

Materials Science and Engineering

Thomas E. Mallouk

Evan Pugh Professor of Materials Chemistry and Physics
Penn State University

Tuesday, October 2, 2012
Tech L211, 4:00pm

Nanomaterials in One Dimension: Exploring Mesoscopic Phenomena in Template-Grown Nanowires

Mesoscopic properties are those that emerge when the size of an object matches a characteristic physical length scale, such as the exciton radius in a semiconductor or the coherence length of Cooper pairs in a superconductor. Nanowires are particularly interesting in this context as quasi-1D materials. By using anodic alumina and track-etched polymer membranes act as hard templates, we have made “striped” and core-shell nanowires with precise control over dimensions and composition. These structural features allow one to explore unusual electronic transport properties of single-crystal nanowires and their possible applications in molecular and nanoscale electronics. The motion of nano- and microwires in fluids is also a mesoscopic phenomenon at low Reynolds number. In this application, bi- and trimetallic nanorods are catalytically self-propelled in fuel-containing

solutions at speeds that are comparable to those of flagellar bacteria. Despite the difference in propulsion mechanisms, catalytic nano- and micromotors are subject to the same external forces as natural motors such as bacteria. Therefore they follow the same scaling laws and exhibit similar emergent behavior (e.g., magnetotaxis, chemotaxis, schooling, and predator-prey behavior). Recently we have found that bimetallic nanowires also undergo autonomous motion and a range of collective behavior in fluids when excited by low power ultrasound. The acoustophoretic propulsion mechanism may be particularly useful for biomedical applications because it is salt-tolerant and does not involve toxic chemical fuels.

Bio: Thomas E. Mallouk was born in New York and received an Sc.B. degree in 1977 from Brown University. He was a graduate student at the University of California, Berkeley, and a postdoctoral fellow at MIT. In 1985, he joined the Chemistry faculty at the University of Texas at Austin. In 1993 he moved to Penn State, where he is now Evan Pugh Professor of Materials Chemistry and Physics. His research has focused on the application of inorganic materials to different problems in solid state and surface chemistry, including photochemical energy conversion, nanoscale electronics, catalysis and electrocatalysis, chemical sensing, nano- and microscale motors, superconductivity, and environmental remediation. He is the author of approximately 350 publications, including a few good ones. He is an Associate Editor of the *Journal of the American Chemical Society* and Associate Director of the Penn State MRSEC, the *Center for Nanoscale Science*.

Thomas Tsakalakos

Distinguished Professor, Materials Science and Engineering Department
Rutgers University

Tuesday, October 9, 2012
Tech L211, 4:00pm

Accelerating Materials Development by In-Situ Strain and Phase Mapping Synchrotron Probe

Strain and Phase Mapping Advanced Synchrotron Probe Technique provides an experimental tool for research and development programs designed to accelerate materials and manufacturing innovation. We will demonstrate the applicability of the technique in the Acceleration of materials development and deployment process conceptualized efforts of Materials Genome Initiative: Energy, Life Prediction and Ceramic Nanocomposites for optical applications.

Energy Dispersive X-Ray Diffraction (EDXRD) Synchrotron Probe Technique is used to identify internal processes of batteries, full-sized commercial embodiments, under real operating conditions. The development of “in situ analytical tools” characterizing the structural changes of the cathode, separator, electrolyte, and anode materials constitutes a breakthrough for battery development. Moreover, the operation of commercially available

lithium based batteries using EDXRD will be discussed as a novel technique that provide in-situ characterization of batteries in their manufactured geometries and packaging. The potential for failure due to fatigue cracking under various environmental conditions is an omnipresent problem in the life of load bearing engineering components. Most models predict fatigue crack growth based upon the locally singular crack tip strain/stress fields. High energy synchrotron based x-ray diffraction techniques have evolved providing a wealth of detail for crack strain fields. EDXRD experiments are used to perform local crack plane strain profiling of steel and aluminum alloys compact tension specimens in different environments. The EDXRD mapping of a three-dimensional space distribution of local residual stresses at the crack tip, mapping of the plastic zone, influenced by the combined chemical and stress effects, is a promising step toward life predictions of these alloys. The phase field microelasticity theory in conjunction with the time-dependent Ginzburg–Landau equation will be introduced for the long-range strain-induced interaction stress corrosion cracking by cracks, hydrogen and oxide formations.

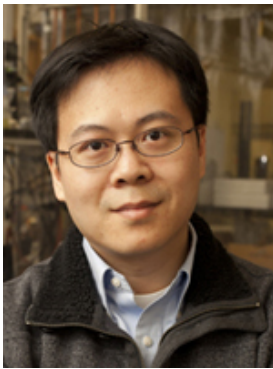
Biography: Professor Tsakalakos is one of the pioneers of the field of Nanostructured Materials and Technology and was the Founder and Editor-in-Chief of the Nanostructured Materials Journal for over ten years, publishing 12 volumes of scientific work in Nanomaterials Research. Prof. Tsakalakos participated in the NanoTechnology Initiative (NNI) initiated by Pres. Clinton and continues to have a major input to the field of Mechanical Properties of Nanostructured Materials. His recent research activities have focused on Nanostructured films and Coatings, processing of nanoparticles and advanced characterization methods such as Light Source Synchrotron including studies of nanostructures as well as Magnetic Nanostructures which is considered a significant contribution to “magnetic storage and sensing”. His work in the 70’s and early 80’s established Dr. Tsakalakos as an authority in the field of Nanomultilayers. Most recently, his work on 3D internal stresses determination by synchrotron probe at the nanoscale level has been recognized by Defense University Research Initiative on Nanotechnology as innovative approach to the new field of nanomechanics. Other earlier research activities include Nanotechnology for Magnetic storage, biomedical and catalysis applications.

Materials Science and Engineering

Jiaying Huang

Assistant Professor, Materials Science and Engineering Department
Northwestern University

Tuesday, October 16, 2012
Tech L211, 4:00pm

**Graphene Oxide: Curiosities, Challenges and Solutions**

Graphite oxide sheets, now called graphene oxide (GO), are made by exfoliation of graphite using century-old chemical reactions. Interest in this old material has resurged with the rapid development of graphene since 2004, as GO is considered to be a promising precursor for bulk production of graphene. Apart from making graphene, GO itself also has many intriguing properties. For example, GO can be viewed as soft material such as two-dimensional (2D) polymers, highly anisotropic colloids that can form liquid crystals, membranes, or 2D surfactants.

In this talk, I will share some curiosity driven discoveries such as the use of GO as surfactant, which has led to all-carbon composites for solar cells. GO sheets can also re-stack to construct nanofluidic ion channels. Next, I will highlight a few problems associated with the manufacturing and processing of GO and its graphene product, including the potential fire risk of GO, the difficulties of imaging these single atomic layers and their ease of aggregation during processing. Strategies and solutions to address these problems will be introduced.

Biography: Jiaying Huang is an Assistant Professor of Materials Science and Engineering and the Morris E. Fine Junior Professor in Materials and Manufacturing at Northwestern University. He received a B.S. in Chemical Physics from the University of Science and Technology of China in 2000, a Ph.D. in chemistry from the University of California, Los Angeles (UCLA) in 2004, and became a Miller Research Fellow at the University of California, Berkeley before joining Northwestern in 2007. His main research interest is in the general area of material chemistry and processing. Some of the examples include 2D soft materials, organic nanocrystals and metal nanostructures. He is also interested in the application of these materials in energy conversion and storage, as well as using them as a platform for materials education. He is a recipient of the Alfred P. Sloan Research Fellowship and the NSF CAREER Award.

Derk Joester

Assistant Professor, Materials Science and Engineering Department
Northwestern University

Tuesday, October 23, 2012
Tech L211, 4:00pm

**Reverse Engineering Biological Crystal Growth**

Biom mineralization, the formation of hard tissues such as bones, shells, and teeth, is a bottom-up crystal growth process with unrivalled control over hierarchical architecture and mechanical properties. Many hallmarks of biological crystal growth have yet to be reproduced *in vitro*: simultaneous polymorph control, and growth of smoothly curving and branching single crystals. Mastering the capabilities of the biosynthetic machinery offers fascinating opportunities from material synthesis to environmental remediation.

However, it is extremely challenging to isolate the role of individual elements of the biological crystal growth machinery. To address this problem, we have established a unique *in vitro* cell culture system where we can control intracellular biom mineralization. In particular, we are able to direct primary mesenchyme cells (PMCs) isolated from the sea urchin embryo to collaboratively deposit oriented, single crystalline calcite spicules using surface micro-patterning. In a recent breakthrough, we have discovered that a recombinant sea urchin homolog of vascular endothelial growth factor, rVEFG, induces PMC in culture to switch from bi-directional crystal growth to threefold rotationally symmetric branching. Remarkably, the change in crystal habit occurs with a switch of crystal growth direction from the *c*-axis to the *a*-axes of the calcite lattice. This provides unprecedented opportunities to study cellular control over crystal growth processes.

The ability of PMCs to control crystal growth direction and create single crystals with smoothly curving surfaces has been linked to the use of a metastable precursor, amorphous calcium carbonate (ACC). How cells synthesize, stabilize, and control the phase transformation of ACC to a crystalline polymorph remains largely unknown. Based on a model system in which we synthesized and stabilized ACC nanoparticles in liposomes, I will discuss the influence of confinement and membrane chemistry on nucleation and growth of biom minerals at biological length scales.

Finally, I present our efforts to better understand the nano-composite nature of biom minerals. Proteins and other macromolecules occluded in the mineral are part of the organic matrix that mediates crystal nucleation, growth, and controls the materials properties of the composite. Atom probe tomography (APT), an imaging mass spectrometry technique of unrivalled spatial resolution (< 0.2 nm) and chemical sensitivity, allows us to dramatically improve our understanding of the complex chemistry and structure of nano-scale organic/inorganic interfaces in the ultrahard biomagnetite tooth cusp of the chiton, a mollusk that literally munches on rocks. I will report on our recent efforts to expand APT analysis to tooth enamel, dentin, and bone, among others.

Biography: Derk is originally from Munich (Germany) and studied Chemistry in Tübingen. He travelled to the US on a Fulbright Scholarship to study Chemistry and Biochemistry, and then went on to get his Diploma in Organic Chemistry at ETH Zurich, Switzerland in 1998. He received his Ph.D. for work carried out in supramolecular chemistry with Prof. François Diederich at ETH Zurich in 2003, and in the same year became a Postdoctoral Fellow at Weizmann Institute of Science in the lab of Prof. Lia Addadi in the Department of Structural Biology. From 2005-2007 he continued his research at the Weizmann Institute as a Minerva Fellow. In September 2007 he accepted a position at the Materials Science & Engineering Department at Northwestern University, Evanston, Illinois. He was appointed the Morris E. Fine Professor of Materials and Manufacturing 2009-2011. His research interests include biological processing of composite materials and the structure and properties of the resulting hierarchical architectures.

Robert Klie

Associate Professor, Department of Physics
University of Illinois at Chicago

Tuesday, November 6, 2012
Tech L211, 4:00pm

**Chemical Analysis with Sub-Å Resolution: The Power and Challenges of Aberration-Corrected Scanning Transmission Electron Microscopy**

The last few years have seen a paradigm change in scanning transmission electron microscopy, STEM, with unprecedented improvements in both spatial and spectroscopic resolution being realized by aberration correctors, cold-field emission guns and monochromators. The successful correction of lens aberrations has greatly advanced the ability of the STEM to provide direct, real space imaging at atomic resolution. Very complementary to reciprocal space methods, this is especially advantageous for aperiodic systems, nanostructures, interfaces and point defects. Aberration-correction has also enabled the development of new imaging techniques, such as incoherent annular bright field (ABF) imaging, which enables the direct visualization of light atoms, such as hydrogen. While these instrumentation developments have brought notable successes in materials analysis, in particular for hetero-interfaces, catalysis and thin-film studies, they have also challenged the established experimental protocols and our fundamental understanding of both imaging and spectroscopy in the STEM. Aberration correction also allows increased flexibility in choosing the appropriate electron energy to minimize beam induced damage while maintaining atomic-resolution (e.g. 60 keV electrons for studying graphene with 1.3 Å resolution).

Here, I will present the latest results from the new probe aberration-corrected cold-field emission JEOL JEM-ARM200CF at UIC, which allows in-situ characterization with 78 pm spatial resolution and an energy resolution of 350 meV in the temperature range between 10 K and 1,300 K using a variety of in-situ heating, cooling, tomography and electrical feedback holders. The primary electron energy can be chosen between 80 and 200 kV. I will show how low-energy imaging can now be used to characterize beam-sensitive materials without significant loss in spatial resolution and how such experiments enable direct correlation with other techniques, including atom-probe tomography and first-principles modeling.

I will discuss the direct imaging of hydrogen atomic column in β -NbH [110], and its application to superconducting RF cavity development. A direct comparison with local electrode atom probe (LEAP) tomography will be presented. Next, the ferroelectric polarization in BaTiO₃ thin films will be quantified using ABF and HAADF imaging and the effects of interfacial charge accumulation on the density of states will be discussed. Finally, I will show that single atom imaging can be achieved in heterogeneous catalysts, and that promoter effects can be studied on the atomic scale. The effects of defects and interfaces on the local atomic and electronic structures in these materials will be discussed. I will conclude with a perspective on future developments in STEM analysis.

Biography: Dr. Robert F. Klie began his undergraduate education at the University of Bonn in Germany and received his PhD from the University of Illinois. After graduating in 2002, Dr. Klie joined the Materials Science Department at Brookhaven National Laboratory as a Goldhaber Fellow. In 2006, Dr. Klie joined the Physics Department at the University of Illinois – Chicago as an Assistant Professor and was promoted to Associate Professor in 2011. At the University of Illinois at Chicago, Dr. Klie has pioneered in-situ heating and cooling experiments using atomic-resolution Z-contrast imaging and EELS of oxide grain boundaries, heterogeneous catalysts, as well as semiconductor thin-films. In 2008, Dr. Klie was awarded a National Science Foundation (NSF) CAREER award and in 2010, he was granted \$3M from the NSF to purchase an aberration-corrected, cold-field emission scanning transmission electron microscope at the University of Illinois – Chicago. The JEOL JEM-ARM200CF was installed at UIC earlier this year and is now one of the highest resolution 200 kV STEM in the United States which allows for in-situ experiments, and provides 68 pm spatial, as well as 0.35 eV energy resolution.

Materials Science and Engineering

Michele Manuel

Assistant Professor, Materials Science and Engineering Department
University of Florida

Tuesday, November 13, 2012
Tech L211, 4:00pm



Smart Multifunctional Metal Matrix Composite Design

Modern materials contain extraordinary levels of complexity with components spanning a hierarchy of length scales. Designing materials that contain complex microstructures and demonstrate unique behaviors would be difficult solely using a reductionist approach to materials development. Although this approach has led to many technological breakthroughs, the rapid evolution of technology and the need for a shortened materials development cycle are driving materials scientists toward a more predictive approach based on design.

Metal matrix composites (MMC) have the potential to demonstrate extraordinary properties including, but not limited to, high strength and toughness. The metal matrix composites that are the focus of this presentation utilize design objectives that incorporate low-cost processing techniques to develop sustainable engineering materials. We are currently developing methods to integrate structural and mechanically-active materials in to metal matrices for use in smart/multifunctional biomimetic systems. Such materials would have the capability of performing higher-ordered tasks such as sensing, and health-monitoring. This talk seeks to present the challenges and opportunities in metal matrix composite development, as well as shed new light on the potential of non-traditional methods to metal matrix composite design and fabrication that can lead to composites with unique behaviors. The focus of the talk will illustrate the impact of a thermodynamically-driven, systematic design approach to address and provide solutions for the problems of the past.

Biography: Michele Manuel is an Assistant Professor in the Department of Materials Science and Engineering at the University of Florida. She received her Ph.D in Materials Science and Engineering at Northwestern University in 2007 and her B.S. in Materials Science and Engineering at the University of Florida. She is the recipient of the NSF CAREER, NASA Early Career and TMS Young Leaders Professional Development Awards. Her research lies in the basic understanding of the relationship between processing, structure, properties and performance. She uses a systems-based materials design approach that couples experimental research with theory and mechanistic modeling for the accelerated development of materials. Her current research is focused on the use of systems-level design methods to advance the development of new materials through microstructure optimization. Of specific interest are biomedical, lightweight, multifunctional, and self-healing alloys.

Materials Science and Engineering

Paul V. Braun

Professor, Materials Science and Engineering Department
University of Illinois at Urbana-Champaign

Tuesday, December 4, 2012
Tech L211, 4:00pm

Self-Assembly of Ultra-High Power Batteries and 3D Optoelectronically Active Photonic Crystals



Over the past decade, the sophistication of self and directed-assembly approaches for functional composite structures has increased dramatically, however, application of such structures in real-world systems has remained largely elusive, in part because such structures almost always contain finite defect densities. The storing, generating and harvesting of photons and electrons presents a unique opportunity for self-assembled composite materials. These applications are not only generally much more defect tolerant than for example self-assembled computational electronics, but also for these areas to make a substantive impact on the world energy situation, they must be produced in exceptionally large volume. In my talk, I will attempt to capture the state-of-the-art in highly functional self-assembled three-dimensional composites for energy harvesting and storage illustrated with examples from both my research and other groups with a particular focus on high charge and discharge rate nanostructured electrochemical energy storage systems (batteries and supercapacitors), and photonic crystals which exhibit unprecedented control over the absorption and emission of light (lasers, LEDs, and solar cells). If time permits, I will also give a vignette from our work on mechanochemistry.

Biography: Paul V. Braun is the Ivan Racheff Professor of Materials Science and Engineering, and an affiliate of multiple other departments at the University of Illinois at Urbana-Champaign. Prof. Braun's research focuses on the synthesis and properties of 3D architectures with a focus on materials with unique optical, electrochemical, thermal, and mechanical properties. Prof. Braun received his B.S. degree with distinction from Cornell University in 1993, and his Ph.D. in Materials Science and Engineering from Illinois in 1998 with Prof. Samuel Stupp. Following a postdoctoral appointment at Bell Labs, Lucent Technologies, he joined the faculty at Illinois in 1999. Prof. Braun has co-authored a book, authored over 150 peer-reviewed publications, been awarded multiple patents, and has founded two companies. He is the recipient of the Friedrich Wilhelm Bessel Research Award of the Humboldt Foundation (2010), the Stanley H. Pierce Faculty Award (2010), a 3M Nontenured Faculty Award, the 2002 Robert Lansing Hardy Award from TMS, a Beckman Young Investigator Award (2001), the Xerox Award for Faculty Research (2004, 2009), and multiple teaching awards. In 2006, he was named a University Scholar by the University of Illinois, and in 2011 was named the Ivan Racheff Professor of Materials Science and Engineering.

Materials Science and Engineering

Dane Morgan

Associate Professor, Materials Science and Engineering Department
University of Wisconsin – Madison

Tuesday, January 22, 2013
Tech L211, 4:00pm

Molecular Scale Understanding and Design of Solid Oxide Fuel Cell Cathodes

From peak oil to global warming to grid stability, a host of issues suggest that our methods for obtaining energy will have to change dramatically over the next few decades. Solid Oxide Fuel Cells (SOFCs) extract energy from fuels electrochemically, and offer a clean, low-emission, quiet, reliable, fuel adaptable, and highly efficient way to obtain power. Many researchers are therefore exploring SOFCs for applications ranging from integration into coal and gas power plants to distributed power for buildings. An outstanding challenge in the design of SOFCs is that they must catalyze the oxygen reduction reaction, $O_2(\text{gas}) + 2e^- \rightarrow 2O^{2-}(\text{solid})$. This reaction requires good catalysts and can only be done efficiently at high temperature, limiting the durability and applicability of the fuel cells. There is therefore a strong interest in developing improved catalysts for SOFCs. Present SOFC catalysts are typically perovskite oxides, which can reduce O_2 gas and transport O^{2-} through their bulk to the electrolyte. However, this unusual chemical reaction is still poorly understood, inhibiting the development of improved SOFC technologies. In this talk I will discuss how ab initio quantum mechanical methods can be used to better understand and design improved cathode materials. As the SOFC cathode reaction includes both oxygen reduction and bulk transport, the catalytic performance of perovskites couples strongly to both their bulk and surface defect thermokinetics. We will demonstrate how bulk defect properties can be predicted, including defect chemistry and kinetics and potential coupling to strain. We then demonstrate some of the challenges of predicting perovskite catalytic activity, and discuss both direct mechanistic approaches and how correlating descriptors with the activity can be used to predict performance.

Biography: Dane Morgan obtained a PhD from U.C. Berkeley in 1998, was a postdoctoral researcher and research associate at MIT until 2004, and is now an associate professor at University of Wisconsin, Madison. His work combines thermostatics and thermokinetics analyses with atomic scale calculations to understand and predict materials properties. A major focus of Morgan's work is energy applications, including fuel cells, batteries, and nuclear materials, but he also works in the areas of high-pressure and aqueous mineral geoscience and defect properties in semiconductors. Morgan has published over 100 papers in the above areas. Morgan has a strong interest in the commercial application of materials modeling and has done extensive consulting with companies as well as served as Vice President of Research at Pellion Technologies, a battery startup company.

Kevin J. Hemker

Professor and Chair, Department of Mechanical Engineering
Johns Hopkins University

Tuesday, January 29, 2013
Tech L211, 4:00pm

“Micro-scale Characterization and Multi-scale Failure Modeling of Layered Thermal Protection Systems”

Modern thermal and environmental protection systems have multiple layers and functionalities, and important phenomena governing the life of these systems occur in each layer and especially at the interfaces between layers. Mechanical characterization of the various layers is complicated by their reduced dimensionality and the need to measure small-scale and scale-specific properties at elevated temperatures. This talk will highlight recent micro-scale experiments that have been developed to characterize constituent properties and summarize the incorporation of these experimental findings into two salient TBC failure models. The first employs a special purpose multilayer code, developed by Balint and Hutchinson and applicable to TGO rumpling and ratcheting. The second describes a collaborative experimental and multi-scale modeling effort to develop a design code for systems that fail by abrupt delamination along the TGO-bond coat interface. A new experimental technique for measuring mode II delamination toughness, the compression edge delamination test, will also be presented, and insight gained from this work will be interpreted in context of the need for hierarchical models of layered material systems.

Biography: Kevin Hemker is the Alonzo G. Decker Chair of Mechanical Engineering and is currently Professor and Chair of the Department of Mechanical Engineering at Johns Hopkins University, and holds joint appointments in the Departments of Materials Science & Engineering and Earth & Planetary Sciences. He holds a BS in metallurgy from the University of Cincinnati (1985), MS and PhD degrees in materials science and engineering from Stanford University (1990), and completed a postdoctoral fellowship in physics at the Ecole Polytechnique Federale de Lausanne. He is a former editor of Scripta Materialia, is on the board of directors of The Minerals, Metals, Materials Society (TMS), a fellow of the American Society of Mechanical Engineers (ASME), a Fellow of the American Society of Metals (ASM International), and a member of the DARPA Defense Sciences Research Council (DSRC).

Materials Science and Engineering

Jeff Eastman

Materials Scientist

Argonne National Laboratory

Tuesday, February 19, 2013

Tech L211, 4:00pm

In-Situ Synchrotron X-ray Studies of the Synthesis and Behavior of Ferroelectric and Conducting Oxide Thin Film Heterostructures

Intense interest is focused on the growth science and behavior of epitaxial oxide thin films because of continuing discoveries of new interesting and important properties. The key to achieving desired functionality of oxide heterostructures is the ability to synthesize high-quality films with full control of factors such as composition, crystallographic orientation, surface termination, and strain state. Many of the most promising thin film synthesis techniques involve non-vacuum, high-temperature environmental conditions that are difficult or impossible to probe using standard spectroscopic or structural probes. However, the use of high-energy X-rays available at synchrotron sources such as the Advanced Photon Source (APS) provides an opportunity to obtain real-time atomic-level structural and chemical information during synthesis, and to characterize post-growth behavior in high temperature controlled gas environments. This talk will describe results from two ongoing studies that both employ an in-situ X-ray approach to understand and control the synthesis behavior of complex oxide epitaxial thin film heterostructures. In one example I will describe how studies of the synthesis and ferroelectric behavior of epitaxial PbTiO_3 thin films have revealed that the electrical boundary conditions imposed by the gas environment in contact with the sample can play a key role in controlling the equilibrium polarization structure. I will also describe a second study in which in-situ X-ray techniques are providing insight into the oxygen exchange behavior of $\text{La}_{0.6}\text{Sr}_{0.4}\text{Co}_{0.2}\text{Fe}_{0.8}\text{O}_{3-\delta}$ thin film heterostructures under controlled electrochemical potentials, relevant to the behavior of solid oxide fuel cell cathodes. Future plans aimed at understanding the possible interplay between ferroelectricity and conduction behavior in epitaxial heterostructures will also be described.

Biography: Jeffrey Eastman was educated at the University of Illinois, Urbana-Champaign (B.S. and M.S. in Metallurgical Engineering) and at Cornell University (Ph.D. in Materials Science). His Ph.D. thesis work used transmission electron microscopy techniques to investigate the structure of grain boundaries in oxide materials. Following receipt of his Ph.D., he was awarded an Alexander von Humboldt Post-Doctoral Fellowship and spent two years in Stuttgart, Germany at the Max-Planck-Institut für Metallforschung, where he investigated the structure of metal-oxide heterointerfaces. In 1987 he joined the Materials Science Division of Argonne National Laboratory. His research at Argonne has probed the structures and properties of epitaxial oxide and nitride thin film heterostructures, as well as that of nanocrystalline materials. He has authored or co-authored over 140 publications and his work has been cited in the scientific literature more than 6600 times. His work has also resulted in five granted patents. He currently leads a program at Argonne focused on creating and characterizing novel conducting oxide heterostructures. The fundamental science discovered in this program is relevant to many envisioned future energy applications.

Two Genes Memorial Lecture

Eugene W. Skinner and Eugene P. Lautenschlager Memorial Lecture

DNA is Not Merely the Secret of Life: Controlling Nanoscale Structure with Molecular Information



Nadrian (Ned) C. Seeman

Margaret and Herman Sokol Professor of Chemistry
New York University

We build branched DNA species that can be joined using Watson-Crick base pairing to produce N-connected objects and lattices. We have used ligation to construct DNA stick-polyhedra and topological targets, such as Borromean rings or a Solomon's knot. Branched junctions with up to 12 arms have been made.

Nanorobotics is a key area of application. We have made robust 2-state and 3-state sequence-dependent devices that change states by varied hybridization topology. Bipedal walkers, both clocked and autonomous have been built. We have constructed a molecular assembly line by combining a DNA origami layer with three 2-state devices, so that there are eight different states represented by their arrangements. We have demonstrated that all eight products can be built from this system.

A central goal of DNA nanotechnology is the self-assembly of periodic matter. We have constructed 2-dimensional DNA arrays with designed patterns from many different motifs. We have used DNA scaffolding to organize active DNA components. We have used pairs of 2-state devices to capture a variety of different DNA targets.

One of the key aims of DNA-based materials research is to construct complex material patterns that can be reproduced. We have recently built such a system from bent TX molecules, which can reach 2 generations of replication. This system represents a first step towards self-reproducing materials.

Recently, we have self-assembled a 3D crystalline array and have solved its crystal structure to 4 Å resolution, using unbiased crystallographic methods, shown below. More than ten other crystals have been designed following the same principles of sticky-ended cohesion. We can use crystals with two molecules in the crystallographic repeat to control the color of the crystals. Thus, structural DNA nanotechnology has fulfilled its initial goal of controlling the structure of DNA in three dimensions.

However, this is only a milestone, not an end point. We must now advance to controlling the structure of other components as guests in DNA structures. We have achieved this objective in 1D with amyloid fibrils, and in 1D, 2D and 3D with gold nanoparticles. However, this is still a highly problematic enterprise, both synthetically and analytically. With routine control of non-DNA species, a new era in nanoscale control will await us.

This research has been supported by the NIGMS, NSF, ARO, ONR and DOE. This lecture is sponsored by the **McCormick School of Engineering**, the Departments of **Biomedical Engineering, Chemical and Biological Engineering, Materials Science and Engineering**, and the **Institute for Bionanotechnology in Medicine (IBNAM)** and a training grant from the **National Institute of Health**.



**Thursday, February 21st at 4:00 p.m., Tech Institute L361 Reception to Follow –
Tech Institute, Willens' Wing, Second Floor**

Materials Science and Engineering

David Kisailus

Professor, Materials Science & Chemical and Environmental Engineering

University of California at Riverside

Tuesday, March 12, 2013

Tech L211, 4:00pm

From Nature to Engineering: Biomineralized Organisms Provide Inspiration for Synthesis of Nanostructured Materials

There is an alarming increase of a variety of new chemicals that are now being discharged into the wastewater system. This is predominantly due to the rapid emergence of technological developments within industries (e.g., pharmaceuticals) and is causing increased concern for public health and safety. Titanium Dioxide (TiO_2) is an abundant, inexpensive heterogeneous photocatalytic material that rapidly and completely mineralizes organics without harmful byproducts. TiO_2 is synthesized by various methods such as chemical and physical vapor deposition, which require high temperatures or extreme atmospheric conditions (e.g., high vacuum) to achieve the desired phase and size of the material.

Nature provides exquisite examples of hierarchically structured biomineralized composites produced at low temperatures and under environmentally benign conditions with extreme fidelity. These structures are often controlled by a combination of an underlying organic template and an exact control of a solution microenvironment, which serve as a guide for precise nucleation and growth of mineral, significantly affecting the mineral size, phase and orientation. The resulting nano and microstructured materials perform significantly better than their constituents and provide us with design guidelines for synthetic pathways to new materials. Here, we utilize biologically-inspired scaffolds to template the nucleation and growth of inorganic materials such as TiO_2 , which aid in controlling the size and phase of these particles. Nanosized rutile and anatase particles were synthesized hydrothermally at relatively low temperatures and mild pH conditions. The effects of reaction conditions on phase and grain size were investigated and discussed from coordination chemistry and coarsening mechanisms. By modifying solution conditions, we have produced a self-supporting porous, high surface area TiO_2 nanoparticle membrane with controlled crystallite size, phase, and porosity. These bulk porous TiO_2 membranes can be utilized in photocatalytic applications, eliminating the need for nanoparticle recovery systems, thereby reducing processing costs and increasing amount of viable applications of photocatalytic systems.

Biography: David Kisailus is an assistant Professor in the department of Chemical and Environmental Engineering at the University of California, Riverside. His background and formal training includes chemical engineering, materials science and molecular biology. Thus, his research truly encompasses nanomaterials and biomaterials. Through his experience with the study of biological systems, the *Kisailus Biomimetics and Nanostructured Materials Lab* provides an understanding of synthetic control variables can lead to novel materials through biological -inspiration, -mimetics, and -mediation. Current research involves Bio-mimetics and Bio-inspired Materials Synthesis of semiconducting materials, structure-functional analyses and biomimetic demonstration of impact and abrasion resistant materials, solution phase precursor synthesis of ceramic and semiconducting materials for photocatalytic membranes, nanoparticle synthesis and self-assembly. Based on these interests, he has written or co-authored more than 40 papers (including in *Science*, *Advanced Materials*, *PNAS*, *ACS Nano*, *JACS*, etc.) and patents in the areas of bio-mimetics, bio-inspired materials synthesis, ceramic processing, thin film growth, nano and energy-based materials (fuel cells, batteries). Prior to joining UCR, his research at HRL Laboratories included conceiving synthetic strategies for the Hydrogen Fuel Cell Program. He has investigated the synthesis and self-assembly of nanoscaled materials from bio-inspired and bio-mimetic platforms. Prior to HRL, Professor Kisailus was a post-doctoral researcher at UC Santa Barbara, where he investigated biological pathways to novel materials and extended this to bio-mimetic and inspired systems. He received his Ph.D. from the Department of Materials at the University of California, Santa Barbara in 2002, where he developed novel solution routes to epitaxial thin films and nanocrystals of GaN. Prior to this, he received his M.S. from the Department of Materials Science and Engineering from the University of Florida in 2000, where he synthesized ceramic colloids and investigated densification behavior of glass-ceramic composites.

Materials Science and Engineering

Nasim Alem

Assistant Professor, Materials Science and Engineering Department
Pennsylvania State University

Tuesday, April 16, 2013
Tech L211, 4:00pm

Defects in two dimensional crystals: An ultra-high resolution aberration-corrected electron microscopy study



Graphene and hexagonal boron nitride (h-BN) are considered new emerging materials with potential applications in sensing, hydrogen storage, and electronics. The configuration of defects and edges in these crystals can have a significant impact on their resulting physical, chemical and electronic properties. In addition, small distortions in the atomic structure of such crystal membranes can lead to peculiar physical, chemical and electronic properties at the bulk. During the past decade, aberration-corrected transmission electron microscopy (TEM) has revolutionized our understanding of nanoscale phenomena by opening up the possibility of imaging every single atom within a crystal. This study investigates the atomic structure of h-BN and graphene using the aberration-corrected electron microscope, TEAM, located at Lawrence Berkeley

National Laboratory. This study presents *in situ* formation, growth and migration of defects in h-BN and their interaction dynamics with adatoms and molecules under the electron beam. In addition, the atomic scale structural distortions at the defects and edges are identified. This talk also addresses the atomic scale structural transformations in graphene under electrical bias.

Biography: Nasim Alem received her B.S. degree in Metallurgical Engineering from Sharif University of Technology, Tehran, Iran and her M.S. degree in Materials Science and Engineering from Worcester Polytechnic Institute in Worcester, MA. She completed her PhD in 2009 from the Materials science Department at Northwestern University under Vinayak Dravid. Nasim has been a postdoc in the Physics Department at University of California Berkeley and National Center for Electron Microscopy at Lawrence Berkeley National Lab, before joining The Pennsylvania State University as an assistant professor in 2013.

Nasim's research is focused on the role of defects and edges on the physical, chemical and electronic properties of crystals. Using Transmission Electron Microscopy, she has been studying the formation, growth and dynamics of defects in two dimensional crystals, i.e. graphene and hexagonal boron nitride and how their structure can affect the resulting properties of these crystals. This investigation is critical to further nano-engineer materials for desirable properties.

Nasim is currently a visiting scientist at the National Center for Electron Microscopy at Lawrence Berkeley National Laboratory and an assistant professor in the Materials Science and Engineering Department in The Pennsylvania State University.

Materials Science and Engineering

Jeffrey C. Grossman

*Carl Richard Soderberg Associate Professor of Power Engineering
Department of Materials Science and Engineering
Massachusetts Institute of Technology*

**Tuesday, April 30, 2013
Tech L211, 4:00pm**

“New Materials for Solar Capture and Storage”

One of the greatest challenges of the 21st century will be to understand, invent, and engineer new mechanisms and materials for energy production, energy storage and energy transport to counter the deleterious environmental and political impacts of our long-standing reliance on fossil fuels. Current renewable energy conversion and storage technologies are too expensive, too inefficient, or both, substantially limiting their use and global impact. At the core of the energy challenge is a materials choice: many of the key mechanisms that convert and store energy are dominated by the intrinsic properties of the active materials involved. Our imperative is thus to predict, identify and manufacture new materials and designs as comprehensively and rapidly as possible, as the pressing challenge of producing and storing energy renewably calls for game-changing leaps forward rather than our current path of incremental advances. Toward that end, we use both computational and experimental approaches that serve to elucidate fundamental mechanisms as well as predict new concepts and solutions. Two examples of such an approach for the design of new materials for solar capture and storage will be presented. First, I will discuss the design of an unconventional platform for closed-cycle solar thermal fuels that takes advantage of rigid nanoscale templates to tune chemical interactions between bound photoisomers, leading to energy densities comparable to Li-ion batteries. Second, I will present our work on the design of photovoltaic (PV) active layers comprised exclusively of non-polymer based carbon nano-structures, and the prediction of layered materials that could lead to "ultra-thin thin-film" PV.

Biography: Jeffrey C. Grossman is a Professor in the Department of Materials Science and Engineering at the Massachusetts Institute of Technology. He majored in physics at Johns Hopkins University, where he received his bachelor's degree, and then went to the University of Illinois to carry out his graduate studies, where he earned a Ph.D. in theoretical physics. Professor Grossman performed postdoctoral work at U.C. Berkeley, and was then awarded the Lawrence Fellowship at the Lawrence Livermore National Laboratory, where he helped to establish their research program in nanotechnology. He returned to U.C. Berkeley as Director of a Nanoscience Center and Head of the Computational Nanoscience research group, which he founded, with a focus on designing new materials for energy applications. Prof. Grossman joined MIT in Fall 2009, assuming a position that was the result of an interdepartmental search organized by the School of Engineering, for faculty pursuing energy research. At MIT, he leads a research group that develops and applies a wide range of theory and simulation techniques to gain fundamental understanding, develop new insights based on this understanding, and then use these insights to design new materials for energy conversion and storage with improved properties – working closely with experimental groups at each step. Recently, Professor Grossman has launched his own experimental Lab to complement the modeling work. He has published more than 90 scientific papers on the topics of solar photovoltaics, thermoelectrics, hydrogen storage, solar fuels, nanotechnology, and self-assembly. He has appeared on a number of radio and television shows to discuss new materials for energy including NPR's On Point, the Fred Friendly PBS series and the Eopolis program on the Discovery Channel. He holds 11 current or pending U.S. patents.

Materials Science and Engineering

**Hai-Quan Mao**

Associate Professor,
Materials Science and Engineering and Whitaker Biomedical
Engineering Institute
Johns Hopkins University

Tuesday, May 7, 2013
Tech L211, 4:00pm

Plasmid-Templated Shape Control of Condensed DNA–Polymer Micelles

One of the critical challenges for efficient non-viral gene delivery *in vivo* is the ability to control the transport properties in biological milieu of DNA-containing nanoparticles. Recently, nanoparticle shape has been identified as an important factor determining these properties. However, until now it has not been possible to control the shape of nanoparticles containing packaged plasmid DNA. We have developed a new approach to achieve an exquisite shape control of nanocomplexes of plasmid DNA and polyethylene glycol (PEG)–polycation copolymers. This lecture covers the experimental strategies to realize shape tunability from spherical and rod-like to worm-like DNA/polymer nanoparticles through variation of polymer structure and solvent polarity, and molecular dynamics simulations aiming at identifying the key parameters modulating shape control in DNA/polymer nanoparticle assembly. Our study reveals the dual role of plasmid DNA as an active payload and as a shape template. More importantly, we have demonstrated the shape-dependent cellular uptake, transfection efficiency *in vitro* and *in vivo*. These findings open up a new avenue for controlling the shape of DNA-compacting nanoparticles and enhancing gene delivery efficiency. These micelles may serve as virus-mimetic nanoparticles for elucidating the role of shape in determining particle transport properties and bioactivities.

Biography: Professor Hai-Quan Mao received his Ph.D. in polymer chemistry in 1993 from Wuhan University in China. He completed his postdoctoral training in the Department of Biomedical Engineering at Johns Hopkins University from 1995 to 1998, and moved to Johns Hopkins in Singapore as a co-principal investigator. In 2003, Dr. Mao joined the Department of Materials Science and Engineering and the Whitaker Biomedical Engineering Institute at the Johns Hopkins University as an assistant professor. He was promoted to associate professor with tenure in 2009.

Professor Mao currently is a member of the Translational Tissue Engineering Center at Johns Hopkins School of Medicine, and the Institute of NanoBioTechnology at Johns Hopkins University. Dr. Mao's research work received the Capsugel Awards for Outstanding Research from the Controlled Release Society in 1998 and 2001 for his innovative research in nanoparticle designs for gene delivery, the National Science Foundation Faculty Early Career Award in 2008. He also received the Johns Hopkins University Excellence in Teaching Award in 2008. His current research focuses on engineering polymeric nanomaterials for therapeutic delivery and regenerative medicine applications.

Materials Science and Engineering

**James Rondinelli**

Assistant Professor
Materials Science and Engineering Department
Drexel University

Tuesday, May 14, 2013
Tech L211, 4:00pm

Disruptive Design Strategies for Emergent Ferroics

There are two main routes to accelerate materials discoveries for advanced electronic and sustainable energy technologies: serendipitous realization through conventional synthesis or computationally guided growth of novel materials through, *e.g.*, artificial structuring of bulk compounds at the atomic scale. Recently, the launch of the Materials Genome Initiative (MGI) at the national level has reinvigorated the search for new routes to accelerate the discovery of advanced materials for rapid deployment—the aim being to evolve a “hunter and gatherer” discovery paradigm into the cultivation of materials by design.

Within this setting, and motivated by prospects of integrating perovskite-structured oxides into electronic devices to reduce consumer power consumption, I describe in this talk the design methodology and theoretical discovery of a new class of “rotation-induced” ferroelectric materials. Bottom-up engineering of the atomic framework structure, specifically rotations of transition metal octahedra at the unit cell level, is applied to realize ferroelectricity in artificial ABO_3 -structured composites formed by interleaving two bulk materials with no tendency to such behavior. This emergent, chemistry-independent, form of ferroelectricity – *octahedral rotation-induced ferroelectricity* – offers a reliable means to externally address and achieve deterministic electric-field control over magnetism. I discuss the required crystal-chemistry criteria, which are obtained from a combination of group theoretical methods and electronic-structure computations, to select the compositions and stoichiometries giving polarizations comparable to the best known ferroelectric oxides. I then show how the approach is readily translated to $A_nB_nO_{3n+1}$ ($n=1$ or 2) Ruddlesden-Popper (RP) oxides with disconnected layers of corner-sharing octahedra to design improper multiferroism in a class of manganites using (pseudo)-rotations that describe Jahn-Teller distortions. I conclude by suggesting new materials families to search for unconventional forms of ferroic (or anti-ferroic) behavior, and more broadly how this general approach of physical properties by atomistic structure design within the MGI is immediately amenable to other material functionalities.

Biography: Dr. James Rondinelli is an Assistant Professor in the Materials Science and Engineering Department at Drexel University in Philadelphia, PA, and leader of the Materials Theory and Design Group. His research interests are in the first-principles design and understanding of functional complex oxide- and fluoride-based materials—inorganic compounds that are expected to play a major role in new sustainable energy technologies. Rondinelli has received numerous awards including the Defense Advanced Research Projects Agency (DARPA) Young Faculty Award (2012), ARO Young Investigator Program (YIP) award (2012), Outstanding Research Award from the MSE Department (2012), and an Argonne Scholar Fellowship (2010-11). He attended Northwestern University (2006), graduating *cum laude* with a B.S. in Materials Science and Engineering. In 2010 he received a Ph.D. in Materials Science from the University of California, Santa Barbara. Following that he was appointed as an Argonne Scholar and the Joseph Katz Distinguished Postdoctoral Fellow in the X-ray Science Division at Argonne National Laboratory (2010-2011). Dr. Rondinelli has (co)-authored more than 25 peer-reviewed publications on the physics and design of complex oxides in prestigious journals, including *Nature Nanotech.*, *Nature Mater.*, *Adv. Mater.*, and *Phys. Rev. Lett.*, among others, with more than 550 citations and an average citation per paper of 24.4 (h -index=13).

Arumugam Manthiram

*Joe C. Walter Chair in Engineering
Director, Texas Materials Institute
The University of Texas at Austin*

**Tuesday, May 21, 2013
Tech L211, 4:00pm**

“Materials Challenges and Prospects of Electrical Energy Storage”



Electrical energy stored in batteries, particularly lithium-ion batteries, powers most of the modern portable electronic devices such as cellphones and laptops. Batteries are also being pursued intensively for electric vehicles and stationary storage of electricity produced by renewable sources like solar and wind. However, their adoption for transportation and stationary storage applications requires significant reduction in cost, long cycle life, increase in energy and power, and improvement in safety, which are in turn controlled by the component materials used in batteries. Clearly, development of new materials for existing battery technologies or new battery chemistries at an affordable cost with long life is needed to address our future energy needs. Accordingly, after providing an overview of the current status, this presentation will focus on the development of next generation of electrode materials for lithium-ion batteries as well as new battery chemistries such as sodium-ion batteries and dual-electrolyte lithium-air batteries.

Specifically, high-capacity, high-voltage oxide and high-capacity sulfur cathodes as well as safe nano-engineered alloy anodes for lithium-ion batteries will be first presented, emphasizing the importance of optimizing the surface and bulk structures and novel cell configurations to overcome the persistent problems in the field. Sodium is more abundant than lithium, so development of electrode materials for sodium-ion batteries will then be presented. Finally, dual-electrolyte lithium-air cells in which the lithium anode in an organic electrolyte is separated by a solid electrolyte from the air electrode in an aqueous catholyte solution will be presented.

Biography: Arumugam Manthiram is currently the Joe C. Walter Chair in Engineering and Director of the Texas Materials Institute and the Materials Science and Engineering Graduate Program at the University of Texas at Austin. He received B.S. (1974) and M.S. (1976) degrees in chemistry from Madurai University, India, and a Ph.D. degree in chemistry in 1980 from the Indian Institute of Technology, Madras. After working as a Lecturer in India and as a postdoctoral researcher at the University of Oxford and at the University of Texas at Austin (UT-Austin), he became an Assistant Professor at UT-Austin in 1991 and rose to the rank of Professor in 2000.

Dr. Manthiram's research is focused on rechargeable batteries, fuel cells, and supercapacitors, specifically engaged in developing new, low-cost, efficient materials, novel chemical synthesis and processing approaches, and a fundamental understanding of their structure-property-performance relationships. He is a Co-founder of ActaCell, a lithium-ion battery startup in Austin. He has authored about 500 publications, including 400 journal articles, and 8 patents. He is the Regional (USA) Editor of *Solid State Ionics* and is serving as an editorial board member for 5 other journals.

Dr. Manthiram received the Engineering Foundation Faculty Excellence Award in 1994, Mechanical Engineering Department Faculty Leadership Award in 1996, Mechanical Engineering Department Outstanding Teaching Award in 2011, and the University of Texas Outstanding Graduate Teaching award in 2012. He was elected as a Fellow of the American Ceramic Society in 2004, a Founding Fellow of the World Academy of Materials and Manufacturing Engineering in 2006, and a Fellow of the Electrochemical Society in 2011. He was awarded the Charlotte Maer Patton Centennial Fellowship in Engineering in 1998, the Ashley H. Priddy Centennial Professorship in Engineering in 2002, the BF Goodrich Endowed Professorship in Materials Engineering in 2006, the Jack S. Josey Professorship in Energy Studies in 2008, and the Joe C. Walter Chair in Engineering in 2009.



Dr. ALI ERDEMIR is a Distinguished Fellow and a Senior Scientist at Argonne National Laboratory with international recognition and significant accomplishments in the fields of materials science, surface engineering, and tribology. He received his M.S. and Ph.D. degrees in Materials Science and Engineering from the Georgia Institute of Technology in 1982 and 1986, respectively and his B.S. from Istanbul Technical University in 1977. In recognition of his pioneering research, Dr. Erdemir has received numerous awards and honors, including the University of Chicago's Medal of Distinguished Performance, five R&D-100 Awards; two Al Sonntag and an Edmond E. Bisson Awards from the Society of Tribologists and Lubrication Engineers, and an Innovative Research Award from the Tribology Division of ASME. He is a Fellow ASME, AVS, ASM-International, and STLE. He holds 20 U.S. and international patents, presented more than 150 invited/keynote/plenary talks, authored/co-authored more than 260 research articles, 16 book/handbook chapters, and edited two books. His current research is directed toward nano-scale design and large-scale manufacturing of new materials, coatings, and lubricants for a broad range of applications in manufacturing, transportation and other energy conversion and utilization systems.

Dissociative Extraction of DLC Boundary Films from Lubricating Oils at Sliding Contact Interfaces by Catalytically Active Nanocomposite Coatings

Ali Erdemir
Argonne National Laboratory
Energy Systems Division
Argonne, IL 60439

Nanocomposite coatings hold great promise for enhancing performance, efficiency, and durability of many types of rolling, rotating, and sliding engine parts and components mainly because of their impressive mechanical and tribological properties. In this presentation, we discuss the details of some novel nanocomposite coatings that are capable of extracting diamondlike carbon (DLC) boundary films from lubricating oils at sliding contact interfaces. Specifically, in these coatings, we identified and strategically combined catalytically active hard (nitrides, carbides, or oxides of Mo, W, V, Re, etc.) and soft phases (such as Ag, Ni, Pd, Au, Cu, etc.) in one coating at some optimum concentrations. When tested under severe contact conditions, these designer coatings were able to dissociate long-chain hydrocarbon molecules of lubricating oils into shorter, dimers and trimers and then deposit them on sliding surfaces as lubricious and highly protective DLC boundary films. Using UV Raman and TOF-SIMS, we have elucidated the structural chemistry of these boundary films and confirmed that they were indeed similar to that of conventional DLC films that are deposited using plasma-based CVD and PVD processes. Under severe sliding, reciprocating, and scuffing test conditions, these DLC boundary films were able to reduce friction by more than 50% and provide extreme resistance to wear and scuffing.

Materials Science and Engineering



Michael Brenner

Professor, Applied Mathematics and Applied Physics
Harvard School of Engineering and Applied Sciences

Tuesday, June 4, 2013
Tech L211, 4:00pm

"Colloidal self-assembly and self-replication"

Self-assembly is the idea of creating a system whose component parts spontaneously assemble into a structure of interest; In biological systems this is enabled by a complex set of interactions between the components.

Recent technological advances have created the opportunity for making objects so that every particle interacts with every other particle in a different way. What are the fundamental principles for designing a self-assembling system? How should the interactions be chosen to promote the assembly of a particular structure? i.e. Should bonds be chosen to be reversible or irreversible? Given a set of design rules, can all structures be built with high yield? Or are some structures more designable than others? We will discuss answers to these questions through theory, numerical simulation and experiment on colloidal sphere systems. We will also discuss some recent theoretical ideas about how to build self-replicating colloidal clusters.

Biography: Michael Brenner is the Glover Professor of Applied Mathematics and Applied Physics at the Harvard School of Engineering and Applied Sciences. He received his PhD in Physics at the University of Chicago, but spent much of his graduate student days wandering the halls of Tech at Northwestern University.

His research uses math to examine a wide variety of problems in science and engineering, ranging from understanding the shapes of whale flippers, to answering ordinary questions about daily life, such as why a droplet of fluid splashes when it collides with a solid surface.