Department of

Materials Science & Engineering

UF | UNIVERSITY *of* FLORIDA

The University

The University of Florida is the oldest and largest of Florida's 11 state universities. Today, with approximately 48,000 students, UF is the fourth largest university in the United States. UF has 21 colleges and schools offering more than 100 undergraduate degree programs. The Graduate School coordinates more than 200 graduate programs. Professional degree programs include dentistry, medicine, pharmacy, veterinary medicine and law.

As a land-grant university identified by the Morrill Act of 1862, UF has a special focus on engineering, as well as agriculture, with a mandate to deliver the practical benefits of university research throughout the state. To meet this goal, UF has over 100 interdisciplinary research centers, bureaus and institutes on campus. UF is ranked among the nation's top research universities and is a member of the Association of American Universities.

The university employs approximately 4,000 faculty members and more than 7,000 administrative, professional and support employees. In addition to the 2,000-acre main Gainesville campus, UF has research centers, extension operations, clinics and other facilities and affiliates in every Florida county.

The College

The College of Engineering is the largest professional school at the UF, the second largest of all the colleges and one of the three largest research units. There are over 300 faculty members in 11 academic departments, which offer bachelor's, master's and doctoral degrees in 17 disciplines, including aerospace, agricultural, biomedical, chemical, civil, coastal and oceanographic, computer and information science, computer engineering, electrical, environmental, industrial and systems, materials science, mechanical, nuclear and radiological engineering, and medical physics as well as interdisciplinary studies.

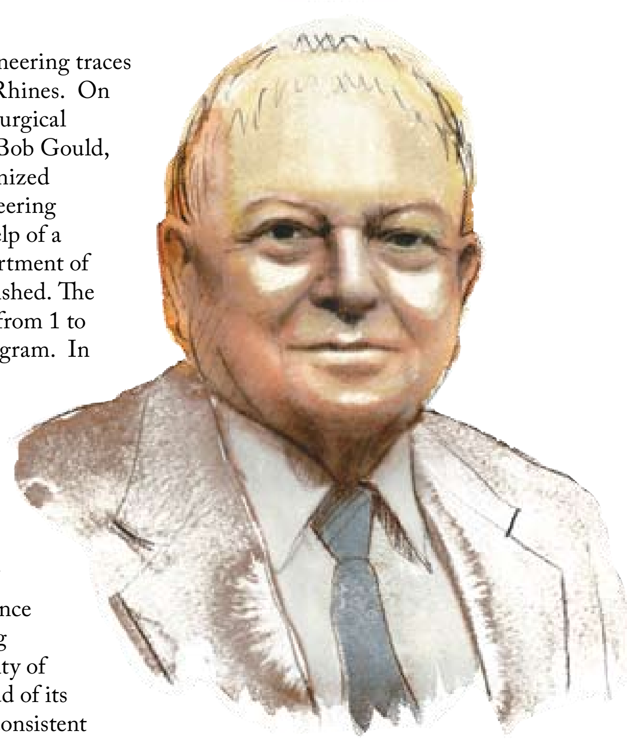
The engineering student body of more than 6,100 includes more than 4,100 undergraduates and 2,000 on-campus graduate students. The college grants more than 1,700 degrees annually.

In 2003-2004, annual research expenditures exceeded $90 million, ranking the college in the top 20 in the nation. A significant amount of interdisciplinary research is conducted through centers ranging from the Florida Center for Solid and Hazardous Waste Management, the Innovative Nuclear Space Power and Propulsion Institute, and the NASA Space Grant Consortium, to the Particle Engineering Research Center and the Center for Intelligent Machines and Robotics.

The growing prowess of the College of Engineering's academic standard continues to be recognized. In its April 2005 edition, *U.S. News & World Report*, in a ranking of public institutions, ranked the college's graduate program as 14th in the nation.

The Department

The Department of Materials Science & Engineering traces its roots back to the efforts of Dr. Frederick Rhines. On September 1, 1959, he established the Metallurgical Research Laboratory with the help of Bob DeHoff, Bob Gould, Ray Rummel and several others. In 1960, they organized an academic curriculum through Mechanical Engineering with a specialty in Metallurgy. By 1962, with the help of a $20,000 NSF laboratory renovation grant, the Department of Metallurgical and Materials Engineering was established. The faculty had grown to 8, graduate students increased from 1 to 8, and 10 undergraduates were committed to the program. In the early 1970s, the department participated in the reorganization of the College of Engineering, emerging as the Department of Materials Science and Engineering and continuing its steady growth in faculty, students, and sponsored research.



Frederick Rhines

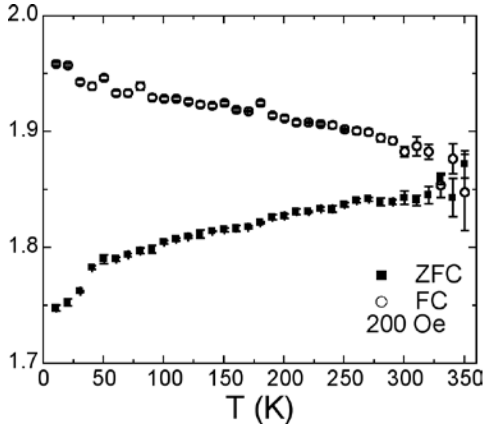
Today, the department of Materials Science & Engineering at the University of Florida is proud of its standing as a consistent top 10 program and one of the largest MSE programs in the country. We currently have more than 30 full time tenure and tenure-track faculty members and an outstanding staff of research scientists whose current research is on display in the pages to follow. We continue to have the best and brightest students, with an average make-up of 200 PhD, 50 MS, and 150-200 undergraduate students. We are proud to lead the nation in our minority population, averaging between 30-40 minority PhD students.

Cammy Abernathy

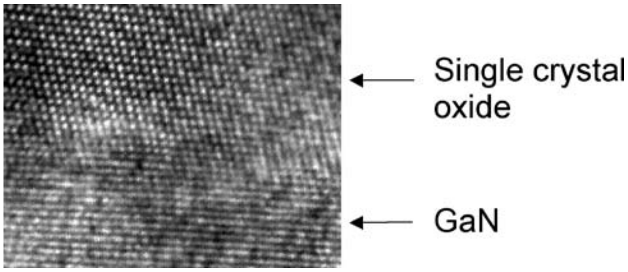
Alumni Professor of Materials Science & Engineering
Associate Dean for Academic Affairs
Ph.D., 1985, Stanford University (94)

Chemistry of electronic materials, metal-organic molecular beam epitaxy, novel gaseous precursors, materials characterization, high-speed electronic and photonic devices, gate dielectrics

Our research is focused on synthesis and characterization of wide bandgap semiconductor materials systems for development of robust integrated sensors and for improved transistors, both for rugged, high power applications and for ultra-fast low power electronics. Synthesis of III-nitride based widebandgap semiconductors and novel oxide dielectrics is done by molecular beam epitaxy (MBE) and metalorganic chemical vapor deposition (MOCVD). One objective of our program is to develop a manufacturable GaN-based MOS transistor technology capable of withstanding extreme environments. Such transistors are expected to find use in a variety of military and commercial communications and radar systems. In addition to transistor development, we also investigate the synthesis of next generation materials for spin based devices, referred to as "spintronics". "Spintronic" materials allow for both semiconducting and magnetic behavior in the same device. Such spin polarized materials offer the promise of achieving gain in a magnetically controlled device, potentially resulting in ultra-low power and ultra-fast transistor operation. We also use a variety of characterization techniques to analyze the surface and interface properties. In addition to the many joint use tools available at UF such as SQUID and TEM, we have several unique capabilities in our lab useful for correlating surface characteristics with underlying magnetic or electronic structure. These include an in-situ XPS/UPS and a short wavelength MOKE.



SQUID plot of magnetization vs. temperature for a constant field of 200 Oe for a GaGdN:Si sample. Since the ZFC and FC curves intersect above 300 K, the sample exhibits ferromagnetic behavior at room temperature.



TEM image of oxide/nitride interface

Bill R. Appleton

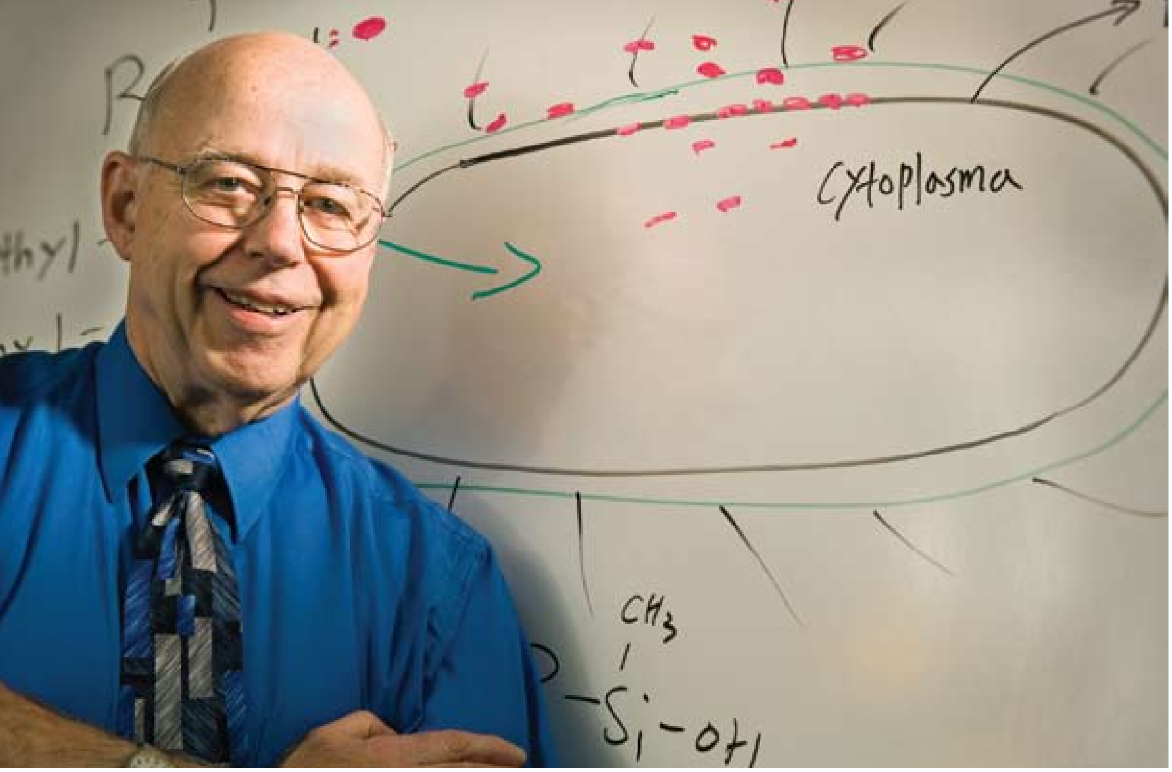
Professor
Director, Nanoscience Institute for Medical and Engineering Technologies
Ph.D., 1966, Rutgers University

Nanoscale Science and Technology
Fundamental Ion-Solid and Laser-Solid Interactions
Ion Implantation and Device Processing
Development of Major Research Facilities

Appleton joined the University of Florida in November 2004 to become Director of the Nanoscience Institute for Medical and Engineering Technologies and direct the scientific development of a new nanofabrication facility for the university, the NIMET Nanoscale Research Facility (NRF). The purpose of NIMET is to consolidate and focus the inter-disciplinary research and development in the fields of nanoscale science and technology, and it involves faculty and staff from several colleges at the UF. As research has spread among the disciplines, so has the need for new equipment and facilities that can address emerging opportunities in NS&T. In response, the State of Florida provided funding to construct the new NRF building. The NRF will provide:

- Class 100-1000 cleanroom facilities for nanofabrication and biotechnology
- State-of-the-art equipment for making and testing nanoscale devices and sensors
- Advanced imaging capabilities for characterization of nanostructures
- New interdisciplinary laboratories for synthesis and processing of nanomaterials and biomaterials
- Offices and interactive space for faculty, users, and collaborators from all disciplines
- Highly trained technical staff to operate the equipment and train students in its use as part of their education.

While the majority of Appleton's time has been spent working with the UF NIMET Committee to translate future scientific requirements into equipment needs and building design, he has initiated a research program to develop an ion beam system for maskless direct deposition, implantation, and imprinting of patterns with nanoscale precision and the ability to select the ion species best suited to the application.



Ronald H. Baney
Research Scientist
Ph.D., 1960, University of Wisconsin

Organometallic and metal-organic routes to ceramics and inorganic/ organic hybrid materials, chemistry of silsesquioxanes and other silicone materials, nuclear reactor materials

Our research divides into two general areas, but spans the spectrum of materials science. These two areas are nuclear reactor materials and bio-materials.

Recent projects in the area of the nuclear reactor materials have included: development of Th/U based fuels to minimize proliferation of plutonium based weapons and to assure stable spent fuel forms for long term storage, B-containing polymers for burnable poison rod assemblies, ceramic corrosion resistant coating on zircaloy fuel cladding, development and processing of silicon carbide based inert matrix fuels for transmutation of long half-life actinide fission products and to reduce the inventories of plutonium, the search for better nuclear fuel forms then the oxides based upon formation of nitrides through novel sol/gel processing, and the use of diamond based nanofluids to dramatically improve the heat transport and critical heat flux in pressurized water nuclear reactors.

Our bio-materials efforts are based upon three chemical systems: organosilicon (silicone) based materials, aminopolysaccharides (chitosan) and oxidized polysaccharides (dialdehyde starch). Among our recent organosilicon based materials research is the discovery of a new class of powerful environmentally friendly antimicrobials called silanols , i.e. silicon alcohols. Research in our group is also under way to improve drug delivery to the brain for Parkinson's, Stroke, Alzheimer, and HIV therapies based upon organosilicon modified drugs to aid in crossing the blood brain barrier which is a major road block for any drugs targeted for the brain. Major efforts in collaboration with Dr. Brennan's group have been the utilization of surface topographical features on silicone surfaces to prevent marine biofouling and settling of other microorganisms.

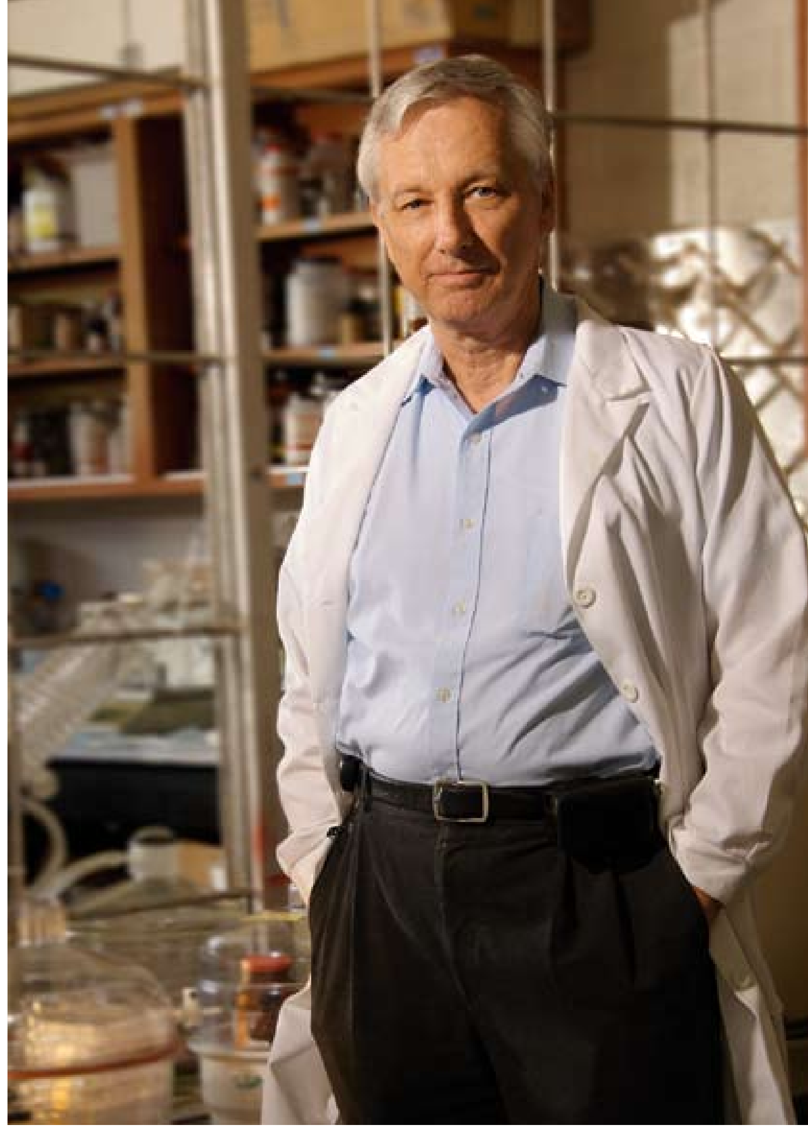
We have modified chitosan so that it can rapidly adsorb overdose amounts of amitriptyline from the blood stream. Amitriptyline is a common suicide route for depressed patients. We have also studied the use of chitosan to remove low levels of tritiated water in the effluence of nuclear reactors.

We are just initiating studies to utilize partially oxidized starch as a bound antiviral. The aim is to develop new low cost masks that could potentially be utilized against such air born viruses as bird flu, if it ever develops into a pandemic.

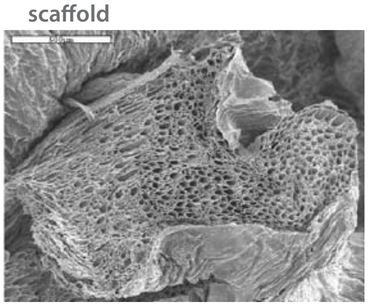
Christopher D. Batich

Professor
Ph.D., 1974, Rutgers University

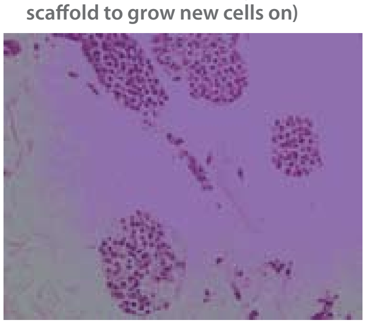
Polymers, surface science, biomaterials, biomedical applications of polymers, guided tissue regeneration



Regeneration of a kidney with stem cells in a decellularized scaffold



decellularized rat kidney (a scaffold to grow new cells on)



A rat scaffold, seeded with mouse stem cells which are growing into a kidney-like structure

Materials are often the limiting or enabling component of a new technology, as are design and use. Our group works closely with others in the healthcare field to understand specific needs for improvements and the materials that will enable those improvements. UF has one of the largest "one site" collections of excellent collaborators in the world and we take advantage of that by visiting each other's areas often. A few of the current activities include:

Regenerative Medicine

Use of stem cells to repair kidney damage:
We have taken mouse embryonic stem cells and have seeded a scaffold based on a very carefully decellularized rat kidney placed in a cell culture incubator. The cells grew into the new environment and remarkably differentiated to resemble healthy kidney cells of various sorts (see figures). Even the glomerulus looked healthy. Work is continuing on how to use the scaffold and how to use the results of this study in kidney damage repair. (Work done with E. Ross, MD in Nephrology, N. Terada, MD PhD, C. Takahashi, MD and B. Willenberg, PhD in Pathology, G. Ellis DVM and C. Adin DVM in Veterinary Medicine, and M. Williams in BME.)

Making synthetic scaffolds for cell growth and differentiation:
Resorbable polymers can be surface modified to produce changes in the way cells respond to them. We have shown that stem cells can be made to form helpatocytes (liver cells) or neurons depending on whether they are coated with gelatin or nothing, for instance. A complex self-assembly of water-soluble polymers and copper ions can be made to form uniaxial tubes which act as a substrate for stem cell growth and maturation.

Diagnostic systems

Using microfabrication, nanoparticles and surface modification, we are working on ways to detect sulfur-mustard gas injuries quickly (funded by NIH) and have an unfunded project on developing a screening test for undiagnosed oral cancer. The latter system is based on a mouth-wash type of analysis that is designed to be simple to use, safe and inexpensive. In addition, we have developed a dip stick test for glucose levels in saliva which correlates reasonably well with blood levels.

The role of iron in neurodegenerative diseases

In close collaboration with Professor Jon Dobson at Keele University in the UK, we are working to determine the role of iron deposits in neurodegenerative diseases such as Parkinson's, Alzheimer's and Huntington's. Using the synchrotron at the Fermi Lab, we have identified unusual mineral deposits at the sites associated with disease in brain tissue from various animals and also human patients. We are attempting to use this information to study ways of diagnosing disease earlier (with MRI) and slowing its progression.

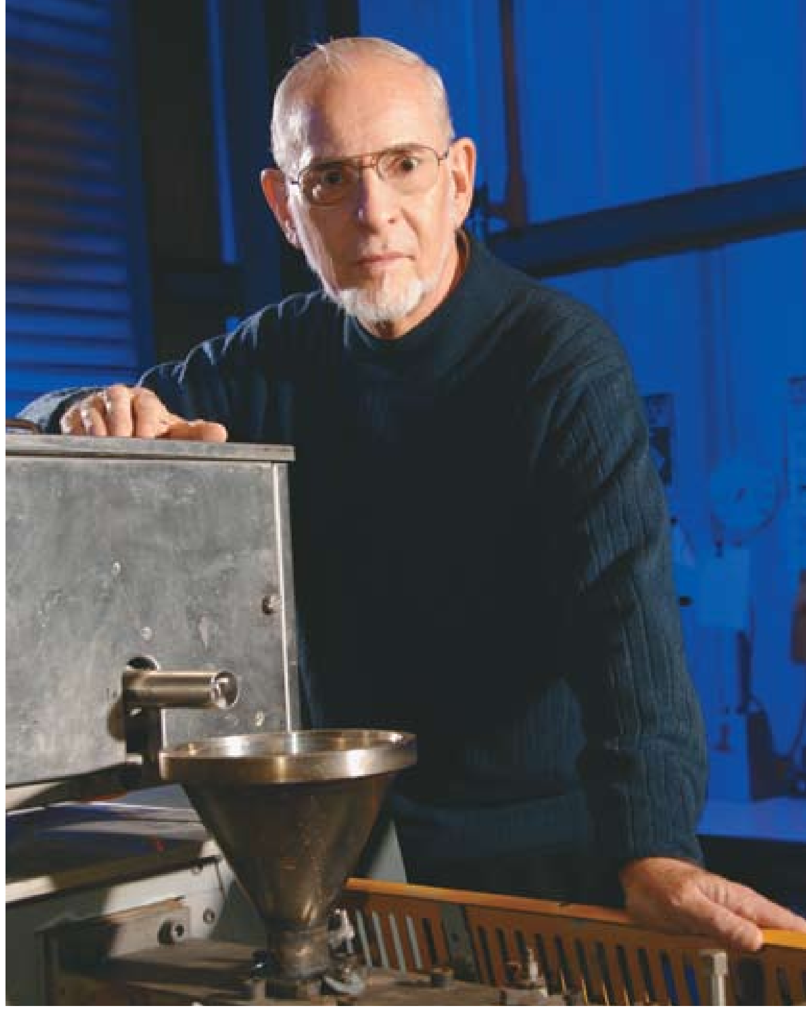
Microbicidal surfaces

We have developed and patented a surface that kills bacteria on contact, and this ("Nimbus") has been licensed to a start-up company in Gainesville (Quick-Med) that is jointly developing this with several UF graduates as employees.

Charles L. Beatty

Professor
Director of Polymer Processing and Properties Center
PhD, 1972, University of Massachusetts

Physical properties and processing of polymers
Recycled plastics
Polymeric Composites



The Polymer Processing Properties Center

The focus of our research is the use of our processing and properties background and facilities to make advances in the development of materials and processes that can solve existing problems better than the current materials and/or processes. Examples of this research are:

A. Isotactic Polypropylene

The recent patent on improving the implant properties of isotactic polypropylene by 13X or 130% is an example of this. This advance is related to modifying the intrinsic relaxation time of the matrix polymer by incorporating nano functionalized elastomeric domains. This impact modification route is a distinctly different mechanism. This work allows blow molded bottles of polypropylene to be made on a commercial basis.

B. Ductile Concrete

Combination of oligomer and silicate nano particles have and are extensively being studied as polymeric nanocomposites in our lab. Extension of this work into cement and concrete has resulted in producing a variety of cements and concretes whose ductility can be controlled and varied. An NSF sponsored workshop will be held in August 2006 with international and USA companies and governmental labs participating. This research is expected to expand significantly.

C. Antibacterial and Antiviral Polymer Modifications

A variety of processes and additives are being explored to produce plastics, nanofiber filters and masks for people to protect food via plastic packaging, food containers, trucks, etc. as well as air supply in buildings and air supply to people (e.g., protection for Asia Flu, SARS, common colds, etc.). All of these routes utilize functionalized polymers to bind the active nano species to kill bacterial and viral agents.

D. Nano-Coatings

Nano particle synthesis and incorporation with functionalized polymers to achieve excellent dispersion and distribution is being utilized to make: (1) transparent wear/abrasion coatings for blast-proof windows; (2) controlled fade-proof wavelength transmission polymeric nano composites for plant growth control, temperature control, etc.; (3) mold, bacteria and biofilm control.

Processing

Reactive Twin-Screw Extrusion
Reaction Injection Molding
Resin Transfer Molding
Single Screw Profile Extrusion
Super-Critical Carbon Dioxide Processing
Sub-Critical Water Processing
Electrospinning
Electrospray
Spin Coating
Atmospheric and Vacuum Plasma Deposition
Nano-Particle, Synthesis, Organic and Inorganic

Properties

High Temperature GPC
High Strain Rate Deformation
Fatigue, Dynamic and Static
Wear/Abrasion Properties

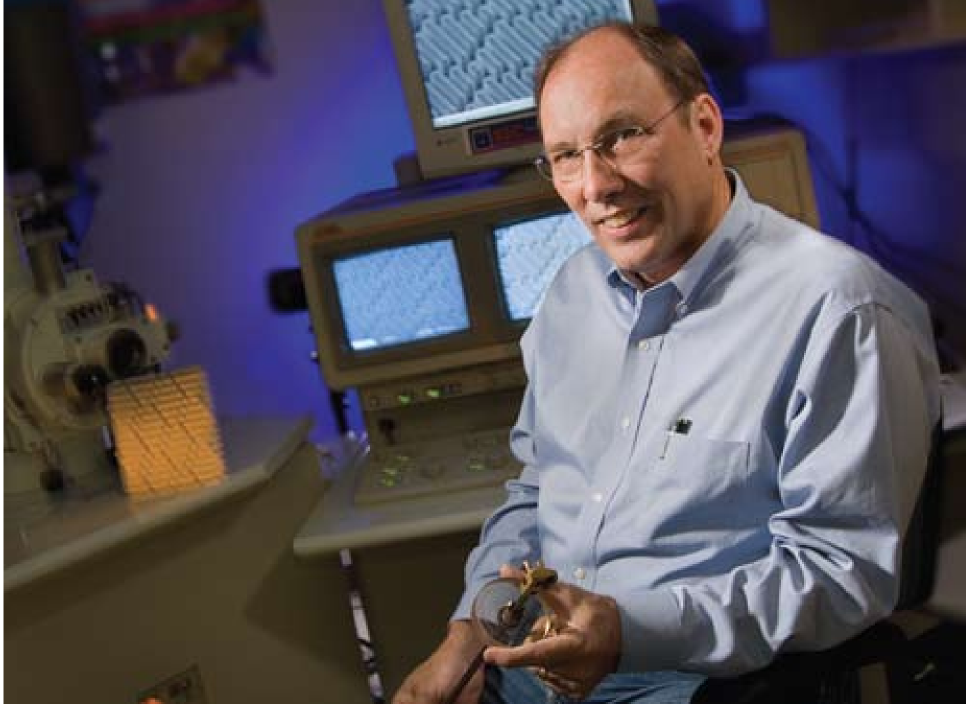
Materials

Polymers, Polymer Alloys, Polymer Composites, Polymer Nano Coatings
Toughened Thermoplastics and Thermosets
Ductile Cement and Ductile Concrete via Nano Modifications
Advanced Asphaltic Materials via Nano Modifications

Anthony B. Brennan

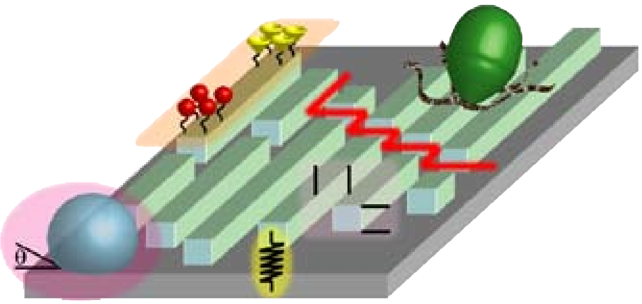
Margaret A. Ross Professor
Ph.D., 1990, Virginia Polytechnic Institute and State University

Structure/Property Behavior of polymers
Sol-gel processing and nanocomposites
Physical aging and long term performance

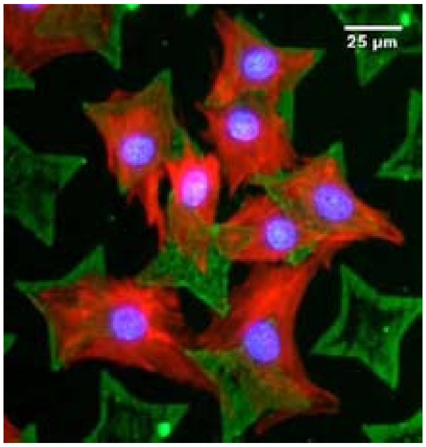


Our research focuses on the design, fabrication and characterization of interfaces/phases with an emphasis on biointerfaces, which mimic natural occurring surfaces. We have developed methods for the fabrication of engineered topographies on a variety of polymers and ceramics for tissue constructs. The topographies extend the structures from the micron scale to the nanometer dimension. These materials, which include a variety of bioneutral and bioactive materials, can also be chemically modified to facilitate the study of the interactive nature of both physical and chemical stimulation by substrates on cell function. We are developing models that enable the investigation of the energy in terms of material properties which relies upon a multidisciplinary approach to engineer surface and bulk properties of polymeric materials for a broad range of applications, including biomedical and defense. To accomplish this, our techniques involve an understanding of the material chemistry, mechanical behavior, processing, and interfacial phenomena in varying environments.

The limiting factor in advancement of biomaterial research has been an understanding of the molecular and cellular interfacial phenomena between the body and the implanted material. The principal focus of our group is to control adhesion and settlement properties by chemically and topographically modifying biomaterials in a novel manner. Our approach investigates the role of patterned materials on behavior of microorganisms with an eye toward applications of these micro-scale interactions. We have successfully demonstrated patterns that inhibit algae, bacteria, endothelial cells and various larvae of marine organisms. Conversely we have also demonstrated specific patterns that enhance the settlement/adhesion and growth of the same organisms. It effectively demonstrates the importance of working within the energy constraints of nature to create the optimum materials for specific biological responses. Other demonstrations of these concepts have been extended in the area of grafting technologies that enable the improved performance of high tenacity fibers and novel electroactive elastomers.



Engineered surface model for studying bioadhesion.



Porcine cardiovascular cell response to patterned fibronectin surfaces. Staining reveals the cytoskeletal structure, focal adhesions and nucleus organization. Surface is a silicone elastomer.

Elliot P. Douglas

Associate Professor
Ph.D.,1993, University of Massachusetts-Amherst

Polymers
Composite Materials
Biomaterials
Student Cognition and Learning

High Performance Thermosetting Resins

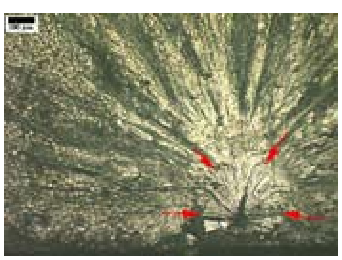
Polymeric thermosets are used extensively in structural applications, as both matrices for fiber-reinforced composites and as adhesives. Current applications range from aerospace structures such as the tail assembly of aircraft to structural reinforcement of concrete bridge structures. Our work in this area covers the entire range from fundamental understanding of thermoset behavior to development of new materials to determination of performance under field conditions. In all cases we seek to relate the structure of the materials to their properties. For example, models have been developed relating moisture permeability and diffusion to the chemical structure and morphology of epoxies. We are working on similar models to describe fracture toughness. These fundamental models are being used in long-term and accelerated aging studies to understand the durability of thermosetting resins and composites. Improved performance is being sought after through the development of both nanoparticle-reinforced thermosets and liquid crystalline thermosets.

Protein Scaffolds Through Self-Assembly

Collagen is a protein that exists in numerous tissues throughout the body. It is a primary component of bone, cartilage, and corneas. Use of collagen as a tissue engineering scaffold provides the opportunity to create implants that mimic the structure of natural tissues, resulting in improved biocompatibility and mechanical properties. We are utilizing the self-assembly behavior of collagen to create novel structures that can be used as either scaffolds for further modification or directly as implants. Bulk collagen scaffolds with controlled porosity are being investigated as the organic component of artificial bone composites. The liquid crystalline nature of collagen is being exploited for both orientation of bulk scaffolds and for surface-induced assembly of thin films. For hard tissue applications the scaffolds being prepared in our lab are subsequently mineralized by Professor Laurie Gower in MSE.

Improved Educational Methods

Improving student learning requires an understanding of how students think and how they respond to different educational settings. We use rigorous educational research techniques, both quantitative and qualitative, to investigate various aspects of engineering education. One area of interest is the nature of critical thinking in engineering and how it is measured. We are also working on projects to develop new approaches to teaching engineering. One example is the development of project-based modules designed to improve student motivation. In another case active-learning techniques as a means to improve student learning are being investigated.



Fracture surface of a liquid crystalline epoxy thermoset. The red arrows indicate the flaw where the fracture initiated. The size of the flaw is used to calculate the fracture toughness. The granular appearance of the surface is related to the size of the liquid crystalline domains.

Optical microscope image of a liquid crystalline collagen solution observed between crossed polarizers. The liquid crystallinity depends on solution concentration, and thus by varying the concentration different degrees of order can be obtained

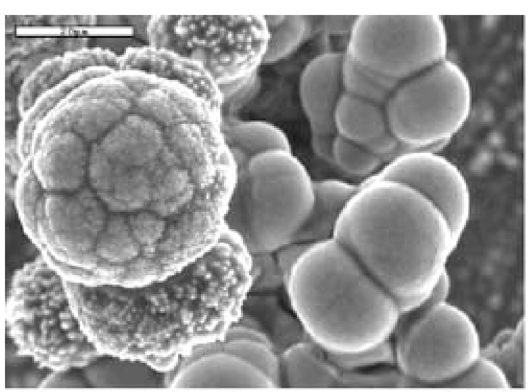
Fereshteh Ebrahimi
Professor
Ph.D., 1982, Colorado School of Mines

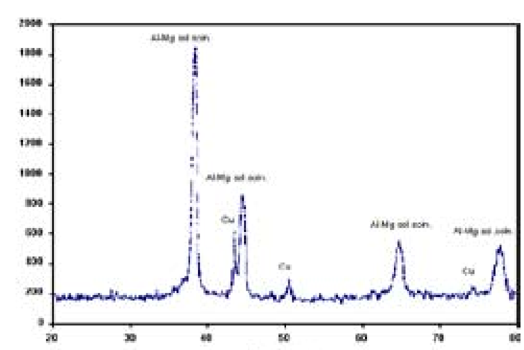
We are interested in the relationship between fabrication, processing, microstructure and properties of crystalline materials with an emphasis on deformation and fracture.

Metallic nanostructures exhibit unique properties that make them suitable for different applications. We fabricate various metallic nanostructures via electrodeposition technique. One of our interests is to understand the mechanisms of deformation and fracture in nanostructures such as multilayers and nanocrystalline metals. Owing to the high quality of materials produced in our lab, we have demonstrated that nanocrystalline metals are inherently ductile while they can possess ultra-high strength levels (>2GPa). The strength and toughness of these materials are comparable to quenched and tempered steels, but their other properties such as corrosion resistance and magnetic properties can be tailored to a specific application. We have demonstrated the existence of a ductile to-brittle transition as a function of grain size in face-centered-cubic metals. Our experimental results have produced key evidences in verification of atomistic simulation results. We are also applying the electrodeposition technique to produce nanocrystalline alloy powders, which can be hydrogenated to complex hydrides for on-board vehicular hydrogen storage. Hydrogen is considered to be the potential future fuel for transportation application and the on-board storage of hydrogen is a major scientific challenge. Coating of metallic implants for improving the material adhesion between bone and metal is another area of research we pursue.

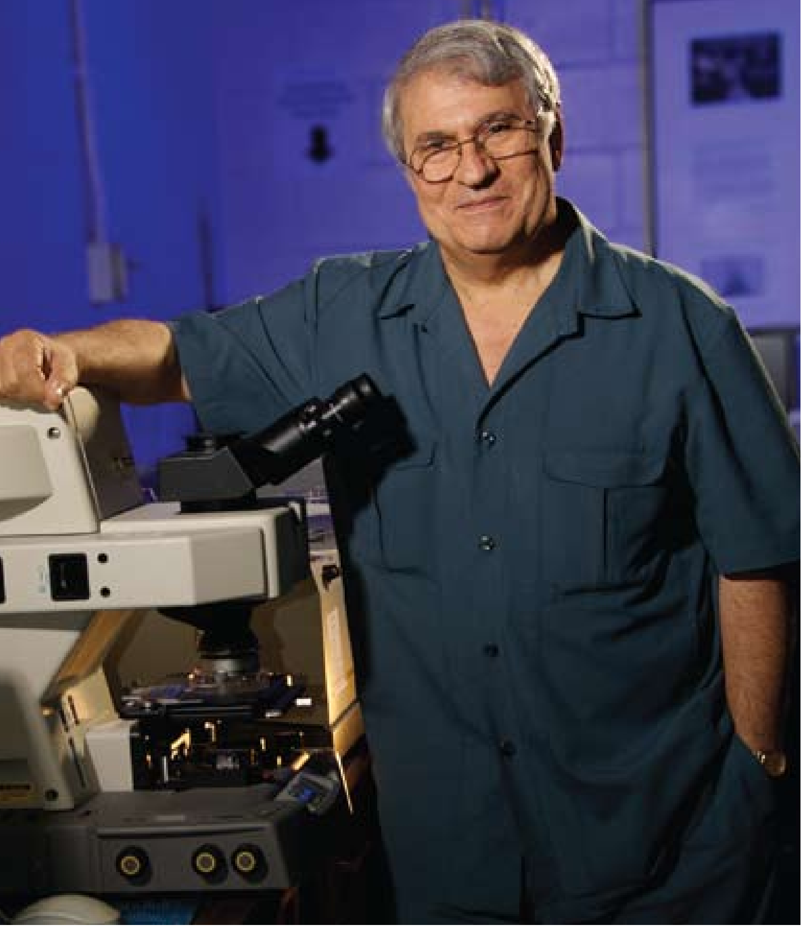
The study of crack initiation and propagation in single crystals is of great importance in applications where single crystals are used as well as in understanding the mechanical failure of polycrystalline materials. We have been studying the mechanical properties of a variety of single crystals including silicone, nickel aluminides and nickel-base superalloys. Our results have shed light on the effect of crystallographic orientation on deformation and fracture processes.

Many materials are used at elevated temperatures and in oxidizing or reducing atmospheres - from blades in turbine engines to components in solid oxide fuel cells (SOFC). We have been studying the effect of environment on mechanical properties of many materials including intermetallics and ceramics.





Electrodeposited super-saturated A-Mg solid solution



Hassan E. El-shall

Associate Professor
Dr. Eng. Sc, 1980, Columbia University

Applied surface chemistry to particulate processing, separation technologies for solid/solid and solid/fluid systems.

In general, our group's research interests involve understanding, modifying, and controlling of interfacial properties of multiphase particulate systems. Examples include Theoretical Aspects of Interfacial Phenomena and its applications in:

Kidney Stone Formation

The mechanism(s) that cause kidney stone formation is not well understood. We are part of an interdisciplinary effort concerning the aggregation/ dispersion characteristics of calcium oxalate crystals in presence of different inorganic and organic species commonly found in urine.

Nano-Particles for Removal of Toxic Substances from Blood/ Water

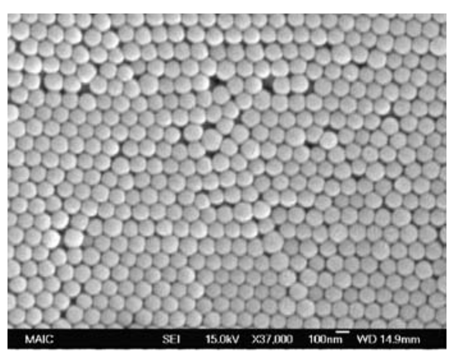
Over 20 million Americans have chronic kidney disease including 320,000 patients with ESRD (End Stage Renal Disease). Research in this area aims at developing a new class of a semi-permeable composite membrane based on synthetic polymer particles in order to effectively discriminate middle molecular weight MMW toxins for medical applications such as Hemodialysis.

Mesoporous Nanocomposite Thin Films for Bacterial and Viral Inactivation

Over 2 million Americans acquire infections (nosocomial) each year while in the hospital. Our goal is to synthesize an ordered mesoporous (pore size between 2-50 nm) thin film containing a combination of antimicrobial and antiviral agents. This thin film will contain photocatalytically active vanadium oxide (V2O5) nanoparticles and elemental silver nanoparticles. The film must be able to inactivate gram-negative and gram-positive bacteria as well as the more resistant viruses. Both inactivation agents are to be studied independently and in combination.

Delignification Process for Treatment of Black Liquor in Kraft and Alkaline Pulping Processes

Until recently, there has been no simple low-cost process for practical lignin separation from black liquor. We have developed a simple and cost effective process to recover lignin biomass for energy generation, soil amendment, and other applications.



Latex composite membranes like these may be used in Hemodialysis membranes for treatment for patients with end stage renal disease (ESRD)

Solid/ Solid Separation for Enhancing Phosphate Recovery

Specifically, we have been involved in research activities dealing with surfactant/solid interaction for improved separation of phosphate from other impurities; crystal modification by surfactants for enhanced filtration of phosphogypsum; separation of phosphate from fine phospahtic clays; surface active reagents for the removal of iron impurities from phosphoric acids by chelation.

Solid/Liquid Separation for Enhancing Dewatering and Consolidation

Waste treatment and disposal is a major problem facing many industries such as phosphate, kaolin, iron ore, and pulp and paper, etc. Our research on flocculation and sold/liquid separation has thus been instrumental in developing patented processes to deal with such waste problems.

Gerhard Fuchs

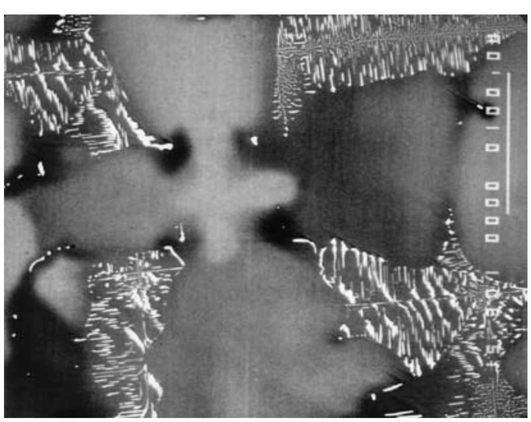
Associate Professor
Ph.D., 1986, Rensselaer Polytechnic Institute

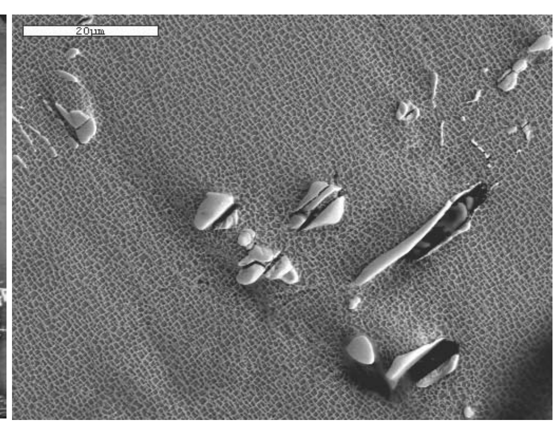
Physical & mechanical metallurgy of structural materials
Microstructure-processing properties

The ability to use materials to higher temperatures, at higher stresses, for longer times and in more aggressive environments is key to the future development of more efficient and environmentally friendly power generation and propulsion systems. Our group works closely with industry on a wide variety of research projects on the development of high temperature materials to meet this need. The industrial collaboration on our research projects often includes both undergraduate and graduate students working with industry during co-ops or internships to complete some of the experimental work.

In the past, most high temperature materials development was performed in an empirical manner which results in long, costly experimental programs. More recently, computational and modeling techniques have been developed to reduce the amount of experimental work necessary. Our research projects have focused on developing a better understanding of the effects of composition and processing on the microstructure and properties of high temperature alloys by using a combination of computational and laboratory experimental techniques. More specifically, our research projects have included the development of a better understanding of the effect of alloying additions on segregation, solidification and the mechanical properties of advanced single crystal Ni-base superalloys. Ultimately, the results of this project will be incorporated into improved thermodynamic and mechanical property databases for single crystal Ni-base superalloys. On-going work includes collaboration with Imperial College (UK) on the development of improved models for directional solidification and properties of advanced single crystal Ni-base superalloys and the use of computational techniques to develop new alloy compositions for industrial gas turbines, including alternate fuel turbines, and solid oxide fuel cell interconnect applications.

As the need for energy and the cost of energy both increase, the ability to produce energy more efficiently and with less environmental impact will be more important. However, without improved high temperature materials, none of these goals can be reached. Therefore, our research has focused on high temperature materials, because it is such a critical technology that has an enormous impact on virtually all of us.





Brent P. Gila

Research Assistant Scientist
Ph.D., 2000, University of Florida

Molecular Beam epitaxy of materials
Materials characterization
Wide bandgap semiconductor materials
High Power/high-temperature device fabrication and testing
Gate dielectrics

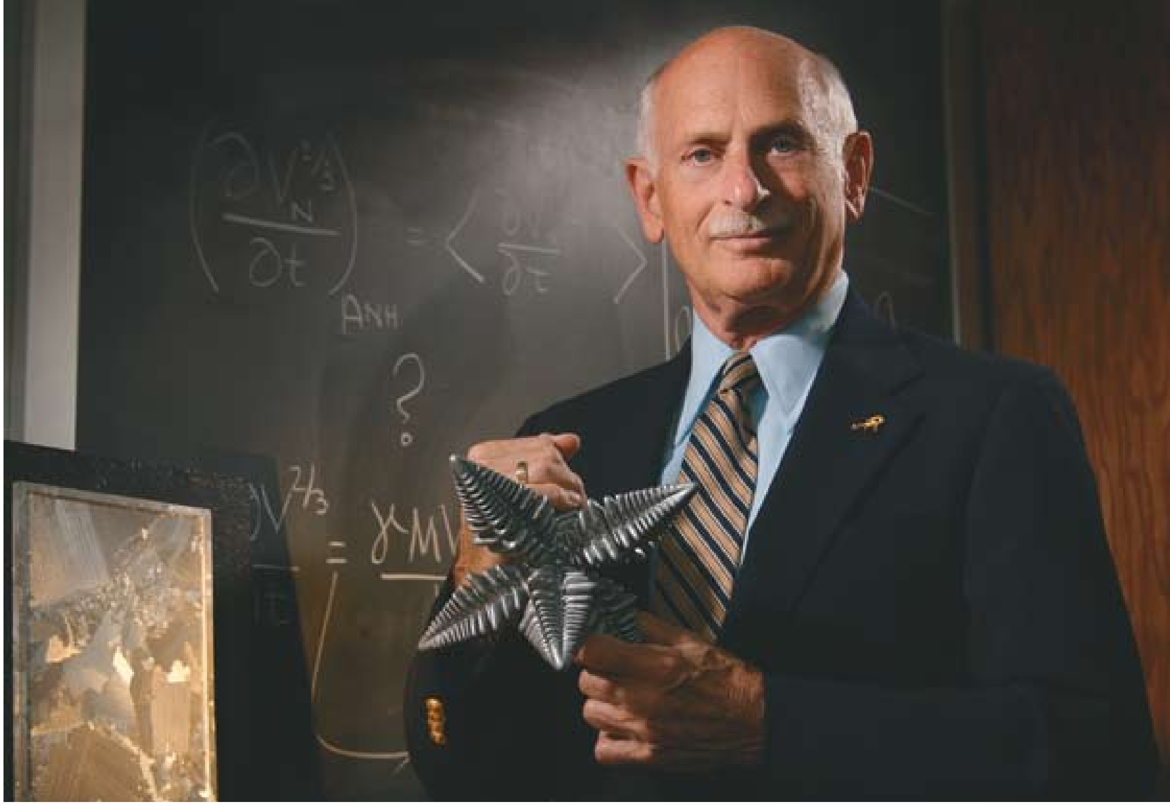
Our research is centered on dielectric materials for wide bandgap semiconductor materials, mostly III-nitride. We currently have two different growth techniques for III-nitrides materials; molecular beam epitaxy\ and metal-organic chemical vapor deposition. For the dielectric materials, we employ MBE to grow single crystal, polycrystal and amorphous oxide films for gate dielectrics, surface passivation, and device isolation. We are also involved in the processing of these materials and structures devices for high power/high temperature applications. Recently we have begun research into the use of these materials as solid-state sensors for gases and liquids and in the growth and processing of nano-scale thin films. And of course, whatever we create, we must characterize. We do extensive electronic testing on our semiconductor and dielectric films and surface and interface characterization as well. The bulk materials are characterized by x-ray diffraction, transmission electron microscopy and photoluminescence. Our goal is to create stable high power transistors based on III-nitride semiconductor materials for use in hybrid vehicles, power transmission, RF power applications and space applications.

Martin E. Glicksman

Ph.D., Rensselaer Polytechnic Institute, 1961
Professor

Solidification of metals; diffusion processes; kinetics and energetics of interfaces; microstructure evolution; crystal growth

In 50 years of research experience the field of Materials Science & Engineering has made incredible advancements and I have had the pleasure of growing into new research areas in step with these advancements. My research started originally in electronic transport in liquid metals, and the growth of alloy single crystals. In 1967 I helped establish NRL's Transformations and Kinetics Branch and later assumed the Chairmanship of the Materials Engineering Department at Rensselaer, and over the next ten years helped RPI develop new academic and research programs in electronic materials and materials processing. In 1986 I was appointed as the John Tod Horton Distinguished Chair in Materials Engineering, pursuing full–time his interests in solidification, microgravity science, crystal growth, and microstructure evolution. My research currently focuses on the following areas:



Dendritic Growth

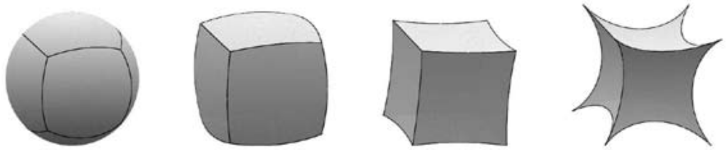
The subject of dendritic growth remains an important contemporary element of solidification modeling, crystal growth, industrial casting and welding. Our research is directed at elucidating the fundamental kinetic and morphological responses of dendritic crystals to their thermal and chemical environments. At present, large-scale computational models of deterministic (as opposed to stochastic) mechanisms for dendritic side-branch formation are under study in cooperation with the University of California at Irvine..

Coarsening of Precipitates

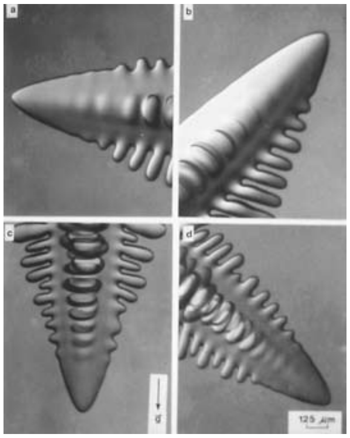
Precipitate coarsening is responsible for the aging and loss of mechanical properties of many materials at elevated temperatures. The physics of coarsening, on which quantitative predictions are based, is a complex subject requiring analysis, modeling and experiments to test and verify its fundamental components. At present, detailed studies on overaged Al-Li two-phase alloys are underway to measure evolving precipitate distributions that develop in these microstructures. High-resolution electron microscopy and x-ray scattering are used to analyze these alloys and obtain detailed kinetic data.

Network Microstructures

There are a large class of materials, including polycrystals, foams, colloids, biological tissues, glasses, and liquid metals that may be represented as irregular networks existing at different length scales, from macroscopic to atomic. The interplay between topological, metrical, and kinetic rules that govern the behavior and evolution of such networks is still poorly understood. New analyses based on differential geometry and topology, combined with numerical modeling and experiments are being developed to advance this field. Current research is collaborative with the Federal University of Volta Redonda, Brazil, and Rensselaer Polytechnic Institute.



6-hedra: These objects, called 6-hedra, are examples of regular polyhedra generalized by Professor Glicksman as an abstract mathematical set, used in the analysis of network structures such as polycrystals, biological tissues, foams, and colloids—all space-filling irregular structures. These objects are much easier to analyze than are irregular polyhedra, and contribute to our recent progress in understanding the behavior of irregular network structures in many materials and systems.

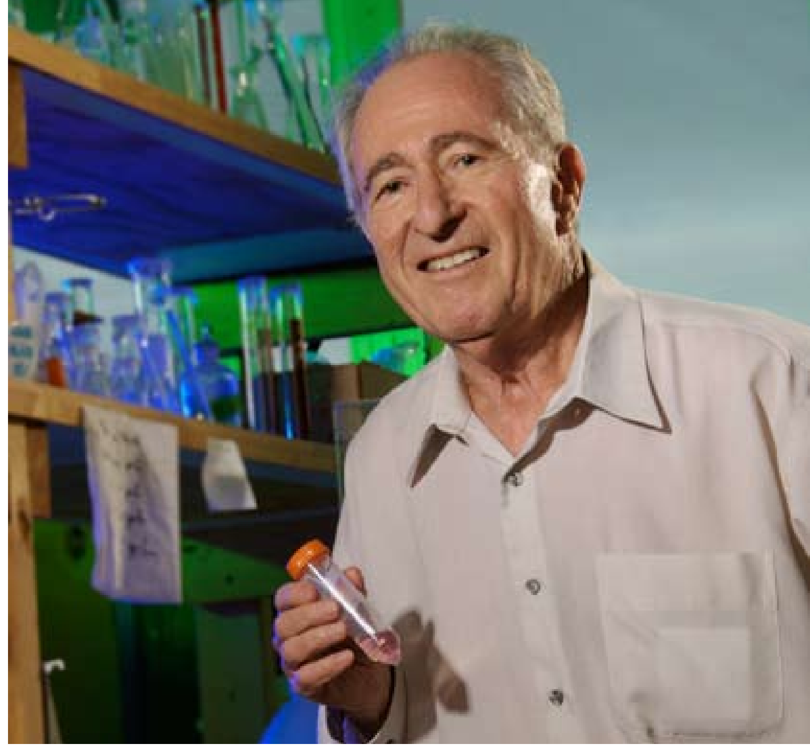


Dendrites-Convective Effects: The four panels show minute tree-like crystals, called dendrites, each growing at a different angle to local (vertical) gravity. The crystal-melt interfaces are affected by hydrodynamic flows (invisible in the micrograph) induced in the surrounding melt by gravity and the thermal diffusion fields surrounding these crystals. Interpreting their morphologies and growth speeds has contributed to our understanding of metallic solidification, and in improving industrial casting and welding processes.

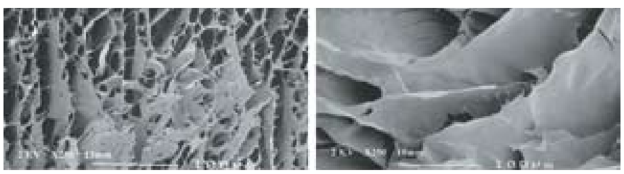
Eugene P. Goldberg

Genzyme Professor
Director, Biomaterials Center
Ph.D., 1953, Brown University

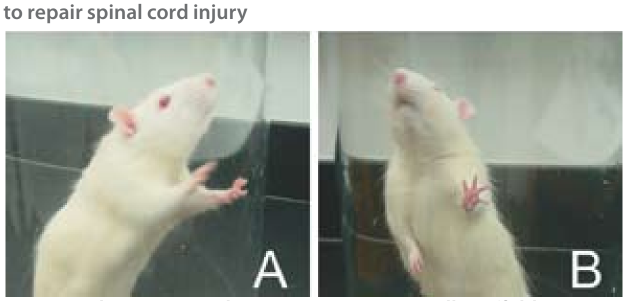
Synthesis and properties of polymers, polymer-drug compositions, biopolymers, medical devices.



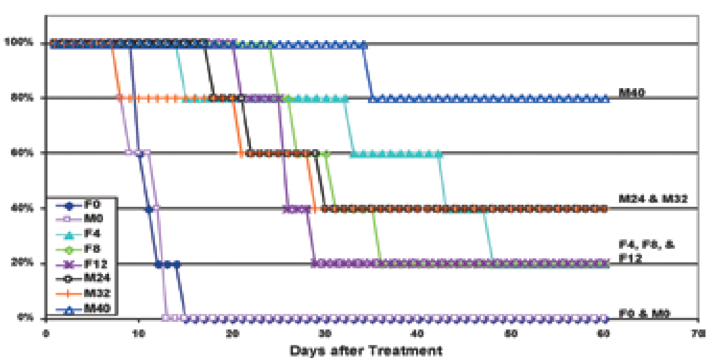
Biomaterials studies have been conducted in Dr. Goldberg's group with emphasis on the following areas of biomedical polymer and device research in collaboration with UF medical faculty and industrial sponsors.



Bioerodable nano-microporous polysaccharide scaffolds for cells to repair spinal cord injury

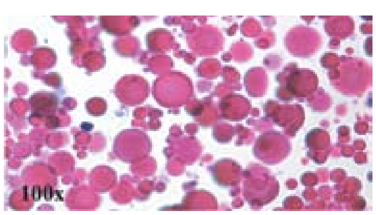


Functional neuromuscular recovery (A) using cell-scaffold implants in rats with spinal cord injury (B)



Greatly extended survival using IT mesosphere therapy in mouse mammary cancer

Drug loaded albumin mesospheres for intratumoral chemotherapy



Wound Healing & Prevention of Postoperative Adhesions

Beginning >20 years ago, we pioneered research aimed at device concepts for inhibiting surgical tissue damage and postoperative adhesions. Surgical solutions and biodegradable barrier films and gels were developed based on hyaluronic acid and carboxymethylcellulose in joint research with Genzyme Corp. Animal and human clinical studies (with Drs. Seeger, Staples, and Peck at UF) resulted in significant anti-adhesion efficacy and clinical use of these devices.

Intratumoral Cancer Chemotherapy using Nano-Meso-Microspheres

Research on this novel approach to localized chemotherapy has been pioneered at UF beginning >25 years ago, initially with NIH. Intratumoral (IT) injections of drug-loaded albumin and DNA mesospheres (1-10 microns) have been very effective in preclinical lung and breast cancer studies. Direct bronchoscopic IT drug injections in lung cancer patients is being done in collaboration with Dr. S. Celikoglu in Istanbul, Turkey at the Nightingale Hospital. Results to date are remarkable with almost immediate relief of airways obstruction and no systemic toxicity.

Nano-Biosurface Studies & Modification of Vascular Stents & Ocular Implants

Gamma and e-beam surface graft polymerization and pulsed laser polymer deposition processes were developed for nanosurface modification of ocular implants (IOLs) and vascular grafts and stents. Research has led to improved foldable IOLs, extended wear contact lenses, and punctum plugs. New concepts for drug eluting vascular stents and IOLs were developed and fundamental nanosurface indentation studies have been conducted.

Spinal Cord Repair with Cell-Biopolymer Compositions

In tissue engineering studies initiated with a Reeve Foundation grant (with Drs. Streit and Mickle of UF's Brain Institute & Depts. of Neuroscience and Neurosurgery), novel porous alginate-DNA-phospholipid implants containing microglial cells were developed. Evaluated in rat models of spinal cord injury, effective axon regeneration and neuromuscular recovery was demonstrated. Also under investigation (with Dr. Reier-Neuroscience) are injectable polymer gels containing viable microglia or stem cells for retina, brain, and spinal cord repair.

Laurie B. Gower

Associate Professor
Ph.D., 1997, University of Massachusetts at Amherst
M.S. in Bioengineering, 1992, University of Utah
B.S. in Engineering Science, 1985, University of Florida

Biomimetic Hard Tissue Engineering
Organic-Inorganic Composites
Engineered Particulates

Scientists and engineers have long been inspired by the beautiful structures and functional properties of the materials formed within living organisms. In particular, the hard tissues of organisms (e.g., bones, teeth, mollusk shells) are composed of minerals which are typically formed in close association with an organic polymeric matrix, and thus are biocomposites. The mineral crystals that are formed by the organisms, called biominerals, frequently have shapes that are very different from the crystal habits produced inorganically. In fact, control over biomineral properties can be accomplished at a myriad of levels, including the regulation of particle size, shape, crystal orientation, polymorphic structure, defect texture, and particle assembly. In many cases, the nanostructure of these biomineral composites increases their strength and toughness, which is invaluable for load-bearing materials such as bones, teeth, and invertebrate shells.

In addition to the mechanical property enhancement, the organic matrix also plays an important role in regulating the formation of the inorganic phase. For example, macromolecular templates are used to direct the nucleation event, vesicular compartments to delineate particle size and shape, and solubilized proteins to regulate the kinetics of crystal nucleation and growth. Our group has been utilizing these concepts in combination with a polymer-induced liquid-precursor (PILP) process to produce novel organic-inorganic composite materials. For example, we have been templating crystallization reactions on self-assembled monolayers, and utilizing this approach to fabricate core-shell particles consisting of fluidic oil-filled emulsion particles encapsulated with an inorganic calcium carbonate shell, for controlled release applications. We have also been able to mimic the nanostructured architecture of bone by mineralizing collagen scaffolds with a polymeric process-directing agent (Figure 1). By mimicking both the composition and nanostructure, we hope to fabricate synthetic bone graft substitute that are both load-bearing and bioresorbable, for regeneration into natural bone tissue.

Overall, the materials chemistry of biomineralization is of interest because there is a demand for low-temperature processing techniques with environmentally friendly materials, and particularly for biomaterials applications where it is desirable to incorporate thermally sensitive organic and/or biological components (e.g. bioreceptor proteins, enzymes for biocatalysis, live cells, etc.) into materials designed with controlled structures. In addition to highly controlled biomineralization processes, we are also interested in the role of biopolymers in pathological biomineralization, such as in biomaterial encrustation and kidney stone formation.

Spherulite of calcium phosphate with concentric laminations resembling the structure of a kidney stone

Mineral film of calcite formed by a polymer-induced liquid-precursor (PILP) process in an aqueous solution at room temperature.

Henry Hess

Assistant Professor
Ph.D., 1999, Freie Universität Berlin

Nanomaterials and nanodevices integrating biomolecular motors

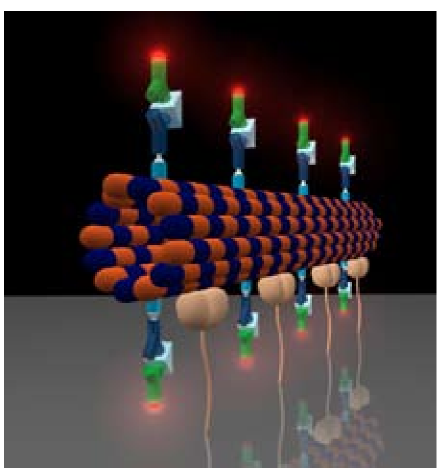
Nanomaterials and nanodevices integrating biomolecular motors

Biomolecular motors, such as the motor protein kinesin, convert chemical energy derived from the hydrolysis of individual ATP molecules into directed, stepwise motion. This enables them to act as fuel-efficient "tractor trailers" within cells, and to actively transport designated cargo, for example vesicles, RNA or viruses, to predetermined locations within cells. In biological systems, motor-driven active transport complements diffusion and pressure-driven fluid flow, providing close control over cargo movements within extremely restricted spaces. For engineers, observing active transport in biology inspires visions of nanofluidic systems for biosensing, of active materials capable of rearranging their components, and even of molecular conveyor belts and forklifts for manufacturing at the nanoscale.

The design of nanofluidic devices, which extend the lab-on-a-chip paradigm to systems with picoliter volumes and submicron channel diameters, presents an immediate opportunity for the application of biomolecular motors. Such dust-particle-sized devices (reminiscent of unicellular organisms) lend themselves to the application of the "smart dust" concept. Smart dust biosensors would be immersed in the liquid sample of interest, independently perform an analysis, and be read out collectively to generate a statistically significant signal. Biomolecular motors that would coat the inner surfaces of such devices and utilize dissolved ATP fuel as an energy source would drive the internal transport and remove the need for peripheral pumps and batteries.

In addition to fulfilling transport functions, biomolecular motors can exert localized forces on nanostructures leading to conformational changes or the rupture of intermolecular bonds. This means that molecular motors can push supramolecular assembly and disassembly processes away from chemical equilibrium and generate dynamic, non-equilibrium structures. These forces could also be exploited in nanorobotics, where the sequential examination or manipulation of molecules by scanning probe microscopes and optical tweezers could be complemented by microscopic arrays of motor-driven actuators.

We are working on realizing these concepts with funding from the DARPA Defense Science Office and the DOE Office of Basic Energy Sciences and in collaboration with researchers from the Sandia National Laboratory, the Naval Research Laboratory, the NIH National Cancer Institute, the Albert Einstein College of Medicine New York, the ETH Zurich (Switzerland), and the Max-Planck-Institute for Molecular Cell Biology and Genetics Dresden (Germany).

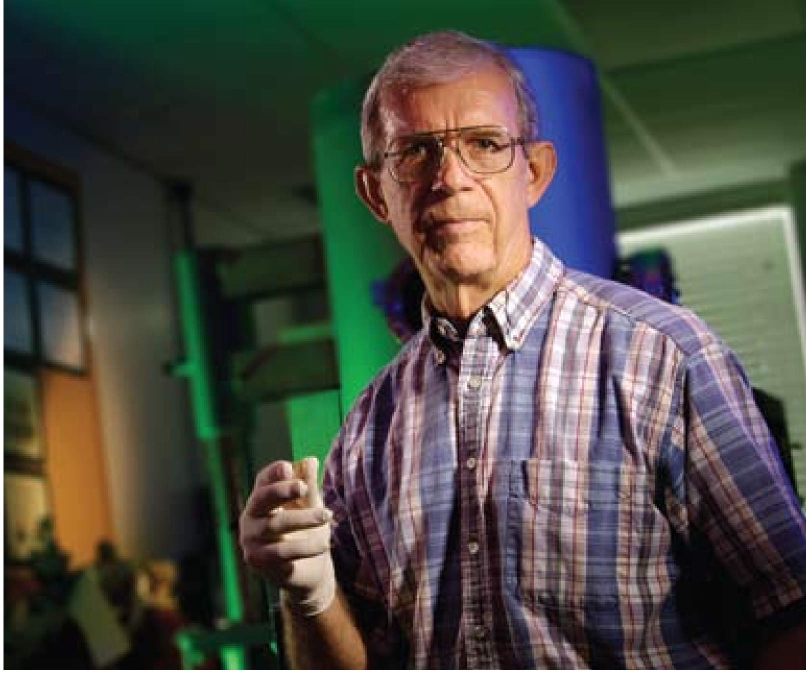


A microtubule (orange/blue, diameter 25 nm) has been functionalized with antibodies to enable the capture and detection of bioagents. Kinesin motors attached to the surface move the microtubule. This nanoscale transport system is also known as "Molecular Shuttle". Image from the March 06 cover of SMALL

Paul H. Holloway

Distinguished Professor, Ellis Verink Professor of Materials Science & Engineering
Director, MICROFABRITECH
Ph.D., 1972, Rensselaer Polytechnic Institute

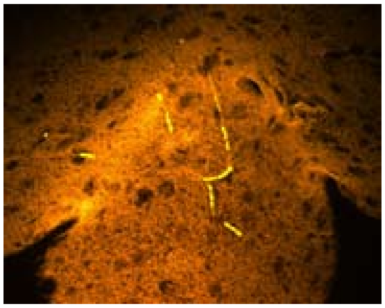
Characterization of surfaces and interfaces
Auger spectroscopy
Electronic and optoelectronic materials



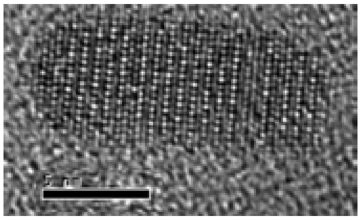
Research in our group is focused on developing materials that are used for elemental and compound semiconductor devices and integrated circuits, and for optoelectronic materials such as inorganic and organic light emitting films and powders used in devices for lighting and displays. Several of our research projects are focused on deposition and characterization of thin films and their surface and interfaces. Examples include metallic conductors for ohmic contacts to semiconductors, and wide bandgap semiconductors with dopants that photo, electro and/or cathodoluminesce in the ultraviolet, visible and/or near infrared regions of the electromagnetic spectrum. For example, we have demonstrated that the screen saver on your computer is necessary because the electron beam in the CRT causes dissociation of impurity gas molecules into reactive atomic species. These reactive species convert the surface of the cathodoluminescent phosphor to a "dead layer" and a 'ghost' image appears if the picture on the screen is not changed with time. We are also studying the visible and near infrared light emitted when a voltage is placed across a thin film of organic or inorganic wide bandgap materials, e.g., electroluminescence. These thin film electroluminescent devices are used for display of information and for emission of light for backlighting or illumination. For example, some of these thin film structures can produce up to eight times more light per watt of electrical power as compared to an incandescent light bulb. Such high efficiency lighting would result in a significant reduction in energy consumption, which is a strong reason for pursuing research in this area.

In addition to working with thin films, we work with luminescent powders ranging in size from micrometers to nanometers. Nanopowders are of particular interest because their small size leads to some novel, interesting properties. For example, nanophosphors can be tuned to generate more white light from the same electrical power, as discussed above. An example of the orange-yellow light emitted from 3 nanometer particles of cadmium sulfide doped with manganese is shown in the figure below. The nanophosphor particles are so small that they only contain about 1000 atoms (see transmission electron micrograph of the zinc cadmium selenide nanoparticle below), and this makes it possible for them to go into small areas. For example, we have attached a cell-penetrating peptide (protein) to the nanoparticle surface and shown that the nanophosphors can penetrate the barrier layer (the blood-brain-barrier layer) that normally makes delivery of drugs to the brain very difficult. The luminescence from the nanoparticles makes it possible to visually detect where the nanophosphors have gone (see micrograph of brain tissue below), which is of great potential benefit for medical diagnosis.

Orange yellow light emission from cadmium sulfide nanophosphors doped with manganese and surface passivated with zinc sulfide (photoluminescence excited by ultraviolet photons).



Photoluminescence from brain tissue infused with nanophosphors that have passed the blood-brain-barrier layer.



Transmission electron micrograph of a zinc cadmium selenide nanophosphor particle showing resolution of the atoms in the 4 nm nanorod.

Rolf E. Hummel

Pamphalon - Professor Emeritus,
Ph.D., 1963 in Physics, University of Stuttgart and Max-Planck-Institute for Materials Research, Stuttgart, Germany
Diplomphysiker, 1960

Electronic, Optical, and magnetic Properties of Materials, Spark-Processing of Materials, Photoluminescence, Differential Reflectometry, Corrosion Optics, Standoff Detection of Energetic Materials

Hummel joined the faculty of the University of Florida's "Metallurgical Research Laboratory" in 1964. At that time this small group was part of the Department of Mechanical Engineering. It has been founded 5 years earlier by F. N. Rhines. The vision of Rhines was to combine the disciplines of metallurgy, ceramics, electronic materials (even though that name has not been coined at that time), and polymers into one department which was later named the Department of Materials Science & Engineering. Hummel played a decisive role in building up this department to its present stature. He started a strong research program in electronic materials, specifically, in optical, electrical, and magnetic materials. One of his major contributions included the invention of the differential reflectometer, a device which is capable of measuring extremely small differences in reflectivity between two almost identical samples and at the same time provides the first derivative of the reflectivity spectrum, thus yielding a more structured -spectrum. Hummel used this equipment to study the electronic properties of metals and dilute alloys, to investigate long-and short-range ordering, to study thin film corrosion products in aqueous solutions, and the effect of ion implantation in silicon and other semiconductors. Most recently he used this technique for the remote detection of explosive materials (such as TNT, RDX etc). The technique is currently considered to be deployed for home-land security.

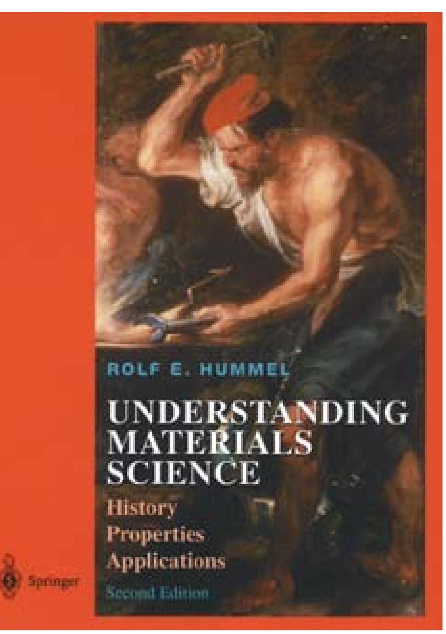
Another research field of Hummel started when he invented spark-processing, a technique which provides light emitting silicon, a feature that cannot be achieved from untreated silicon. His group also discovered that spark-processing yields ferromagnetic silicon whereas ordinary silicon is only diamagnetic.

Hummel is a dedicated teacher who won all together 12 teaching awards, among them many College of Engineering awards, the University of Florida teaching award, the Blue Key Distinguished Faculty Award, and the teaching award from the American Society for Engineering Education.

Hummel authored nearly 200 research papers, seven books (among them two widely used texts in materials science and electronic properties), and has six patents to his name.

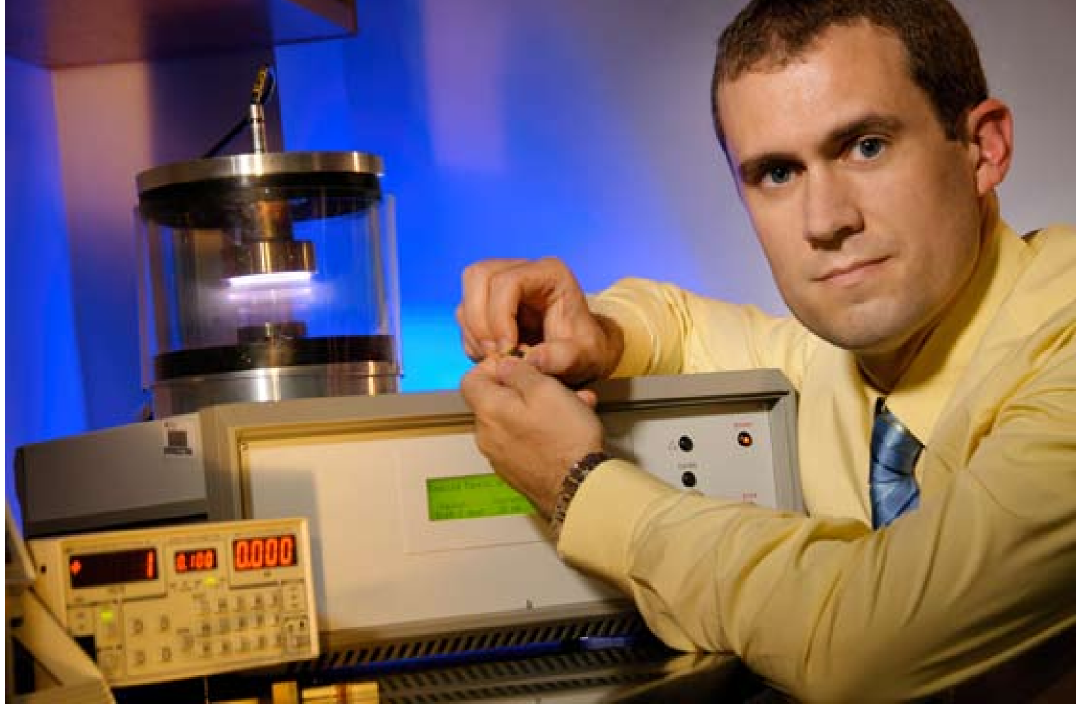
Hummel has used his sabbatical years to follow invitations to universities in Japan, Korea, China, France, New Zealand, and Germany.

Even though, Hummel is formally retired, he still directs a sizable research group, particularly emphasizing remote explosive detection, light emitting substances through spark processing, and ferromagnetic silicon.



Jacob L. Jones
Assistant Professor
Ph.D., 2004, Purdue University

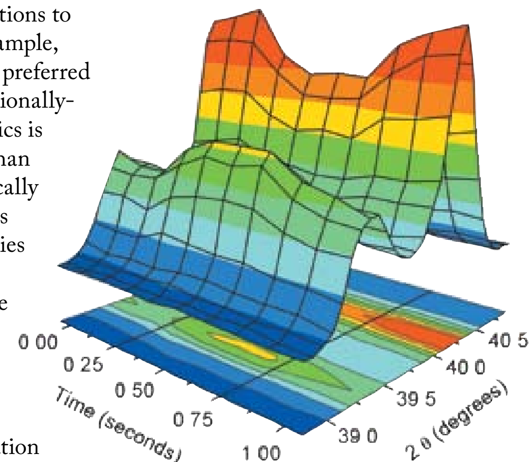
Ceramics
Piezoelectric and Ferroelectric Materials
Crystallographic Texture and Anisotropy
Mechanical Behavior of Materials
Characterization



Our research focuses on characterizing and engineering electromechanical properties. Electromechanical materials generate mechanical strains in response to an electrical stimulus or a change in electric potential in response to a mechanical stress. In this way, electromechanical materials couple the mechanical world in which we live to the electrical, serving as the active material in a wide variety of high technology devices. Examples include diagnostic and therapeutic ultrasound, sonar, vibration and position sensing, large-displacement actuation, micro-technologies including micro-positioning, and renewable power generation or energy harvesting.

Piezoelectric and ferroelectric ceramics are some of the most common electromechanical materials. Our work in this field includes characterizing and optimizing the materials processing and microstructure for enhanced electromechanical behavior. To accomplish this, we use advanced characterization techniques to measure changes in the microstructure both during processing and during the materials' use. These observations include intrinsic changes, evolution of the microstructure, and extrinsic contributions to the properties. For example, we demonstrated that preferred orientation in conventionally-processed piezoceramics is significantly weaker than that which is theoretically possible. This indicates significant opportunities for property optimization. We have also characterized the evolution of subgrain features or domains as a function of time during application of cyclic driving electric fields and their resulting contribution to macroscopic nonlinearities. Ultimately, our research leads to materials with higher energy conversion efficiency, larger electromechanical coupling, reduced nonlinearities, and increased reliability.

Our broader research interests in the field of electroceramics include additional energy conversion and functional materials. However, all of our research initiatives characterize and engineer the underlying physical mechanisms, enabling property enhancement.



Time-resolved diffraction patterns of a lead zirconate titanate (PZT) piezoelectric ceramic during application of a cyclic driving electric field. The positive state of the square waveform is applied between 0.25 and 0.75 seconds. Changes in intensity correspond to changes in the ferroelastic domain structure and a contribution to the macroscopic strain. This behavior leads to nonlinearities and hysteresis in the material's piezoelectric response.

Kevin S. Jones

Professor and Chair
Director, Software & Analysis of Advanced Materials Processing Center
Ph.D., 1987, University of California, Berkeley

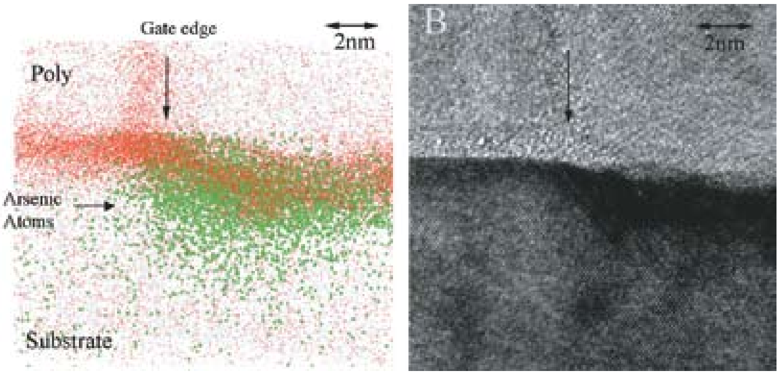
Electronic Materials, semiconductor processing and characterization, ion implantation, transmission electron microscopy

I have spent the past 20 years as a professor studying the processing induced defects in semiconductors. My research has been focused primarily on the area of transmission electron microscopy characterization of defects after ion implantation of various materials (Si, GaAs, Ge, Diamond) and developing an understanding of how defect evolution influences dopant diffusion.

As part of my research I am also co-director of an SWAMP Center (SoftWare and Analysis of Advanced Materials Processing). Through the efforts of the 13 current SWAMP PhD students, this center provides the fundamental understanding necessary to develop models of the front end processing steps used in the manufacturing of silicon integrated circuits. The center also has developed the software necessary to simulate the IC manufacturing process. This center has become internationally recognized as a premier center for this area and the software from the Center (FLOOPS) is the primary software used by many of the chip manufacturers (e.g. Intel) to design the next generation of devices.

In addition to studying defects and diffusion in Si and Ge we are also working on developing single crystal diamond for MEMS and electronic applications. Recently we have expanded our research into the area of characterization of the microstructure of solid oxide fuel cells to develop a better understanding of the structure property relationships in the important class of materials.

I have published over 300 papers on the field of ion implantation and am also Chairman of the International Committee on Ion Implantation Technology. I have been fortunate to win many awards including the 1990 Presidential Young Investigator award from NSF, several teacher of the year awards and the 2006 UF-MSE Triple Point Award.



Cross-section of a Transistor

Local Electrode Atom Probe Measurement

Transmission Electron Microscope Image

Michele Manuel

Assistant Professor
Ph.D. 2007, Northwestern University

Materials design, self-healing alloy composites

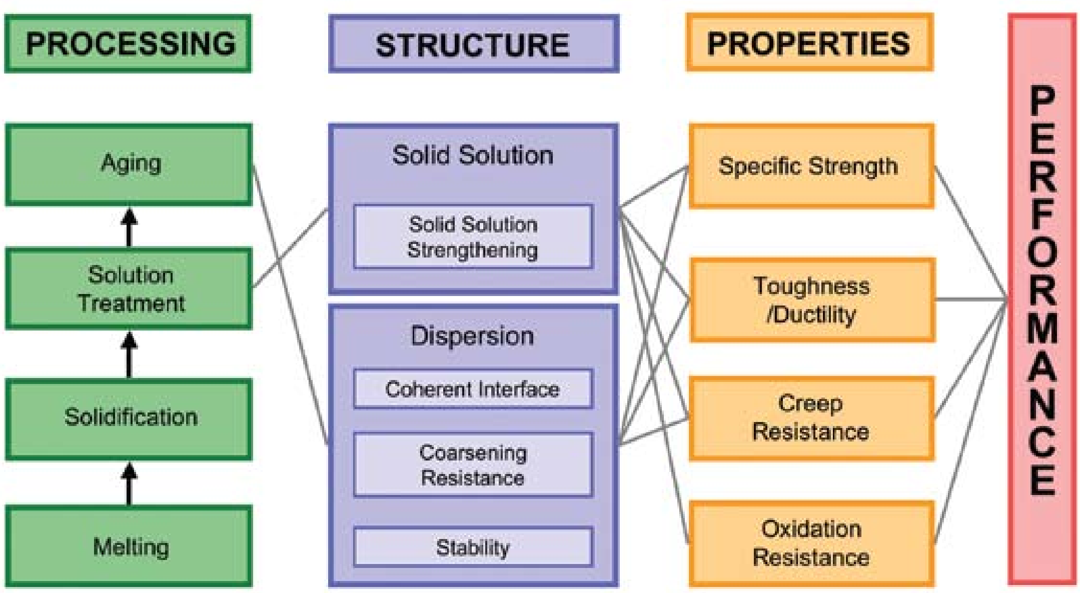
Materials Design: A Systems Approach

Modern materials contain extraordinary levels of complexity with components spanning a hierarchy of length scales. Designing materials which 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.

Our research lies in the basic understanding of the relationship between processing, structure, properties and performance. We use a systems-based materials design approach which couples experimental research with theory and mechanistic modeling for the accelerated development of materials. Microstructural properties are modeled using a toolbox of design models and methods which are strongly tied to materials science. These properties can then be expressed as thermodynamic parameters that can be predicted by using computational thermodynamic tools. Prototypes are then created to experimentally analyze and validate the design models which feed back into the working design for optimizing materials performance while minimizing design iterations. With a clear guide for materials design, large scale experiments can be avoided while promoting the rapid development of complex materials.

Specifically, our research includes the design of structural nanocrystalline-reinforced lightweight alloys for automotive and aerospace applications. This research initiative utilizes design objectives which incorporate low-cost processing techniques to develop sustainable engineering materials. Furthermore, we are concurrently researching the integration of structural and mechanically-active materials for use in smart/multifunctional composites for biomimetic systems. Such materials would have the capability of performing higher-ordered tasks such as communication, sensing, health-monitoring and/or thermal management.

With these tools in hand, materials can be efficiently designed with specific material properties which are optimized for enhanced performance. This allows the material to be designed for the system and not the system to be design around a material. Therefore, an engineering material can be designed from the macro- to nano-scale to optimize system objectives.



John J. (Jack) Mecholsky, Jr.

Professor

Ph.D., 1973, The Catholic University of America

Failure Forensics in Materials
Fracture Mechanics in Ceramics and Glasses
Biomaterials and Biomimetic Design
Laminate Composite Design

Our research group concentrates on understanding the mechanisms of failure in materials with the purpose of suggesting improved methods for fabricating new materials.

Failure Forensics

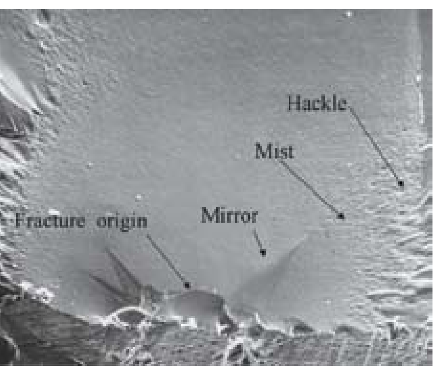
Many material systems fail prematurely. We have developed techniques based on fracture mechanics, fractal geometry and quantitative fractography to be able to understand the nature of failure in fiber optics, high performance ceramic bearings, semi-conductor devices, capacitors, composites and biomaterials. Research in the application of fractal geometry to failure mechanisms has led to a tool by which we are now able to relate bond breaking on the atomic scale to fracture surface characteristics that can be observed with the unaided eye. Both experimental and analytical/modeling techniques has led to this methodology. The basic information has been shown for relatively simple materials such as inorganic glasses and single crystals. It is now appropriate to expand this knowledge to more complicated materials such as polycrystalline materials, natural composites, e.g., bone and teeth, prosthetic devices and laminate composites. ONR and NIH have supported the basis for this research.

Fracture Mechanics Applied to Glasses and Ceramics

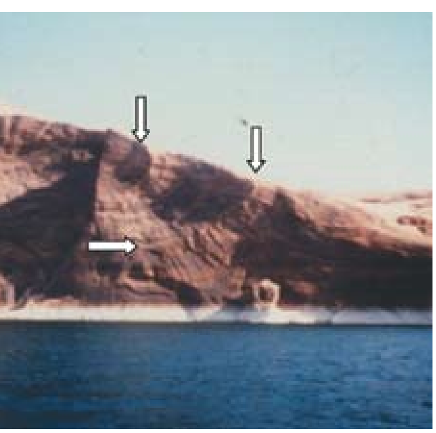
Applying fracture mechanics to the failure analysis of brittle materials has led to a new understanding of toughening mechanisms. We use this knowledge to be able to design tougher and stronger materials. We have been able to identify the size of defects causing failure and have suggested methods by which the effect of these defects can be lessened, e.g., by the introduction of residual compressive stresses. One of the lessons that has been learned is that the principles of fracture mechanics can be applied at many length scales from geologic to nanometer. We have used these principles to determine the cause of failure in manatee bone, crab chelae, human and bovine teeth, as well as more common applications such as silicon nitride bearing material and zinc selenide laser windows. NSWC and NSF have supported this work.

Composite Design

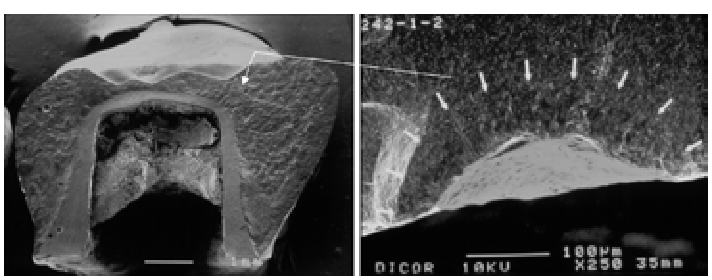
There are many applications which require strength and toughness, i.e., not only do these materials or structures need to withstand great loads, but also need to be able to deflect without breaking. One of the logical ways to accomplish these two goals is to design laminate composites. Nature has accomplished this very well by creating ceramic-polymer laminates, i.e., hydroxyapatite-protein laminates as well as particulate composites. We have studied natural composites in order to mimic the structure and function of these composites. Our research group has designed and fabricated alumina-nickel and silicon nitride-chrome laminates to demonstrate how armor and high performance ceramic bearings and raceways can be improved. We also fabricated Bioglass“-steel and hydroxyapatite-polysulfone laminates to demonstrate methods by which artificial bones can be fabricated. NIH, DARPA, US Biomaterials (now NovaMin Technology) and Pratt & Whitney have supported this work.



Fracture origin in soda-lime-silica (window) glass showing characteristic markings. These markings appear in all materials that fail in a brittle manner.



Fracture at Lake Powell, Utah Brittle fracture can be observed at many length scales. Arrows point to crack arrest lines.



Failure analysis of failed dental crowns from patients have identified needed improvements for commercial products.

Ying Shirley Meng

Assistant Professor
Ph.D., 2005, Singapore-MIT Alliance
(c/o National University of Singapore)

Energy storage and conversion materials: Li -battery electrodes and thermoelectrics
Charge ordering and structure stability in functional ceramics
Size-dependent structure stability and transport properties of nano-scaled materials

Our goal in materials research is to design and develop new materials for advanced energy storage and conversion applications. Conversion of raw materials into usable energy and storage of the energy produced are common aspects of everyday life. The development of new materials to improve upon current capabilities is a key technological challenge of the 21st century. Advances will allow smaller more powerful batteries as well as allowing a greater ability to harness more sustainable energy sources. Our research focuses on the direct integration of novel experimental techniques with ab initio computation methods for rational materials characterization and design.

Materials Design for Advanced Portable Power Sources

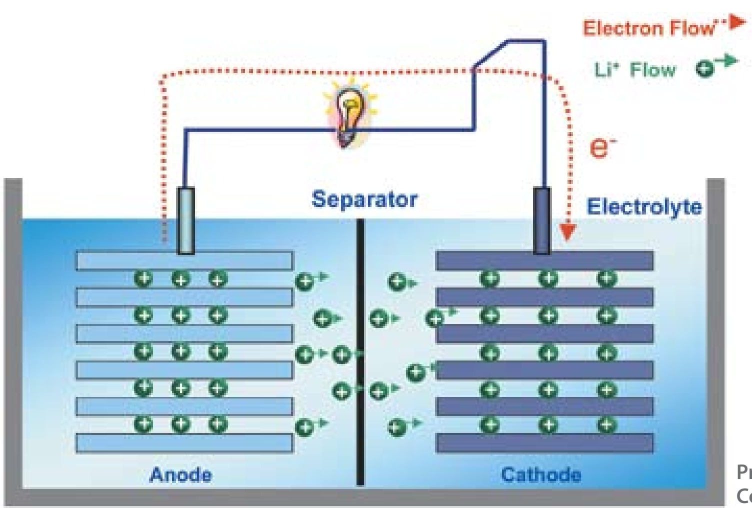
Lithium ion batteries have become a key component of portable electronic devices as they offer high energy density, flexible lightweight design and a longer cycle life than other battery systems. More efficient batteries are required in the development of advanced transportation technologies in order to reduce the use of imported oil and the emission of greenhouse gas. Electrochemical energy storage has been identified as a critical enabling technology for advanced, fuel-efficient, light and heavy duty vehicles. New materials need to be designed to achieve higher energy/power densities, longer cycle lives and better reliability for such applications. We focus on synthesizing new multi-transition metal oxides with higher energy density, faster rate capability and better safety, as well as explore the exact ion transport mechanism and structural stability during the cycling of the battery.

Thermoelectric Materials – Convert Heat to Electricity

Oxides are intriguing for thermoelectric applications as they are relatively cheaper and stable at high temperature. One major application is to recuperate wasted engine heat to electric current, thus increase the engine efficiency. Determination of the stable structures and charge/magnetic ordering is one of the most fundamental steps in obtaining optimum thermoelectric properties of these functional ceramics. We will fabricate high quality oxide films by pulsed laser deposition and characterize their figure-of-merit for thermoelectric applications. The final goal is to propose strategies to further enhance the thermoelectric properties in the family of the oxides.

Structure-Property-Processing Relations of Nano-scale Materials

Materials science emphasizes the study of the structure of materials and of processing-structure-property relations in materials. It is the physics and chemistry of real materials. To understand how the desired properties of a material can be modified, it is necessary to understand the relationships between structure and properties and how the structure can be changed and controlled by the various chemical, thermal, mechanical, or other processes to which a material is subjected during synthesis and in use. Such knowledge is still lacking in the design and development of nano-scale materials, which have generated tremendous interest in the last decade for energy related research areas. For example, in order to achieve high power in batteries nano-scale materials such as inorganic nanotubes and nanowires (TiS_2, TiO_2, MoS_2…)-may offer a plausible solution due to their high surface reactivity: i.e. fast surface transport property for electrode designs in which mass transport is not rate limiting anymore. Through understanding how the thermodynamic and kinetic properties of these tubes/wires differ from the bulk with ab initio study, we can eliminate much guesswork and effectively prescreen candidate nano-scale materials for energy applications. We will apply modern synchrotron X-ray and analytical transmission electron microscopy to explore the structure – property relation in functional nanotubes and nanowires.



Principles of Lithium Ion Batteries
Convert chemical energy to electric energy

Brij M. Moudgil

Distinguished Professor; Director, Minerals Resources Research Center; Director, Engineering Research Center
Dr. Eng. Sc. , 1987, Columbia University

Mineral processing, surface chemistry, fine particle processing, crystal modifiers.

The foundation of Brij M. Moudgil research is fundamental for understanding and for control of nano and atomic scale forces in particulate systems and synthesis of functionalized particles. The work is targeted for advances in separations, microelectronic polishing, controlled drug release formulations, environmentally benign pulp and paper processing, drug detoxification, and nanotoxicology areas. Overall, a systematic attempt for design-based synthesis of engineered particulate systems is underway requiring the development of structure-property-performance correlations.

Moudgil's research specializations are:

Surface Force Measurements and Engineered Particulate Systems – The Foundation For Functional Particulate Materials Innovations

Selective Surfactant Coatings/ Passivation Layers for Advanced Separations and Selective Polishing CMP Slurries

Material Development for Enhanced Photocatalysis for Healthcare and Homeland Security

Cell- Surface Interactions: Developing a Tool for Dynamic Force Range in Nano-Biotechnology & Nanotoxicology

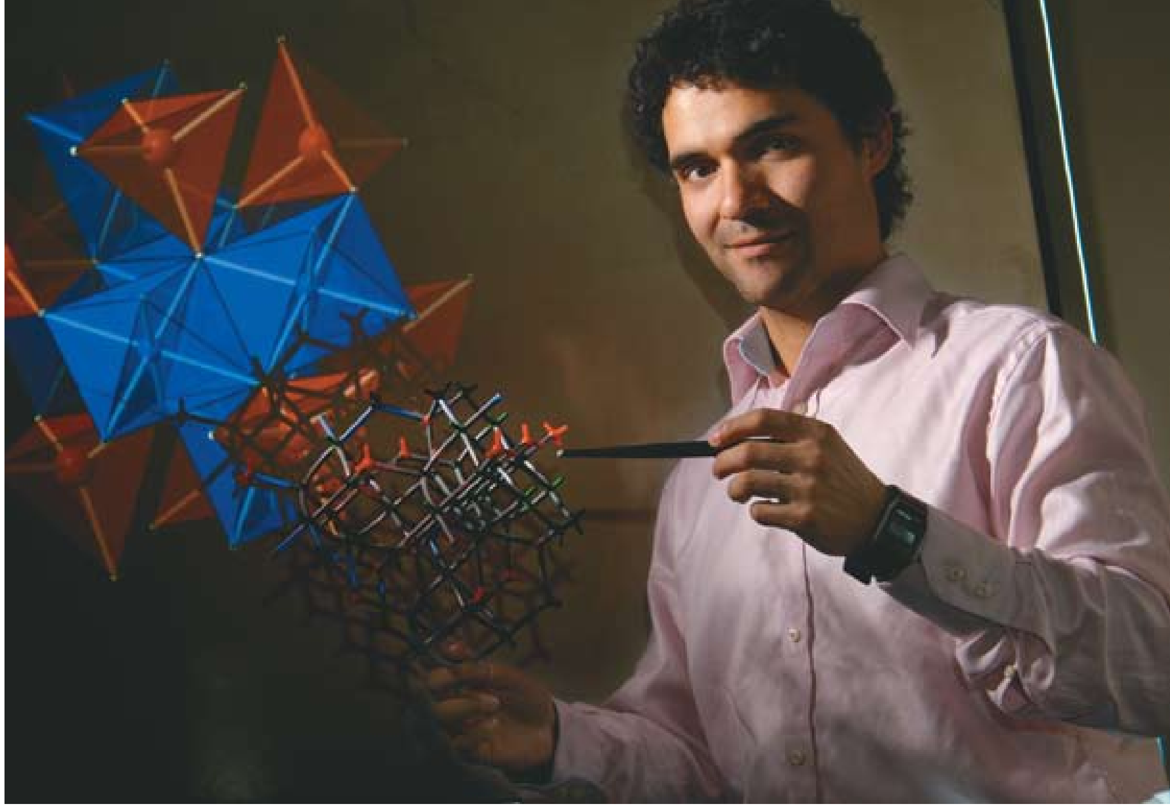
Nanocomposites: Developing a Quantitative Measure of Dispersion for Optimal Nanocomposite Properties

Multimodal Qdot Based Nanoprobe for Real-Time Noninvasive Bioimaging

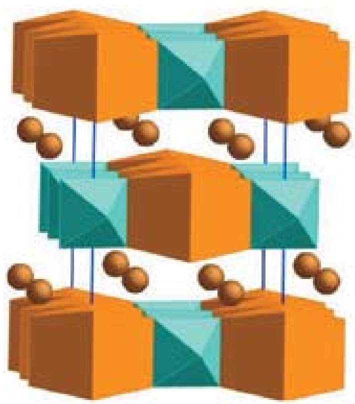
Juan C. Nino

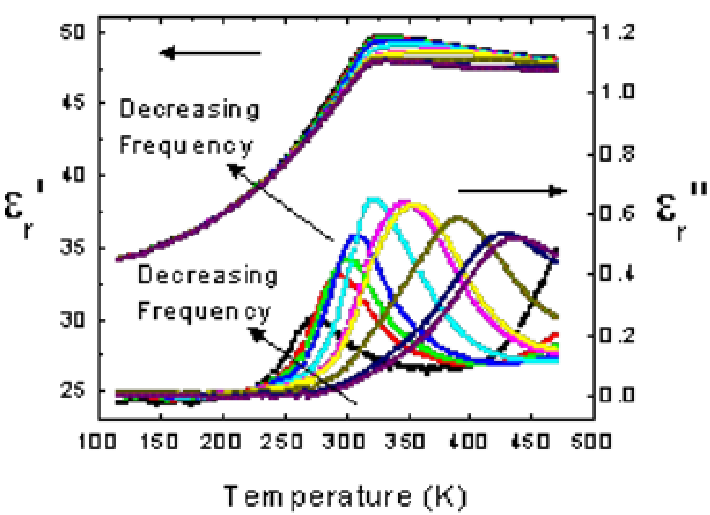
Assistant Professor
Ph.D., 2002, The Pennsylvania State University

Structure-Property Relationships of Electroceramics
Design and Development of Energy-Related Materials
Dielectric, Ferroelectric, and Piezoelectric Devices
Processing Optimization of Nuclear Fuels



NRG
Nino Research Group





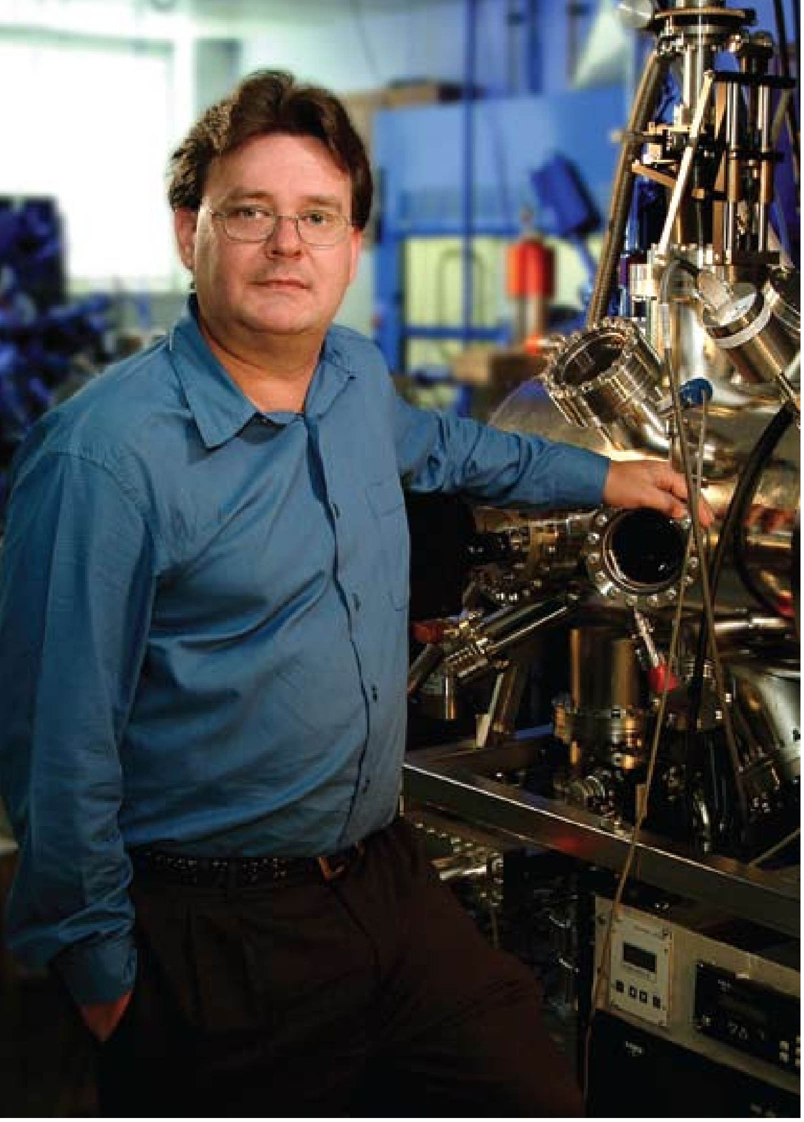
Investigation of structure-dielectric property relationships in electroceramics. Top, schematic of weberite-type crystal structure of Ln_3NbO_7 dielectric ceramics (where Ln is a lanthanide ion). Bottom, frequency and temperature dependent dielectric relaxation observed in these materials. The characteristics of the relaxation are mediated by the composition and ionic displacements in the structure.

The main interest of Nino Research Group is the investigation of fundamental structure-property-processing-performance (sppp) relationships governing energy-related materials systems, with emphasis on electronic and nuclear materials. Research is focused primarily on ceramics, polymers, biomaterials and their composites. Through fundamental materials research and characterization sppp relationships are identified, verified and/or postulated and then are used towards the rational design and development of new and improved materials with properties tailored toward specific applications.

Current research is concentrated in five main areas: (a) co-doping strategies for ionic conductivity enhancement in electrolytes for intermediate temperature solid oxide fuel cells (SOFCs); (b) structure-property relationships in dielectric ceramics for capacitive applications and microwave communication devices (see figure); (c) synthesis and optimization of composite ceramic oxides for inert matrix fuel systems for nuclear reactors; (d) electrospinning of complex oxides for sensing, actuation and catalytic applications; and (e) crystallographic design and synthesis of high temperature proton exchange membranes.

NRG is also involved in other related research areas including: (i) development of pyrochlore ceramic cathodes for SOFCs; (ii) biocompatible ferroelectric nanoparticle systems for hyperthermia cancer treatment; (iii) polymer-ceramic composites for flexible high power capacitors; (iv) vibrational spectroscopy of materials using Raman, infrared and Terahertz spectrometry; and (v) electromechanical optimization of piezoelectric bases microelectromechanical systems.

NRG publications, presentations, projects, student education and related activities are aimed at positioning the group at the forefront of materials development for energy-related applications.



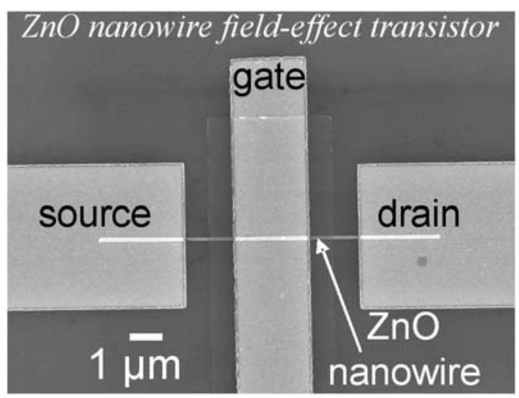
David P. Norton

Professor
Director, University of Florida Nanofabrication Facility
Ph.D., 1989, Louisiana State Universit

Epitaxial film growth
Electronic materials and devices
High-temperature superconductors
Laser Processing

My research focus' on the synthesis and properties of electronic and photonic oxide thin films. Oxides exhibit properties that are relevant to numerous applications. Areas of activity include wide bandgap semiconducting oxides for solid state lighting, dimensionality effects in superconducting and ferroelectric superlattices, artificially structured thin film materials, and oxide epitaxy on dissimilar substrates. While a staff member at Oak Ridge National Laboratory, significant effort was devoted to developing high temperature superconducting wires based on an approach known as Rolling Assisted Biaxially Textured Substrates (RABiTS). This technology is currently being commercialized by several companies. For this development, I shared an R&D 100 Award with fellow colleagues at ORNL in 1999. Additional honors and awards include the American Museum of Science and Energy Technological Achievement Award (1999), Lockheed-Martin Corporation Nova Award (1997), and the DOE Division of Materials Research Competition Award (1996).

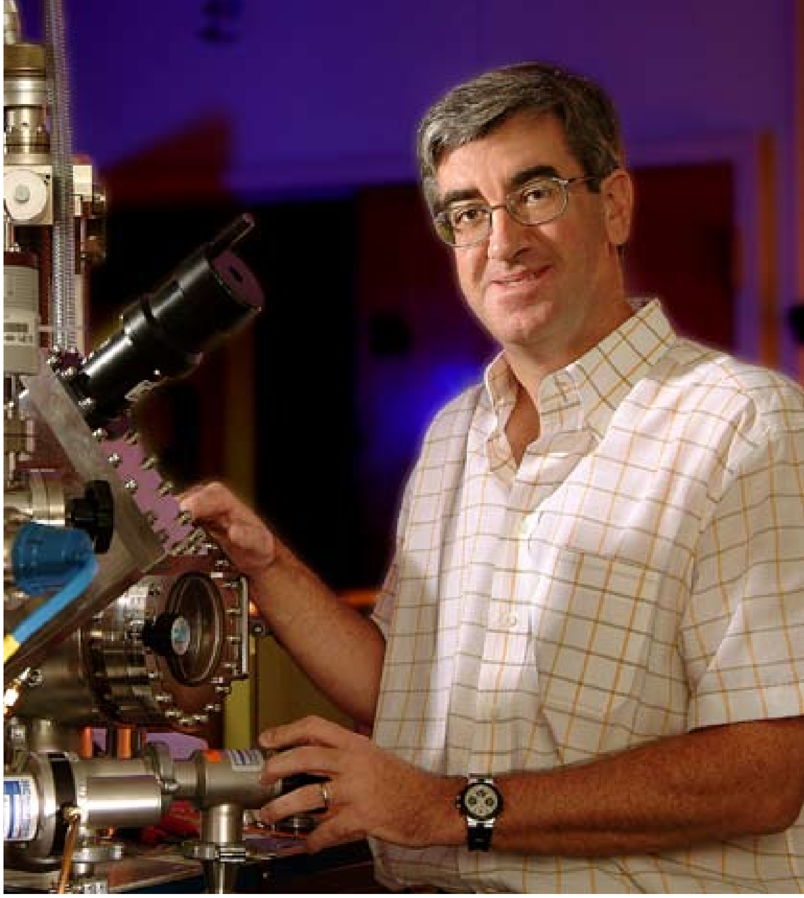
I am currently a member of the American Vacuum Society, the Materials Research Society, the American Physical Society, and the Electrochemical Society.



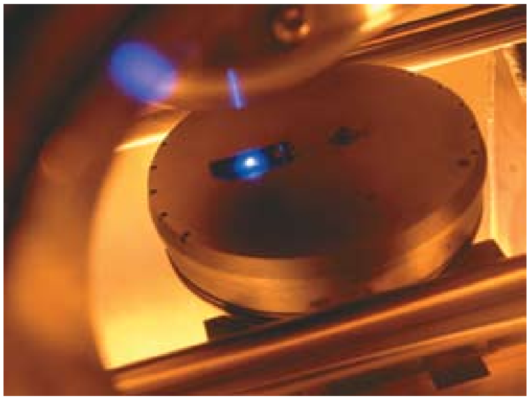
Stephen J. Pearton

Distinguished Professor
Ph.D., 1983, University of Tasmania, Australia
Fellow IEEE, AVS, ECS, APS, TMS

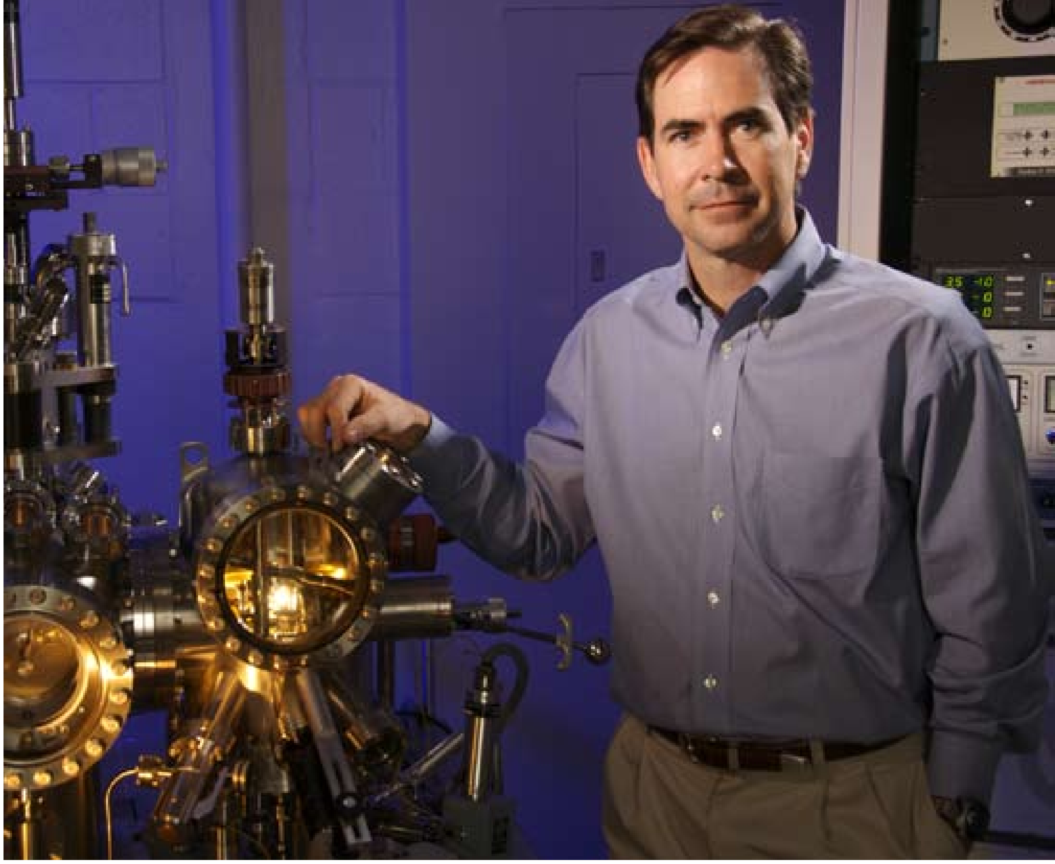
Semiconductor materials, processing and devices
Hydrogen in semiconductors
Physics of semiconductors
3-D integration of multi-chip modules
Solid state sensors
Spintronics



Our work is focused on developing new semiconductor materials systems for applications in high speed and power electronics, solid-state lighting and robust integrated sensors for detection of combustion gases, polar liquids and biogens. Specific on-going projects include processing of semiconductors(especially GaN, GaAs, InP and related alloys), ion implantation, hydrogen in solids, plasma etching, contacts to semiconductors, spin-related phenomena in semiconductors, thermal processing of electronic materials, device physics and electrical characterization. We also have significant efforts in developing sensors, spintronics and solid-state lighting. The basic theme of our efforts is to develop future generations of electronics, photonics and sensors with improved performance, levels of integrations and functionality relative to existing technology. GaN-based devices show great promise for sensor-related technologies because of their enhanced environmental resistance. This environmental resistance may be of great value to the reliability of devices because without the normal insulating dielectric layer silicon-based ISFET devices can display reduced sensitivity over time due to environmental effects on the gate region due to the Na, K, and other detected ions themselves. In addition, GaN technology enables direct integration of the ion channel field effect transistors (FETs) with on-chip blue/UV illumination compact LEDs. Such dual device character may be of use for in-situ toxin destruction, or additional interrogation of each device pixel compared with conventional SiO2-based systems. The heterogeneous integration of material in multiple layers enables three-dimensional (3-D) integrated circuits. Breaking the barrier of traditional integrated circuits limited in two-dimensional (2-D) space, 3-D integrated circuits offer several advantages: 1) significantly higher density integration in same chip area, 2) optimized device technology for each function, 3) significantly shorter and less complicated interconnects to operate at high frequency/high speed. These 3-D integrated circuits will enable Intelligent Microsystems to be built in a much smaller size and yet with much more capabilities. For example, deep-penetrating surveillance is crucial in military intelligence, combat mission, and anti-terrorist operation. An ideal deep-penetrating surveillance device should be very small and easily deployed to the target location. The device should be able to send the collected data back to the central station or satellites very far away. To avoid being detected, wireless transmission at specific radio frequencies is preferred. To have a small antenna for transmission, millimeter-wave frequency is preferred. It also avoids the crowded spectrum at lower microwave frequencies. Since the surveillance device needs to send the signal to the receiving station a long distance away, the transmitted power needs to be high enough to overcome the free space path loss at millimeter-wave frequencies. We are working on approaches to achieve these goals



A sample of ZnCdO shows strong light emission during testing to make future generations of energy efficient lighting.



Scott S. Perry

Professor
Ph.D., 1991, The University of Texas at Austin

Tribology
Materials Chemistry
Surface Science

Surfaces and interfaces are ubiquitous throughout nature and many of today's applications involving advanced materials. Their properties heavily influence widespread phenomena such as adhesion, reactivity, wetting, adsorption, and electrical conductivity. My research involves the use of scanning probe microscopy and ultra high vacuum (UHV) surface analytical techniques to perform atomic and molecular scale studies of the structure, chemical reactivity, and tribological properties of a variety of material surfaces. These include metal oxides and carbides, ultra thin polymer films, and nanocomposities and supported nanoparticles. An important theme throughout this work is the correlation of molecular structure and composition with the measured chemical reactivity and tribological response of the interface. The use of an array of experimental techniques is needed in developing a compete picture of these materials surfaces.

Tribological Studies

Tribology is the study of friction, lubrication, and wear of two bodies in relative motion; modern studies have demonstrated both physical and chemical origins to these phenomena. The need for a greater understanding of tribological fundamentals has been driven largely by technological applications requiring more stringent control of the tribological interface. Examples of this need are prevalent in the microelectronics, aerospace, and biotechnology industries.

This line of research is directed towards developing an atomic scale understanding of interfacial friction as well as the fundamental design of new tribological materials. The approach involves the synthesis and characterization of model and novel chemical interfaces and the measurement of interfacial frictional forces with atomic force microscopy. This broad category of research involves investigations of water-soluble biomimetic lubricant films, hard coating materials, inorganic and polymeric nanocomposites, and modified polymer surfaces.

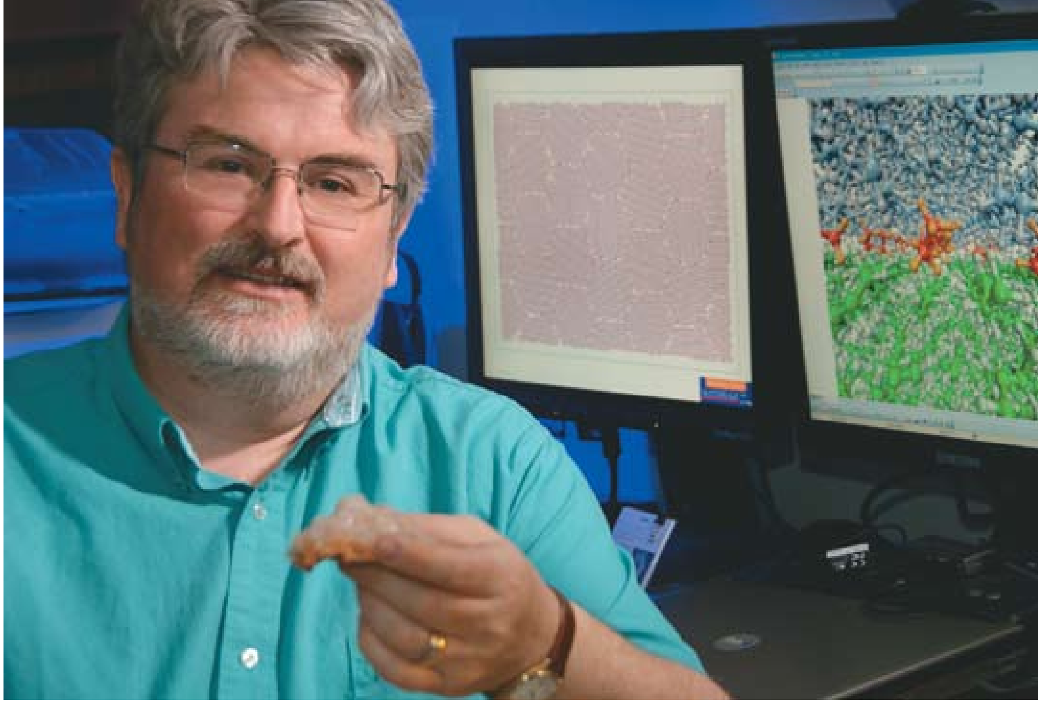
Materials Chemistry

Chemical reactions occurring at materials interfaces represent the fundamental basis of many technologies. The reactivity of these interfaces depends on the surface structure, composition, defect level, and crystalline nature of the solid surface. We are working to measure the local order, crystallinity, and topology of surfaces with scanning probe microscopy techniques and to correlate this structure with knowledge of the chemical reactivity of the surface or unique physical properties resulting arising from interfacial bonding. This experimental approach is being applied to the study of mixed conducting oxides presently used as electrodes in solid oxide fuel cell as well as the development of nanocomposites and supported metal nanoparticles.

Simon R. Phillpot

Professor
Ph. D., 1985, University of Florida

Computational Materials Science
Interfaces in materials
Ferroelectrics
Polycrystalline and nanocrystalline materials
Thermal transport

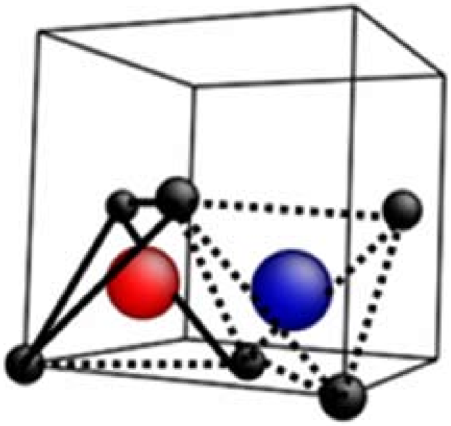


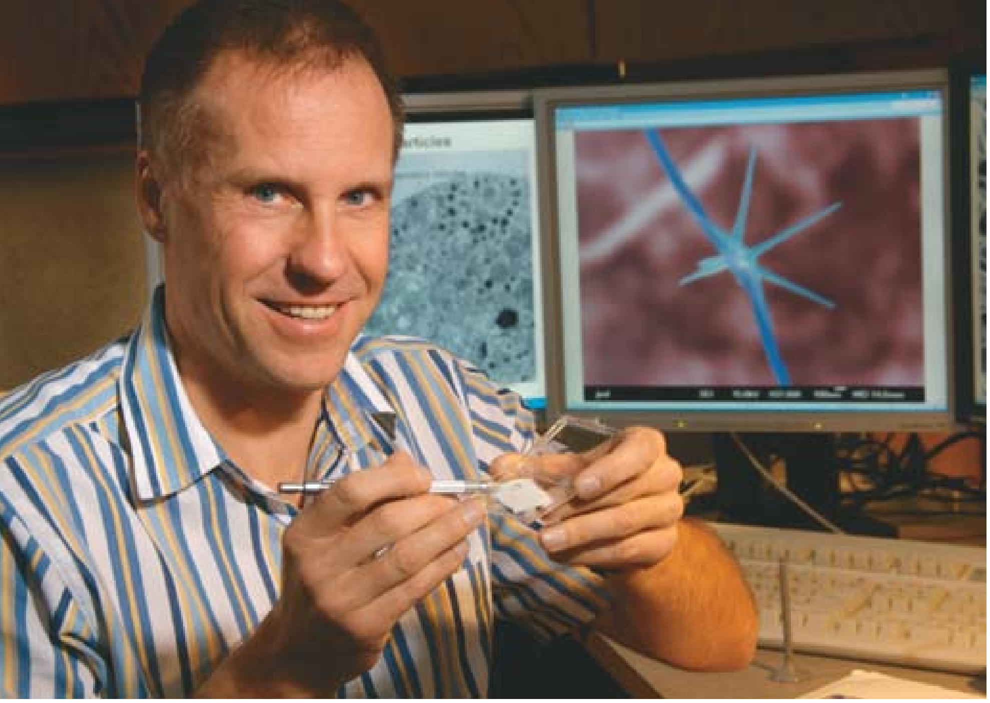
Our work uses computer-based simulation techniques to develop a detailed understanding of the physical processes taking place in materials, with particular reference to their applications in modern technologies. By using methods that treat the atoms and ions explicitly, we can characterize and describe the behavior of materials at the sub-nanometer length scale and with sub-picosecond time resolution. Such detailed information is extremely valuable in constructing detailed mental models of physical processes, in developing our physical intuition, and in interpreting experimental results.

A central aim of our work is to elucidate the effects of microstructure on the physical properties of material. Work in this area includes the ferroelectric properties of thin films; the effects of grain boundaries, interfaces and point defects on thermal transport; the effects of composition and microstructure on the thermo-mechanical properties of nuclear materials; low-friction organic and inorganic materials for space applications; and electrolytes for solid-oxide fuel cells. We also work on developing new simulation approaches that increase the range of materials systems that are accessible to atomic-level simulation techniques, and will expand the complexity and range of phenomena that can be investigated.

Our work is integrated with those of the other computational materials scientists in the department through the Computational Materials Science Focus Group, and with experimental program within MSE and beyond.

Our work relies heavily on advances in computer technology and computer simulation techniques. In particular, the considerable computational resources we need are largely provided by parallel computer clusters (so-called Beowulf clusters) made from consumer electronics, and running the LINUX operating system. In particular, the Florida Laboratory for Advanced Materials Engineering Simulation (FLAMES), which is for the exclusive use of Dr. Phillpot's and Dr. Sinnott's groups, consists of three clusters of Pentium IV computers totaling 240 processors.





Wolfgang M. Sigmund

Professor
Dr. rer. Nat., 1992, Max-Planck-Inst., Stuttgart, Germany

Colloid and interfacial chemistry
Powder Processing
Surface Chemical Modification
Thin Films
Polymers and Ceramics

Cover page made by our group for single fiber measurement

Nanotechnology Enthusiasm

Nanotechnology allows for novel pathways to design and manufacture electronic and structural properties for materials that were not available ten years ago. We are at the core of nanotechnology doing interdisciplinary and multidisciplinary research. We focus on the design, synthesis and processing of nanomaterials where in we collaborate with researchers in other outstanding disciplines at UF and many other universities throughout the world to provide new materials to solve problems in energy, environmental remediation and medicine. Recent success stories of newly created nanomaterials include the abilities to reduce mercury contents in flue gas from coal-fired power plants, to remediate, or purify, air and water of hazardous microbes or organic contaminants, and the promise of altering and tracking cell functions of specifically targeted single cells within a biological organism.

Design

We actively contribute to other disciplines by designing the shapes and sizes of multifunctional and smart nanoparticles. These include core-shell nanoparticles with magnetic properties that spread, collect or locate in specific areas. Optimized electronic features enhance photocatalysis in sunlight, and they also allow for single-molecule detection via surface plasmon-enhanced Raman spectroscopy. For medical applications, multifunctional nanoparticles may contain e.g. redox capabilities as well as electronic markers for detection. It is a wide-open field, and we are excited to provide novel designs for solving more problems in other disciplines. (Sigmund, W., Kim, H., Modification of Carbon Nanotubes in Encyclopedia for Nanotechnology and Nanoscience, Ed. H. Nalwa, Volume 5, 619-631, 2004, ISBN1-58883-061-6)

Synthesis

Novel synthetic techniques yield modified carbon nanotubes, organized carbon nanotube arrays, and a large variety of nanostructures including cables, wires, rods, bands, particles or mesh based on any material, i.e. polymer, metal or ceramic. Our main focus, in collaboration with Delft University (Netherlands), is currently on using electrospinning and electrospraying as new technologies to provide access to ceramic and hybrid nanosystems. These exciting techniques offer the best capabilities to control nano-shape, composition, size and in the near future also location. (W. Sigmund et al., Feature article in J. Amer. Ceram. Soc., February 2006)

Processing

Large 3-dimensional objects are built via direct casting of particles or self-assembly of nanotubes. These processes require dispersion of nano-objects and subsequently their consolidation. Processing is enhanced by the fundamental description of guiding forces based on quantitative measurements. My group pioneered the first direct force measurements for a single nanoparticle in liquid media using the colloid probe technique in an atomic force microscope. (W. Sigmund et al., Feature article in J. Amer. Ceram. Soc., July 2000)

Rajiv K. Singh

Professor
Ph.D., 1989, North Carolina State University (90)

Laser processing of materials, semiconducting and superconducting thin films, coatings, high-Tc superconductors, electron microscopy, diamond thin films

My research interests involve innovative synthesis and processing of electronic materials related to thin films, surface modification, nano-structures and issues related with semiconductor manufacturing. Oxide thin films exhibit a wide range of properties such as high dielectric constants, superconductivity, colossal magnetic resistance, high luminescence, etc. By tailoring its microstructure, the properties and applications of such materials can be optimized. The application of non-equilibrium processing techniques such as high powered lamps, pulsed lasers, microwaves, etc. can be suitably used to create new material and surfaces than is typically not possible via conventional means. Such processing is especially conducive to carbon based materials such as diamond, amorphous carbon films and nanotube structures.

The semiconductor device industry is continually driven to improve performance (faster chip speeds) and lower manufacturing costs. The technical challenges and complexities in fabrication of electronic devices have resulted in a unique opportunities for creation and further development of disruptive micro an and nano-manufacturing technologies. With the continuous development of miniaturization of semiconductor devices, there is growing need to develop novel surfaces, structures and materials with new functionalities. Some of the unique areas in the last decade include, conformal atomic scale thin film deposition techniques, chemical mechanical planarization ultra-rapid thermal processing of materials and creation of mechanically strained structures and surfaces. The nanoscale control provided by such techniques can be effectively used in energy related applications such as solar cells, optoelectronic and power electronic devices, microbatteries, and emerging medical devices.

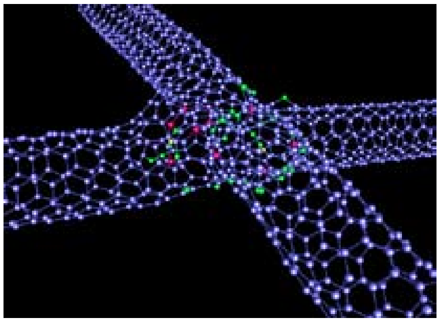
Susan Sinnott

Professor
Ph.D., 1993, Iowa State University

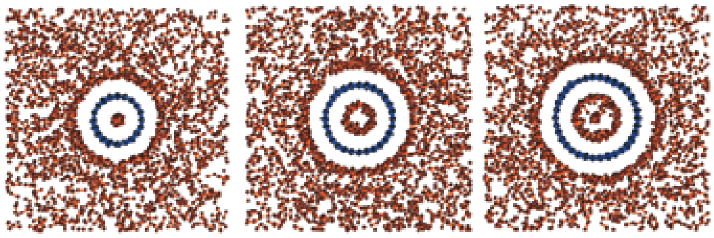
Computational Methods
Thin-film growth
Material Modification through ion-surface interactions
Interfacial segregation of defects and reactive elements
Carbon Nanotubes

The focus of our work is the investigation of the properties and processing of materials using advanced computational tools. In particular, we study materials on the atomic level using methods based on classical and quantum mechanical theories. The specific methodologies we use include molecular dynamics simulations with empirical, many-body potentials and electronic structure calculations using quantum chemical theory and density functional theory. The level of detail afforded by these tools allows us to design new materials and systems, explain experimental data, and make predictions about material behavior under a variety of conditions. In addition to applying these computational tools to the study of materials, we are also actively involved in the development of new methods and the enhancement of existing tools.

Several different processes and materials are being studied. One of these is the chemical modification of polymers, nanostructures, and nanocomposites through polyatomic ion beam deposition. The focus of this work is to better understand how polyatomic ions in low-energy plasmas influence thin-film growth, defect formation, and chemical functionalization of the target material. Another project of particular interest is the study of the role of defects in metal oxide ceramics on surface chemistry and the segregation of impurities to grain boundaries. Insight gained from this project will assist in the development of new device components for fuel cells and gas sensors. In addition, we are active in the study of nanostructured materials, including carbon nanotubes, and nanometer-scale phenomena, including friction. This work elucidates the difference in material properties and physical behavior at the nanometer-scale relative to the micrometer- or macro-scales, and indicates how these differences may be exploited in new devices and apparatus components.



Snapshot from a classical molecular dynamics simulation of a (5,5)-(5,5) carbon nanotube pair welded by electron beam irradiation in classical molecular dynamics simulations. Nanotubes welded in such a manner are found to behave as quantum dots and could be used in the next generation of electronic devices. The atoms are color coded as follows: blue spheres are sp2 carbon, pink spheres are sp3 carbon, green spheres are sp carbon, and yellow spheres are terminal carbon.



Snapshots from classical equilibrium molecular dynamics simulations of oxygen distributions in and around (A) (10,0), (B) (14,0), and (C) (17,0) nanotubes. Note the differences in the distribution as the size of the nanotubes increases. This study illustrates how fluid behavior at the nanoscale differs from behavior at the microscale and macroscale. Nanometer-scale pores, such as carbon nanotubes, are being considered for use as ultrafiltration membranes and nanometer-scale sieves and transducers.

Franky F. So

Associate Professor
Ph.D., 1991, University of Southern California

Organic semiconductor devices
Device physics
Organic thin film growth
Senior Member of IEEE

Our research focuses on organic electronic materials and devices based on molecular materials. Organic semiconductors are interesting in that their properties can be tailored by chemistry, and a wide range of materials with different functionalities can be realized. Organic semiconductors are also attractive for low cost, large area electronics. The current work focuses in three areas: organic thin film growth, device physics and organic based electronic devices.

High efficiency OLED lighting panel demonstrated by OSRAM Opto Semiconductors

Organic electronic devices

In this area of research, we will investigate various novel device architectures to fabricate high performance organic light emitting devices, photovoltaic cells, photodetectors, sensors and thin film transistors using organic materials. In OLED research, we focus on increasing the external power efficiency by doping the transport layers and increasing the external quantum efficiency with different light out-coupling schemes and down-conversion phosphors. In photovoltaics, sensors and transistors, we are exploring different novel device architectures to enhance device performance.

Device physics

Carrier injection and transport properties are the key factors determining the device performance. We are using different techniques such as time-of-flight and dark injection to probe the carrier transport properties in organic materials. The carrier transport and injection properties will be measured as a function of temperature and electric field. We will also investigate the effect of surface treatment on carrier injection. These results will then be correlated with the bulk and interfacial properties of the materials.

Organic thin film growth

To optimize the carrier transport, highly orientated organic crystalline films are desirable. Ideally, we would like to grow epitaxial single crystal thin films on substrates. This is not possible because of the substrates used for organic thin film growth. We are using various novel techniques to growth highly oriented crystalline organic thin films on glass substrates for device applications.

Eric. D. Wachsman

Director, Florida Institute for Sustainable Energy
Director, UF-DOE High Temperature Electrochemistry Center
UF Research Foundation Professor
Ph.D. Materials Science & Engineering, Stanford University, 1990

Ionic and electronic conducting ceramics
Sensor, fuel cell, battery and gas separation applications

Our research is focused on solid ion-conducting materials and electrocatalysts, and their application in improving energy efficiency.

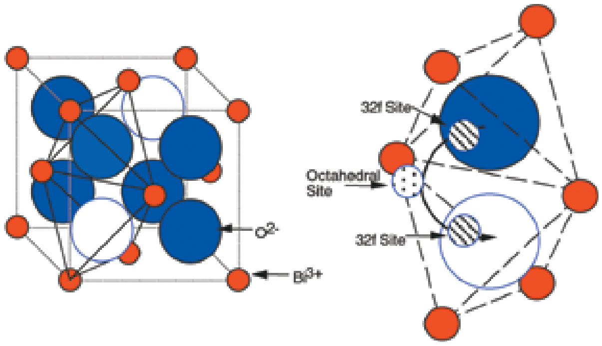
We live in a world were energy production is of paramount importance to the standard of living of developed and developing nations. The availability and location of energy resources has a dramatic impact on world conflict and national security. With a limited global energy supply, energy utilization efficiency becomes more important every day. Moreover, energy utilization efficiency is directly related to global environmental issues such as global warming, acid rain, and numerous smog related lung diseases. Our research specifically addresses these global issues.

Combustiuon Control

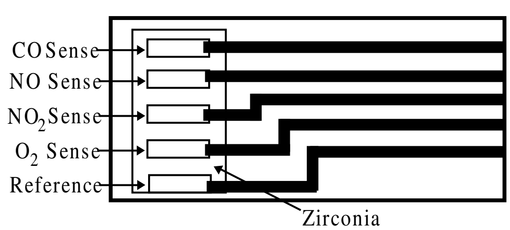
Currently the greatest global energy source, and at the same time the greatest source of atmospheric air pollution, is the combustion of fossil fuels. We developed species (NO_x, CO, etc.) selective solid-state gas sensors based on "Differential Electrode Equilibria" by taking into consideration both catalytic selectivity and the semiconducting response of metal oxide electrodes. The exceptional sensor selectivity has resulted in tremendous commercial and government interest. This work has been recognized by award of several contracts, including DOE, NASA, LANL, and General Electric, and by the selection of Dr. Wachsman to represent the US in a bilateral Japan-US Workshop on the Future of Sensors and Sensor Systems by the US Department of State and the National Academies. These sensors will have the earliest impact on energy utilization and the environment, and will allow dramatically improved combustion control resulting in near term improvement in fuel utilization efficiency and reduced exhaust emissions.

Fuel Cells

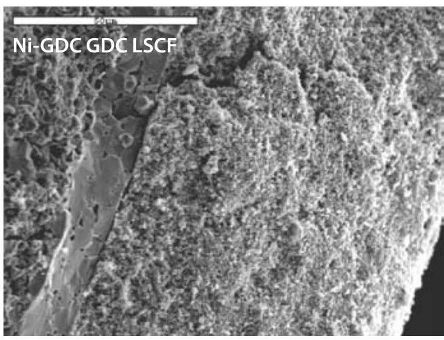
As we transition from inefficient combustion of precious fossil fuels to direct electrochemical oxidation in fuel cells we will realize efficiency gains of 300% and greater. At the same time we will produce 1/3 the amount of CO_2/kWh as well as essentially eliminate the production of pollutants such as NO_x and CO. Our research has made dramatic progress in this regard, developing a new higher performance solid oxide electrolyte (World record highest conductivity) that may permit fuel cell powered vehicles to operate directly within our current gasoline fuel infrastructure. We have also advanced the fundamental understanding of both local structure and thermodynamic properties on ionic transport and electrochemical performance of these materials. This work has been recognized by multiple DOE contracts and the invitation to be the only academic at the DOE workshop charged with writing a report to the U.S. Congress on how to overcome the impediments to commercialization of fuel cells.



Fundamental Transport



Combustion Sensor



Solid Oxide Fuel Cell

Jiangeng Xue
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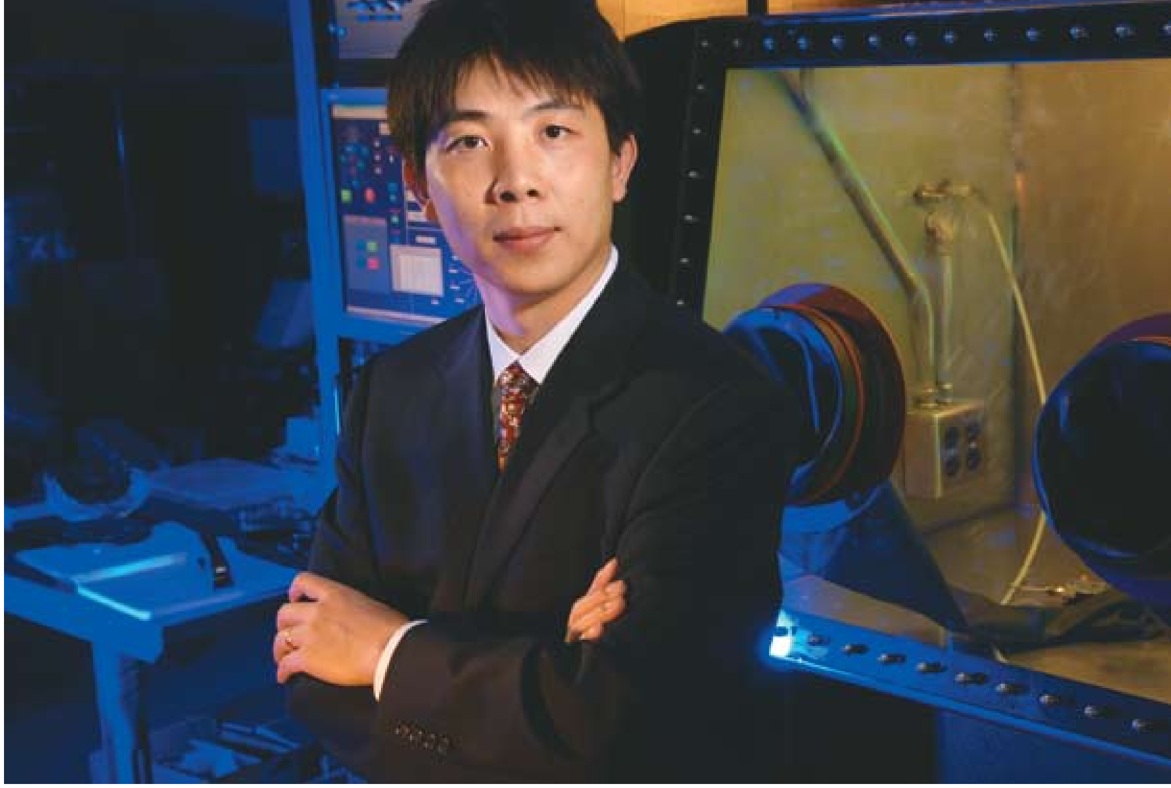
Electronic Materials
Composite Materials
Nanomaterials
Polymers



Organic electronic materials have many technological advantages over their inorganic counterparts, such as low material costs, ease of processing, compatibility with flexible substrates, and tunability of material properties. Our research program is focused on studying those organic materials and related electronic and photonic devices. There are two integral parts of our research: to gain a more profound understanding of the fundamental properties of organic electronic materials, and to develop novel electronic and photonic devices either with interesting performance characteristics or with performance suitable for practical use.

Fundamental properties of organic electronic materials

Organic semiconductors have very different electronic and optical properties from inorganic semiconductors. We study the film growth, the absorption and emission of light, and the charge generation, injection, transport, and recombination processes in organic thin films. Particular attention is paid to the interfaces among organic materials and between organic and inorganic (e.g. metal, metal-oxide, inorganic nanoparticles) materials.

Organic photovoltaic cells

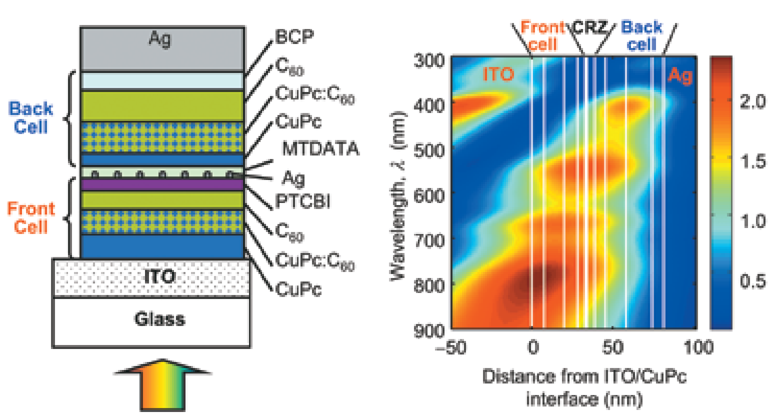
Organic photovoltaic cells have the potential to convert solar energy into electricity in very low cost, thus providing a clean and affordable energy source in the near future to replace the depleting fossil fuels. Built upon our earlier success in achieving high efficiency organic photovoltaic cells, we strive to further improve their efficiencies toward practical application requirements and to enhance their long-term operational stability. Fundamental material properties and device operation principles are investigated, which are the basis for introducing new materials and inventing novel device architectures.

Organic light-emitting devices for display and lighting

Highly efficient, long lived, and versatile organic light-emitting devices (OLEDs) can cover the entire visible spectrum and have applications in flat-panel displays or as general lighting sources. Our research in this field focuses on enhancing the extraction of light emission from OLEDs, and improving the luminescence efficiency by incorporating highly conductive, doped organic charge transport layers.

Other organic devices

We also study other type of electronic and photonic devices based on organic materials, including photodetectors, thin film transistors, chemical sensors. Furthermore, integrated devices incorporating two or more components that provide new functionalities are also studied.



High efficiency tandem organic photovoltaic cell. (left) schematic device structure, (right) calculated optical intensity profile]

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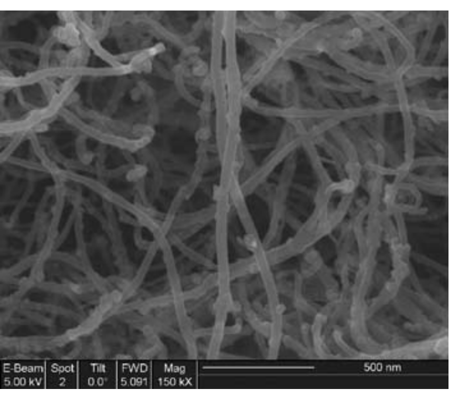
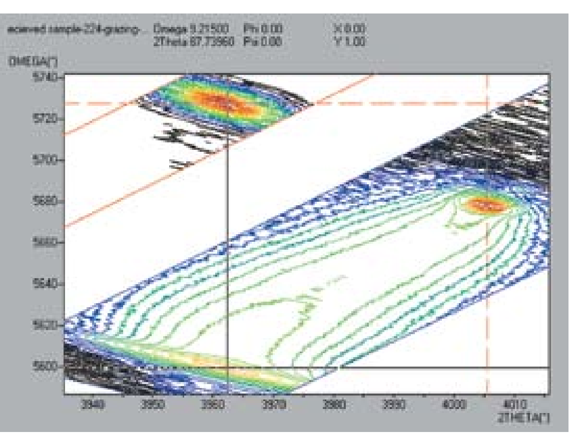


HR-FEGSEM



High-Resolution XRD

The Major Analytical Instrumentation Center (MAIC) is a materials characterization and analysis facility established to provide analytical support for Florida's scientific and engineering community in meeting the challenge of technology development. MAIC is a user oriented facility that provides service to the University of Florida, other universities and non-profit organizations, and the industrial and commercial community.

MAIC is organized to maximize the easy accessibility to its facilities. If someone is properly trained in the use of a particular instrument, access is merely a matter of scheduling. Potential users who are not qualified operators can arrange for instruction. Training is offered on several levels, ranging from simple instrumentation familiarization for experienced users to formal course work available for academic credit.

Daily operation is the responsibility of the staff members who maintain and operate the instruments. Selected for their special expertise, the staff ensures useful information is obtained even in cases when the researcher may have limited experience with the technique.

MAIC facilities include: Conventional and High Resolution (HR) Scanning Electron Microscopy (SEM), Energy Dispersive Spectroscopy (EDS), Electron Backscatter Diffraction (EBSD), Cathodoluminescence (CL), E-Beam Lithography, Conventional and Atomic Resolution Transmission Electron Microscopy (TEM), Electron Energy Loss Spectroscopy (EELS), Annular Dark Field Detector – Z Contrast, Electron Probe Microanalysis (EPMA) - Wavelength Dispersive Spectrometry (WDS), Focused Ion Beam (FIB) - Dual Beam System, Auger Electron Spectroscopy (AES), X-Ray Photoelectron Spectroscopy (XPS or ESCA), Nanomechanical Testing – Triboindenter, Optical Profilometry, Conventional, HR and High Temperature X-Ray Diffraction, Scanning Probe Microscopy (SPM), Atomic Force Microscopy (AFM), Spectral Analysis of Reflectance, Fourier Transform Infra-red (FTIR).

The MAIC facilities also include traditional SEM and TEM sample preparation instrumentation such as ion mills, ultra-cryo microtome, dimpler, sputter coater, ion beam coater, carbon evaporator, and plasma cleaner system.

Center and Partners

Florida Laboratory for Advanced Materials Engineering Simulation (FLAMES)

http://flames.mse.ufl.edu

FLAMES provides a state-of-the-art in-house resource for the computational programs in MSE. The use of consumer electronics allows us to build very powerful parallel computer clusters for remarkably low costs. Moreover, the small unit cost for processes allows us to continuously upgrade the facilities.

Computational Materials Science and Engineering Focus Group

http://compmatsci.mse.ufl.edu.

The Computational Materials Science and Engineering Focus Group uses innovative computer-based approaches and state-of-the-art computational facilities to attack some of the most important conceptual and technological issues in materials science.

UF-DOE High Temperature Electrochemistry Center

http://hitec.mse.ufl.edu

US Department of Energy research center focused on fundamental investigations of transport in, and heterogeneous reactions on the surface of, ion conducting ceramics. Research spans from first principle calculations to development of materials and material microstructures for high temperature electrochemical energy devices.

Florida Institute for Sustainable Energy

www.mae.ufl.edu/Energy

Florida Center of Excellence devoted to developing a broad array of sustainable energy technologies and resources, from fuel cells and hydrogen production to photovoltaics and biomass. Integrating technology, economics and policy to address Florida and US future energy needs.

Particle Engineering Research Center (PERC)

www.erc.ufl.edu

This NSF-funded interdisciplinary research center is devoted to the development of innovative particulate-based systems for next-generation processes and devices that contribute to the nation's economic well being, quality of the environment and public health. The research conducted at PERC impacts a number of diverse industries including advanced materials, environmental, chemical, drug delivery, cell biology, pharmaceutical, mineral, energy, agricultural and food processing. PERC's research and development facility creates the centerpiece of a world-class operation in particle science and technology. The 17,000-square-foot space includes state-of-the-art instrumentation for particle characterization and analysis, including a 5,000-square-foot testbed with a high bay area.

MICROFABRITECH®

www.microfab.ufl.edu

This broadly interdisciplinary program in solid state research and compound semiconductors ranges from fundamental understanding of new materials to the design, testing and characterization of novel devices. The center's research includes faculty from the departments of Chemical Engineering, Electrical & ComputerEngineering, Materials Science & Engineering, Chemistry and Physics. These faculty apply their expertise in advance materials and microelectronics to research in elemental and compound semiconductors (III-V and II-VI) and other advanced materials, such as high-temperature superconductors, conducting polymers, Fermion conductors and magneto-optic materials.

Biomedical Engineering (BME)

www.bme.ufl.edu

The UF Biomedical Engineering department offers biomedical research and educational opportunities for faculty and students from many disciplines, including materials science and engineering. Several of our MSE faculty have a dual appointment in BME. In addition, several MSE Ph.D. students have received M.S. degrees in the BME program, providing them a broad education that is attractive to pharmaceutical, biochemical and biomedical device industries.

Software and Analysis of Advanced Materials Processing (SWAMP)

www.swamp.tec.ufl.edu

The SWAMP Center in the College of Engineering at the University of Florida features interdisciplinary activities aimed at understanding, optimizing, and developing new techniques for the manufacture and design of integrated circuit devices. The center is devoted to understanding and modeling fundamental properties of the materials and devices involved in micro- and nano-electronics. The SWAMP center performs systematic, fundamental experiments designed to verify models of the physics and chemistry of the materials, structures, and processes used in manufacturing advanced microelectronics.

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