodynamics of functional polymers including polymerized ionic liquids and semiconducting and bioinspired polymers. This has led to a host of new and promising applications, particularly in plastic thermoelectrics. Among other awards, Segalman received the 2015 Journal of Polymer Science Innovation Award, the 2012 Dillon Medal from the American Physical Society and is an Alfred P. Sloan Fellow and a Camille Dreyfus Teacher Scholar.
Andrew Rappe  
Professor of Materials Science and Engineering,  
Professor of Chemistry & Co-Director of Pennergy  
University of Pennsylvania  
Tuesday, May 10th, 2016  
4:00pm, Tech L361

The Bulk Photovoltaic Effect in Polar Oxides for Robust and Efficient Solar Energy Harvesting

ABSTRACT: Solar energy is the most promising source of renewable, clean energy to replace the current reliance on fossil fuels. Ferroelectric (FE) materials have recently attracted increased attention as a candidate class of materials for use in photovoltaic devices. Their strong inversion symmetry breaking due to spontaneous polarization allows for excited carrier separation by the bulk of the material and voltages higher than the band gap (Eg), which may allow efficiencies beyond the Shockley-Queisser limit. Ferroelectric oxides are also robust and can be fabricated using low cost methods such as sol-gel thin film deposition and sputtering. Recent work has shown how a decrease in ferroelectric layer thickness and judicious engineering of domain structures and FE-electrode interfaces can dramatically increase the current harvested from FE absorber materials. Further improvements have been blocked by the wide band gaps (Eg =2.7-4 eV) of FE oxides, which allow the use of only 8-20% of the solar spectrum and drastically reduce the upper limit of photovoltaic efficiency.

In this talk, I will discuss new insight into the bulk photovoltaic effect, and materials design to enhance the photovoltaic efficiency. We calculate from first principles the current arising from the “shift current” mechanism, and demonstrate that it quantitatively explains the observed current. Then, we analyze the electronic features that lead to strong photovoltaic effects. Finally, we present new oxides that are strongly polar yet have band gaps in the visible range, offering prospects for greatly enhanced bulk photovoltaic effects.

BIO: Andrew M. Rappe is a Professor of Chemistry and Professor of Materials Science and Engineering at the University of Pennsylvania. He received his A. B. in “Chemistry and Physics” summa cum laude from Harvard University in 1986, and his Ph. D. in “Physics and Chemistry” from MIT in 1992. He was an IBM Postdoctoral Fellow at UC Berkeley before starting at Penn in 1994. Andrew received an NSF CAREER award in 1997, an Alfred P. Sloan Research Fellowship in 1998, and a Camille Dreyfus Teacher-Scholar Award in 1999. He was named a Fellow of the American Physical Society in 2006. Andrew is one of the two founding co-directors of Pennergy: the Penn Center for Energy Innovation. He is also one of the founding co-directors of the VIPER honors program at Penn, the Vagelos Integrated Program in Energy Research. Andrew has published more than 200 peer-reviewed articles. Many of his current research interests revolve around ferroelectric phase transitions in oxides, surface chemistry and catalysis of complex oxides, and the interplay between the two: a) He helped establish relationships between composition and ferroelectric phase transition temperature in bismuth-containing perovskite oxides, b) He predicted that changing chemical vapor composition above a ferroelectric oxide could reorient its polarization, c) He revealed the mechanism of domain wall motion in ferroelectric oxides, d) He showed that changing ferroelectric polarization dramatically changes catalytic activity of supported metal films and nanoparticles, and e) He uses computational materials design to invent new ferroelectric photovoltaics for solar applications. In recent years, he has become actively involved in the theory of hybrid organic-inorganic perovskites and topological materials.
Spin current: the torque wrench of spintronics

Abstract:
Spintronic devices use the spin of the electron as well as its charge. The current in these devices is spin polarized, due to the inclusion of ferromagnetic materials, so that their conductance depends on the state of the ferromagnet. This dependence allows these devices to serve as sensitive magnetic field detectors or as memory elements, in which information is stored in the magnetic state. However, not only does the polarized current depend on the magnetic configuration, but the spin current can manipulate the magnetic state. This recent development has led to rapid progress in novel memory devices. In this talk, I mention existing and proposed spintronic devices and describe the variety of ways in which the spin current can manipulate the magnetization. I focus on bilayers of ferromagnetic thin films on top of non-magnetic films with strong spin orbit coupling. Recent measurements on these systems have shown dramatic effects, but the interpretation of the experiments is still controversial, making it a fast moving exciting field.

Bio:
Mark Stiles received his undergraduate degree in Physics from Yale University, and Ph.D. in Physics from Cornell University. Following postdoctoral research at AT&T Bell Laboratories, he joined the research staff at NIST where he is now a NIST Fellow in the Center for Nanoscale Science and Technology. He is also an Adjunct Professor in the Department of Physics and Astronomy at the Johns Hopkins University. Mark’s research at NIST has focused on the development of theoretical methods for predicting the properties of magnetic nanostructures. He is a Fellow of the American Physical Society and has served the American Physical Society in various capacities.
Electrochemistry in the molten state: from sustainable metal extraction to materials fundamentals

Abstract: Metals and metallurgy played a foundational role in the materials science we learn today, in particular to demonstrate how condensed matter physics allows the prediction of solid-state properties. Similar predictive capacity is lacking for the molten state, and liquid metals and molten oxide or sulfide are again remarkable candidates to progress in that endeavor. Independently of this conceptual landscape, metals remain at the basis of modern society and their affordable and environmentally respectable extraction and recycling is required. In the context of 9 billion people by 2050 and issues such as greenhouse gas emissions, my research group aims at developing alternative approaches for metals extraction and processing. The electrochemistry of the molten state is an integral part of our endeavor, compatible with the deployment of sustainable electric power generation [1]. This seminar offers to report electrochemical studies of a subset of molten oxide [2,3] and sulfide [4] systems. Our results show that the molten state offers unique functionalities (enhanced mass transport, high conductivity, electronic conductivity, thermoelectric power) and that electrochemistry is uniquely positioned to probe the structure and physical chemistry of those systems. In addition, our results provide valuable thermodynamic information, and our experimental developments suggest a faster path to experimental data, along with an improvement in the prediction and modeling capacity of the molten state.

Bio: Prof. Allanore’s research applies to sustainable materials extraction and manufacturing processes. He joined MIT in 2010, after several years of service within one of the world largest iron and steel R&D center. As a faculty in the Department of Materials Science & Engineering, he has developed numerous alternative approaches to metals and minerals extraction and processing, for example a waste-free process to produce a potassium fertilizer from earth-abundant raw materials. In the field of metal extraction, he demonstrated a new electrolyte for metal extraction from sulfides, which offer to produce copper, molybdenum, tin, zinc or precious metals without SOx emissions. With an emphasis on electrochemical methods for both analytical and processing purposes, the Allanore group offers a unique combination of experimental and modeling approaches to promptly investigate the ultimate state of condensed matter, the molten state, and its relation with the corresponding solid-state phases. Prof. Allanore was awarded the TMS DeNora Prize in 2012, recognizing outstanding contribution to the reduction of environmental impacts, especially focused on extractive processing, as well as the Early Career Faculty award also from TMS.