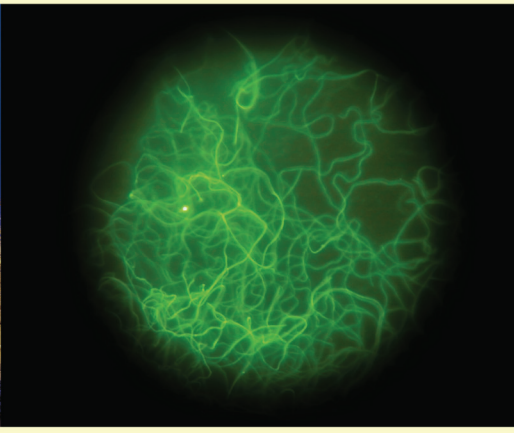
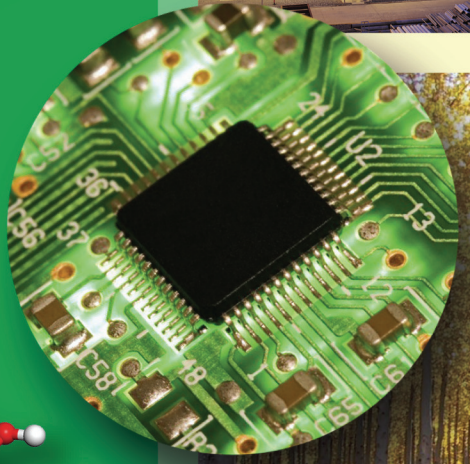
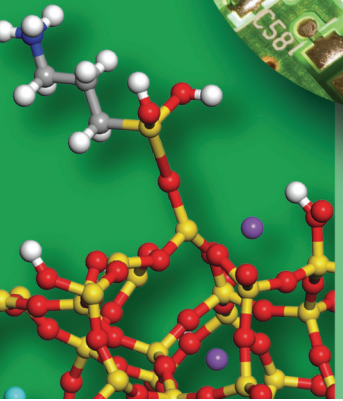
# Compendium of Technology Breakthroughs of NSF Industry/University Cooperative Research Centers

2007







# Compendium of Technology Breakthroughs of NSF Industry/University Cooperative Research Centers 2007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# Preface

This compendium catalogues industry-nominated technological breakthroughs that have emanated from research programs at National Science Foundation Industry/University Cooperative Research Centers (IUCRCs).

The primary data sources for identifying the breakthroughs were industry research scientists who had been or are currently serving as industrial advisory board (IAB) members at an IUCRC. These past or current IAB members were identified by center directors as being the most knowledgeable about accomplishments related to their center's research. These industry scientists were presumably in the best position to objectively decide whether any of the center's research endeavors met the following definition of a technological breakthrough:

> A technological breakthrough or advance was defined as research that led to significant process improvements, new processes or techniques, and new or improved products or services that resulted either directly from, or were indirectly stimulated by the center's research program. Up to six IAB member/scientists from each center were invited to participate in structured interviews or online surveys between November 2006 and January 2007.

The contributions of these industry scientists were essential to the development of this compendium. The entries contained herein are representative of the countless IUCRC related collaborative efforts of university and industry scientists over the past 30 years.

# Table of Contents

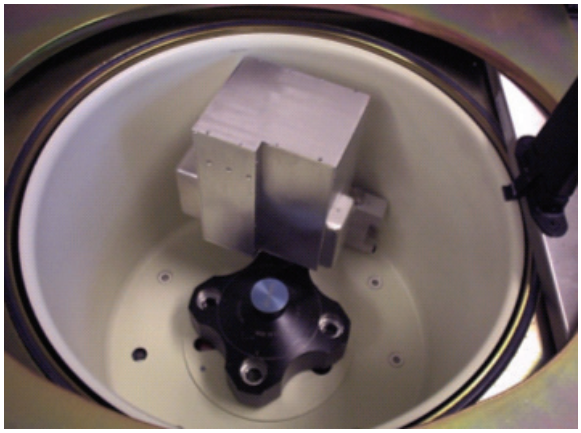
# Biomolecular Interaction Technologies Center (BITC)

University of New Hampshire, Thomas M. Laue, Director, 603.862.2459, tom.laue@unh.edu
University of Louisville, Jonathan Chaires, 502.852.1172, j.chaires@louisville.edu

Center website: http://www.bitc.unh.edu/

## Fluorescence Detection Optical System

The analytical ultracentrifuge (AUC) is widely used in academic and industrial laboratories to characterize molecular interactions. AUC use in drug discovery research is increasing as a result of advancements in optical systems, accessories and software for this instrument funded by the Biomolecular Interaction Technologies Center (BITC). A fluorescence detection optical system with unparalleled sensitivity and selectivity has been licensed by the University of New Hampshire to Aviv Biomedical, Inc. for commercial production. In 2006, a new company, Spin Analytical, Inc., licensed the technology to produce accessory items: specialty sample holders, a cell alignment tool and an automated cell washer.



Spin Analytical's unique sample holders (cells) allow researchers a wider variety of options in designing their experiments. In drug discovery, it can be necessary to use only a minute amount of molecule in solution, or to work with very high concentrations. Spin Analytical has produced an alignment tool to eliminate human error in aligning cells by eye, and an automated cell washer that saves time and can reduce human exposure to hazardous substances. Aggregation of injectable protein therapeutics is of great medical concern to BITC members. The Food and Drug Administration has encouraged the pharmaceutical companies to use multiple methods to test their products for aggregates. Three BITC member companies have shown that the improved accuracy offered by Spin Analytical technology is critical to the proper characterization of small quantities of aggregates.

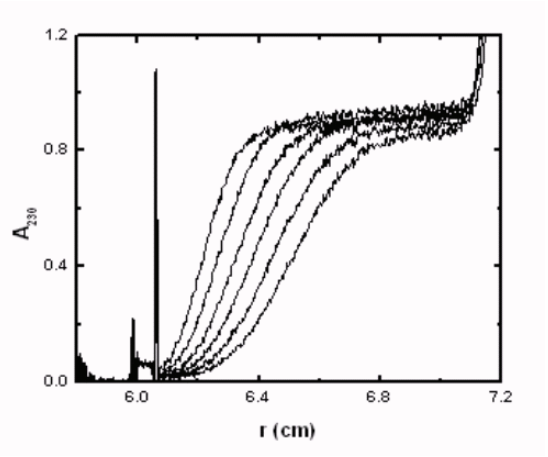
The Federal Drug Administration has recognized the value of sedimentation velocity experiments in the analytical ultracentrifuge in characterizing the physical properties of molecules under consideration as drug candidates. For example, the tendency of a large protein molecule to self-associate in solution can result in aggregation. In the human body, drug aggregation and other problems associated with the metabolism of a drug in blood serum can lead to anaphylactic shock, an often fatal condition. These accessories for the analytical ultracentrifuge assist scientists in developing safe and effective drugs. As an independent start-up company, Spin Analytical, Inc., can be responsive in meeting varying needs of these laboratories. For more information, contact Dr. Thomas M. Laue, 603.862.2459, tom.laue@unh.edu.

## Method to Measure High-Affinity Interactions of Macromolecules

Until now, there have been few experimental methodologies to measure very high-affinity interactions of macromolecules--interactions that are important in biological systems and in developing new therapeutic drugs. Research at the Biomolecular Interaction Technologies Center (BITC) has led to a method of making such measurements using a fluorescence optical system for the analytical ultracentrifuge in combination with fluorescent tagging of a macromolecule in the complex. The method allows chemical parameters to be determined for the formation of the complex, such as stoichiometry, equilibrium association constant, and thermodynamics of the interaction. When the project is completed in 2004, the technology will allow a researcher to study high-affinity binding as well as investigate any complex linked association/dissociation phenomena occurring with the binding event. For more information, contact Dr. Thomas M. Laue, 603.862.2459, tom.laue@unh.edu.

## Absorbance Optical System and Data Acquisition Software for the Analytical Ultracentrifuge

A new high-precision absorbance optical system and data acquisition software for the analytical ultracentrifuge developed by BITC will improve the throughput of analytical ultra-centrifugation. Without Dr. Laue's effort, this advance would not be possible: Beckman, the company that developed the analytical ultracentrifuge, had not designed further upgrades since launching the instrument in early 1990s. Currently, the Beckman absorbance optical system uses a flash lamp and moving slit over a photomultiplier tube and operates too slowly to acquire data for sedimentation velocity experiments suitable for rapid analysis. The new system will aid drug discovery research in pharmaceutical companies. For more information, contact Dr. Thomas M. Laue, 603.862.2459, tom.laue@unh.edu.



# Center for Sensors and Actuators Center (BSAC)

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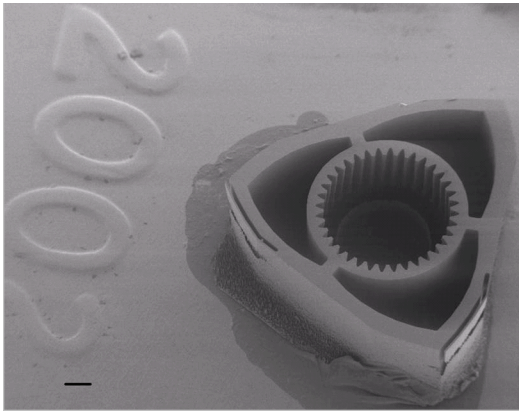
## Rotary Internal Combustion Engine on a Chip



Researchers at the Berkeley Sensors and Actuators Center (BSAC) at the University of California-Berkeley designed and micro-fabricated engine components with features on the scale of tens of microns and an overall scale of millimeters with etch depths as large as 900 µm. These MEMS engines--much like conventional-sized gasoline-powered generators--will be used to convert the stored chemical energy of liquid hydrocarbon fuels into usable electric power in the 10-100 mW range. Research efforts to develop the required auxiliary systems similar to those found on a modern automotive hybrid engine (ignition, fuel delivery, integrated generator) are ongoing. The system is expected to deliver specific power (W/kg) superior to conventional systems and to leverage the inherent advantages of liquid hydrocarbons: storage, safety, and specific energy (W-hr/kg). Several BSAC member companies, such as Textron Systems and Harris Corporation, have participated in the DARPA-funded research and testing of this device. For more information, contact Dr. David Walther, 510.387.4749, walther@eecs.berkeley.edu.

## Radio-Equipped Wireless Sensors called “Smart Dust”


Researchers at the Berkeley Sensors and Actuators Center (BSAC) at the University of California-Berkeley designed and micro-fabricated engine components with features on the scale of tens of microns and an overall scale of millimeters with etch depths as large as 900 µm. These MEMS engines--much like conventional-sized gasoline-powered generators--will be used to convert the stored chemical energy of liquid hydrocarbon fuels into usable electric power in the 10-100 mW range. Research efforts to develop the required auxiliary systems similar to those found on a modern automotive hybrid engine (ignition, fuel delivery, integrated generator) are ongoing. The system is expected to deliver specific power (W/kg) superior to conventional systems and to leverage the inherent advantages of liquid hydrocarbons: storage, safety, and specific energy (W-hr/kg). Several BSAC member companies, such as Textron Systems and Harris Corporation, have participated in the DARPA-funded research and testing of this device. For more information, contact Dr. David Walther, 510.387.4749, walther@eecs.berkeley.edu.

# Center for Advanced Computing and Communication (CACC)

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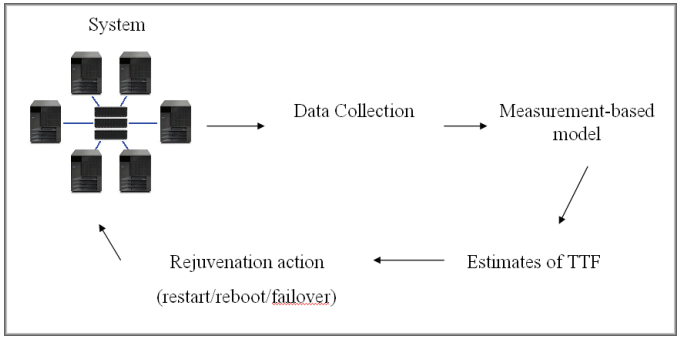
Duke University, Kishor Trivedi, 919.660.5269, kst@ee.duke.edu

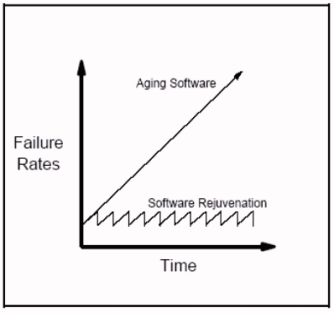
Center website: http://www.ece.ncsu.edu/cacc/index.php

## Software Rejuvenation




CACC researchers have developed a method to detect problems of memory leak, data corruption, and fragmentation that have plagued a wide range of computer systems and networking components. These problems build up over time and lead to performance degradation, hanging, and other failures of computing systems. Memory leak is a phenomenon in which memory resources in computing systems decrease over time and eventually cause system problems. The problem occurs because software programs request memory but sometimes don't release it, and this unreleased memory accumulates over time.

The researchers collected empirical data on these problems at the center and developed a way to monitor the course of the deterioration and to predict when future problems would occur so that preventive measures could be taken. This software rejuvenation method has been adopted by IBM in their X-series servers, and other companies including Sun Microsystems and Microsoft are in the process of adopting this technology. For more information, contact Dr. Kishor Trivedi, 919.401.0299 ext. 306, kst@ee.duke.edu.



# Center for Advanced Manufacturing and Packaging of Microwave, Optical and Digital Electronics (CAMPmode)

University of Colorado at Boulder, Roop Mahajan, Director, 614.688.8233,
roop.mahajan@colorado.edu

Center website: http://www.nsf.gov/eng/iucrc/directory/camp.jsp

## Atomic Layer Deposition

Atomic Layer Deposition (ALD) on MEMS contacting surfaces for increased reliability. Work performed at the Center for Advanced Manufacturing and Packaging of Microwave, Optical and Digital Electronics (CAMPmode) indicates that ALD will increase the switch life of MEMS devices and that it also provides a way of depositing alternating layers of dielectric for a controlled charge bleed-off. For more information, contact Roop Mahajan, University of Colorado at Boulder, 614.688.8233, roop.mahajan@colorado.edu.

## MEMS for Ultra-Cold Atomic Physics

The ultimate goal of this CAMPmode research has been to create a new generation of devices based on Bose-Einstein Condensation (BEC), such as gyroscopes and gravitational field sensors, that are orders of magnitude more precise than the current state-of-the-art. Like the photons in a laser beams, the atoms in a BEC act coherently, although the coherence of a BEC is significantly better than that of a traditional laser. It is the improvement in coherence that provides the increase in sensitivity of these 'atom lasers' made from BEC. Although BEC was first demonstrated in the laboratory only eight years ago, CU is already moving toward creating and utilizing it in a packageable device. A 1 $cm^2$ chip, intended for BEC production on the microscale has also been used to magnetically and optically trap Rubidium atoms, the first step in BEC production. Finally, a MEMS version of the magneto-optical trap is in fabrication. For more information, contact Roop Mahajan, University of Colorado at Boulder, 614.688.8233, roop.mahajan@colorado.edu.

# Center for Advanced Polymer & Composite Engineering (CAPCE)

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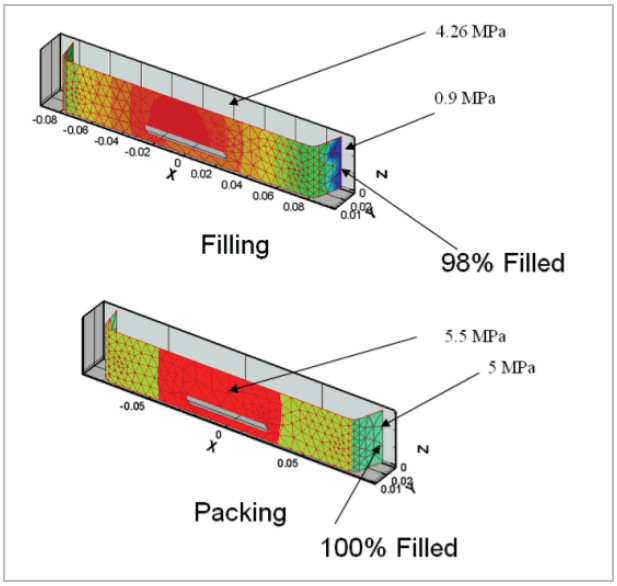
Florida State University, Ben Wang, 850.410.6339, indwang1@eng.fsu.edu
University of Wisconsin-Madison, Tom Turng, turng@engr.wisc.edu

Center website: http://www.capce.ohio-state.edu/

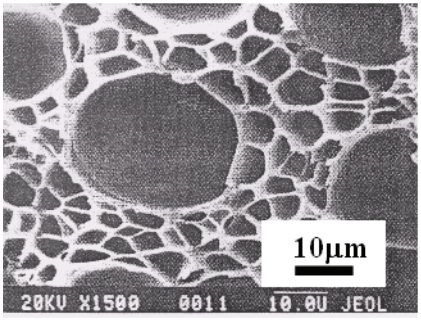
## Software for Enhancing In-Mold Coating Processes of Plastic and Composite Products

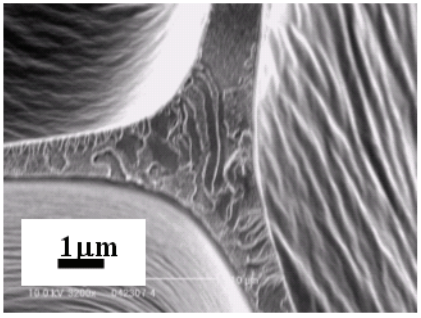



CAPCE research led by Jose Castro has produced new software to enhance in-mold coating processes. The technique of in-mold coating has the potential to revolutionize the coating and paint processing industries because it allows the coatings to be injected under high pressure right inside the mold used, for instance, to create an automotive body panel, rather than having to run the part through long coating production lines that are expensive, energy consuming, and release solvents into the environment. Software developed by the center provides the ability to predict the flow of in-mold coating processes, saving time and money compared to the previous approach. A center member company is paying patent application costs for this technology. Applications extend beyond the automotive industry to include many kinds of plastic and composite products. For more information, contact Jose M. Castro, Ohio State University, 614.688.8233, castro.38@osu.edu.

## Nanocomposite Foam Breakthrough

The worldwide value of plastic foams was $2 billion in 2000. However, current applications are limited by the fact that foams have poor toughness, strength, and surface quality and low thermal stability, lack fire retardance, and release environmentally-harmful gases. Researchers at Ohio State's I/UCR Center for Advanced Polymer and Composite Engineering (CAPCE) have developed a novel method with the potential to improve foam properties by a factor of 3 or 4. Such improvements are expected to dramatically increase the worldwide demand for plastic foams and increase the U.S. market share in the building and transportation industry, in packaging and as absorbent materials for the health care industry. The method has attracted a great deal of interest from industry and the media. The method involves mixing specially-treated clay nanoparticles with the materials to be foamed, then blowing the foams with carbon dioxide using supercritical fluids technology. The new process for making the foam will have many environmental benefits, including reduced energy use when the material is applied as an insulator in building construction and the elimination of ozone-depleting materials in the foam-making process. In addition, the resulting plastic foam is also fire retardant. Tests with Owens Corning and other companies have demonstrated the feasibility of cost-effective mass production. Scale-up activities for commercialization are being carried out through a $1.9 million NIST-ATP project with Owens Corning and a $2 million equipment award for Low Cost Nanocomposite Foams from State of Ohio Wright Center Capital Project Funds. For more information contact L. James Lee, The Ohio State University, 614.292.2408, Lee.31@osu.edu or Roland Loh, Owens Corning Foam System, Roland.loh@owenscorning.com.



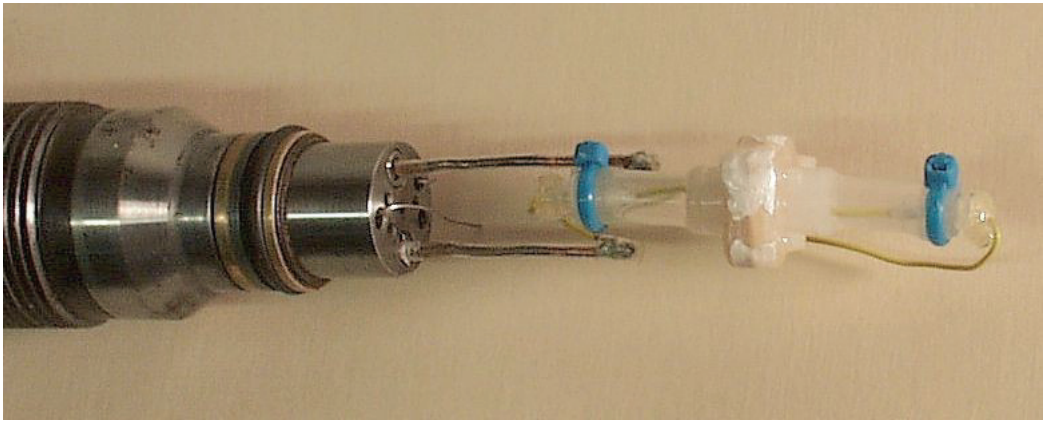

Above: Micrograph of polymeric nanocomposite foams. Proper design of the nanoparticle type, content, dispersion, and orientation supports a wide spectrum of foams with well-defined pore structures.

# Center for Advanced Processing and Packaging Studies (CAPPS)

Ohio State University, Sudhir Sastry, Director, 614.292.3508, sastry.2@osu.edu.

Center website: http://www.fst.ohio-state.edu/CAPPS/index.html

## High Pressure pH Probe



It has been known for many years, on theoretical grounds, that the pH of various food systems may be reduced under pressure, yet to date there have been no means of studying this phenomenon. There has been a wealth of literature reporting the effect of pressure on inactivation of microorganisms in various buffer systems, yet it was known that the degree to which the pH lowering effect of high pressure is a factor in inactivation kinetics measured in different buffer systems. This High Pressure pH Measuring Device, or probe, developed at the Center for Advanced Processing and Packaging Studies (CAPPS), can determine the pH of fluids at extremely high pressures; on the order of 600 MPa (87,000 psi). No such device had been previously available to study acid / base equilibrium phenomena under extreme pressure conditions. High Pressure Processing is a technology that uses extreme pressures, instead of heat, to pasteurize foods. The probe is beginning to be employed commercially in the food industry for a number of high quality product applications such as processed meats, shellfish and the preservation of products containing heat-labile fruit and vegetables. The development of a high pressure pH probe should finally enable a better understanding of the pressure / pH shift / microbiological effects. With this new probe as a research tool, it is becoming more possible to develop and select food acidulant systems that reach low pH levels under pressure (thus improving HPP antimicrobial effectiveness) yet allow for organoleptically acceptable products at 1 atm when they are consumed. For more information, contact Dr. Sudhir Sastry at Ohio State University, 614.292.3508, sastry.2@osu.edu.

## Continuous Microwave Sterilization of Fluid Foodstuffs

Research conducted at the Center for Advanced Processing and Packaging Studies (CAPPS) utilized technology that allows fluids to be continuously and very rapidly heated, in a tube, by a focused microwave source. Aseptic processing of fluid foods has been practiced by industry for a fairly long time, but the quality of foods produced conventionally, by indirect heat transfer through the walls of a tube, has been limited by the rate at which the food can be heated to pasteurization/sterilization temperatures. To eliminate microorganisms, the food must be exposed to a certain target temperature for a defined period of time; slow heating will degrade the quality of the food during heat-up. This is a particular problem with highly viscous fluids that tend to have poor heat transfer rates from a heated wall. By conducting heat with microwaves, heating rates can be substantially increased with dramatic improvement in quality, without the need for scraped surface heat exchangers and large surface area heat exchangers. This innovation has permitted a number of viscous food products to be prepared with a significant improvement in quality. Continuous microwave processing may be further extensible to food systems with particulates. For more information, contact Josip Simunovic, 919.513.3190, josip_simunovic@ncsu.edu or Dr. Ken Swartzel, 919.513.2063, ken_swartzel@ncsu.edu both at North Carolina State University.

Above: With CAPPS support, Dr. Pablo Coronel has developed a number of methods and devices to advance the implementation of continuous flow microwave processing during his doctoral and post-graduate studies at NCSU.

# Center for Advanced Studies in Novel Surfactants (CASNS)

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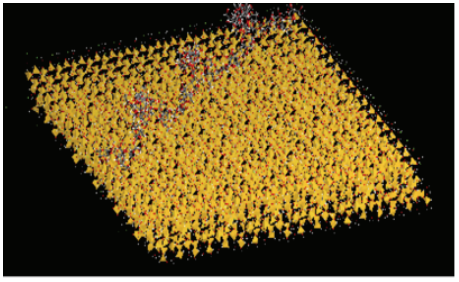
Center website: http://www.columbia.edu/cu/iucrc/

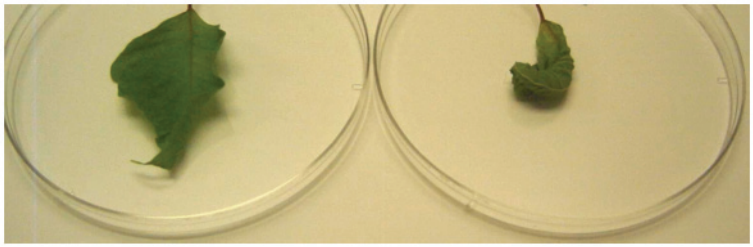
## Enhanced Products to Aid Mineral Processing



One of the business units in the sponsor chemical company develops products for use in the mineral processing and mining industries. Suppression of the mineral talc is a problem in flotation processes used in mineral separation industries. Currently, some polysaccharides are used in the industry for the depression of talc, but an understanding has been lacking of how the polysaccharides function, a knowledge that would allow the design of molecules with better efficiency. Research at the Center for Advanced Studies in Novel Surfactants (CASNS) has addressed problems related to the depression of talc using polysaccharides. The research has provided important insights that have been used to design better molecules for this application. Based on this research the company has made and tested new polymers. Initial tests yielded promising candidates that are now in field testing. Developing a new product to commercialization can take 5 to 10 years, including all stages of toxicological and environmental testing. Such testing helps assure that the product meets specifications and satisfies all regulatory requirements. In addition to the talc studies, center students helped to develop a rapid screening technique now in use by the company to identify products that have improved processes that recover precious metals from ores. For more information, contact Dr. P. Somasundaran, 212.854.2926, ps24@columbia.edu.

## Advances in Basic Science of Skin Cleansing

Fundamental research at the Center for Advanced Studies in Novel Surfactants (CASNS) on surfactant binding to proteins has benefited development of skin cleansing and skin care products at a center sponsor's main R&D center for skin research. Washing and cleansing can be a damaging process for skin, so the choice of surfactant becomes very critical in order to minimize damage. Insights on surfactant blends are critically important in deciding what kind of blends to incorporate into product formulations. One of the key factors is surfactant micelle charge density, which affects the irritation potential of surfactants. The goal is to minimize charge density up to a point, because with zero charge density, as in non-ionic surfactants, there is usually not enough lather and foam to satisfy customer demand. Formulation science focuses on how to blend components to achieve the desired balance. Fundamental work has been conducted on surfactant binding to proteins. Researchers have investigated how when protein denaturation occurs the surfactant binds, how reversible it is, and how it may be affected by variables such as cleanser pH and temperature. Insights gained from this research are being used by a center sponsor in skin cleansing and skin care products. For more information, contact Dr. P. Somasundaran, 212.854.2926, ps24@columbia.edu.



Above: Mild surfactant treated leaf after exposure to open air for 48 hours-barrier in better condition limiting water loss (left); Harsh surfactant treated leaf after exposure to open air for 48 hours-damage to barrier leads to rapid water loss (right).

## Characterization of Nanostructures in Mixed Surfactant Solutions

An analytical ultracentrifugation (AUC) technique is used for the first time to quantitatively determine the nanostructures of colloid complexes in surfactant/surfactant, surfactant/phenol and surfactant/protein mixtures in solutions. This technique is nondestructive and is particularly powerful for distinguishing the size and shape of various colloidal species in solution on a nanoscale. Information on micellar size, shape and aggregation number for a sugar-based surfactant has been obtained using AUC recently. More interestingly, coexistence of two types of micelles in mixed polyethylene oxide/sugar-based surfactant has been revealed. Also micellar growth has been identified for the first time in the sugar-based in the presence of phenol. Both dynamic and equilibrium characteristics of nanoparticles, nanogels for drug-delivery, polymer-surfactant and surfactant/protein mixtures can be obtained using this technique. A number of industries, such as personal care, drugs, nano-technology, enhanced oil recovery and mineral processing can produce next generation products using information on speciation, in terms of the type, size and shape of these supramolecular structures. For more information, contact Dr. P. Somasundaran, 212.854.2926, ps24@columbia.edu.

## Mechanisms of Interactions of Surfactants With Liquid Vesicles and Biomembranes

Results of research conducted at the Center for Advanced Studies in Novel Surfactants (CASNS) on membrane-surfactant interactions with simpler biomembranes such as phosphatidic acid (PA) and phosphatidyl choline (PC) liposomes using electron spin resonance and fluorescence demonstrated for the first time in the history of liposome research that one of the liposome component, (PA) exits first upon interaction with the surfactant, dodecyl sulfate (DS) causing liposome disintegration. It was also discovered that while cholesterol made the liposome more resistant towards the surfactant, protein made the liposome more vulnerable. It was also seen that protein undergoes structural reorientation in the presence of DS, with its preferential exit out of the liposome membrane, causing the liposome disintegration. These findings have significant implications for the formulation and use of consumer and drug products.

The results on the mechanisms of surfactant interaction with biomembranes help industry formulate efficient and milder personal care products. For more information, contact Dr. P. Somasundaran, 212.854.2926, ps24@columbia.edu.

## Conformational Behavior of Hydrophobically Modified Polymers

Hydrophobically modified polymers have been tuned for nanodomains that can extract and deliver at will cosmetics/drugs/toxins by controlling pH, temperature or ionic strength of the system. These systems have the advantage that they have features of both the polymers and the surfactants. Due to the associative nature of the hydrophobic groups, hydrophobically modified polymers can form intramolecular nanodomains at all concentrations of the polymer and inter-molecular aggregates under different conditions. Thus, poly (maleic acid/octyl vinyl ether) forms hydrophobic nanodomains that can solubilize and release drugs, dirt etc. by changing pH, salinity and/or temperature. Changes in the size and structure of the nanodomains thus formed have important applications in rheology control, coating, delivery of actives and removal of overdose toxins. For more information, contact Dr. P. Somasundaran, 212.854.2926, ps24@columbia.edu.

## Novel Polymeric Nanoparticles for Extraction and Release of Drugs and Fragrance

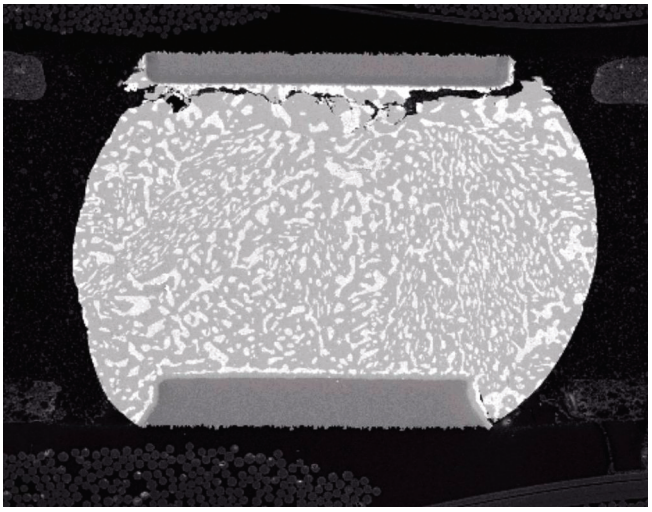
Nanoparticles are finding-increasing applications as effective drug/attribute delivery devices. Researchers at the Center for Advanced Studies in Novel Surfactants (CASNS) have synthesized poly (acrylic acid) and polymeric nanoparticles that successfully incorporate fragrances and antimicrobial agents into nanoparticles. Novel polyacrylamide and poly (acrylic acid) nanoparticles (20 –100nm) have been synthesized by reverse microemulsion. It was observed that 1% cross-linked poly(acrylic acid) nanoparticles could incorporate 38% of linalyl acetate added to the system in about 4 hours. The efficacy of extraction increased further when the nanoparticles were modified with hydrophobic moieties such as propyl amine and hexyl amine. The efficacy of these nanoparticles was excellent also for the extraction and release of vanillin, a flavoring ingredient for food materials and perfumes. For more information, contact Dr. P. Somasundaran, 212.854.2926, ps24@columbia.edu

# Center for Advanced Vehicle Electronics (CAVE)

Auburn University, Jeff Suhling, Director, 334.844.3332, jsuhling@eng.auburn.edu

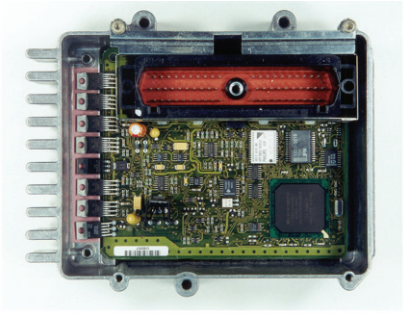
Center website: http://cave.auburn.edu/

## Improved Electronics Reliability for Terrestrial and Space Vehicles

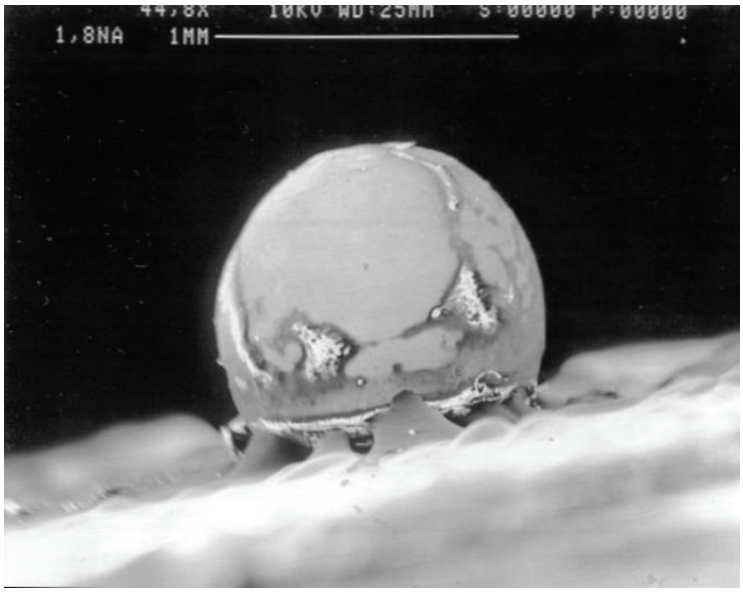


The Center for Advanced Vehicle Electronics (CAVE) has a number of industrial partners who design, develop, and manufacture state of-the-art electronic control modules for terrestrial and space vehicles. The electronic assemblies must operate reliably for long periods of time in hostile environments including extreme high temperatures and low temperatures, large temperature swings, high humidities, and exposure to corrosive fluids. The results from center projects in the areas of damage mechanics, physics of failure, materials science, and manufacturing processes have helped identify a number of key factors which have impaired progress in enhancing product longevity. Studies to measure the aging microstructure and crack propagation rates in solder joints, as well as characterize the growth kinetics of brittle inter-metallic compounds have led to significant process improvements in flip-chip and ball grid array component reliability for Daimler-Chrysler Corporation. Methodologies have been developed to inhibit crack propagation in solder joints by controlling several critical design variables during soldering operations and module assembly processes. This has led to a set of design guidelines and a decision support toolkit for area array packaging that has been developed for use by NASA.

Theoretical and experimental studies of the heat transfer in populated printed circuit boards using finite element simulations and miniature temperature sensors have led to identification of heat-susceptible locations that impact circuit reliability. This has been especially useful for Siemens VDO Automotive Corporation, which manufactures a variety of electronic modules for ground vehicles that are mounted on the engine block or embedded in the transmission. For more information, contact Jeff Suhling, Auburn University, 334.844.3332, jsuhling@eng.auburn.edu. Right: An automotive electronics module; Above: A cracked solder joint.

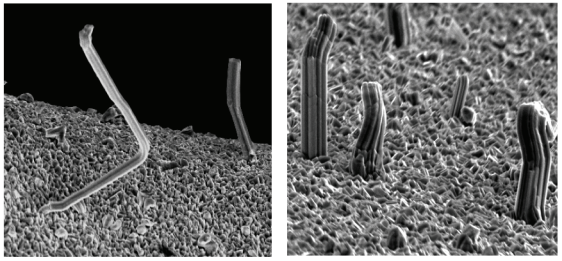


## New Experimental Techniques to Study Solder Materials and Processes




Work in the Center for Advanced Vehicle Electronics has led to the development of several new innovative experimental techniques to study solder alloys. A unique scanning electron microscope has been developed that allows for real-time and *in-situ* studies of the melting, wetting, and spreading of solder alloys and pastes. The system allows for microscopic observation of the advancing molten solder with simultaneous analysis of alloy-substrate chemical reactions during wetting. It is highly unusual to undertake studies of liquids in expensive and high-performance vacuum systems due to potentially high vapor pressures and flux outgassing. Results from the use of this novel facility have especially benefited Cookson Electronics and Henkel-Multicore, two CAVE industrial sponsors who specialize in solder materials and technology. In addition to the ability to study molten solders, CAVE is the first organization to develop a scanning electron microscope to measure strains in materials during repetitive temperature cycling processes such as those common in under-the-hood electronics. A third unique apparatus in CAVE is a custom-made surface analysis system that enables *in-situ* studies of surface segregation during melting and wetting processes. For more information, contact Jeff Suhling, Auburn University, 334.844.3332, jsuhling@eng.auburn.edu.
Above: A molten solder ball.

## State-of-the-Art Electronics Assembly Operations and Pb-Free Solder Alloys



Researchers at the Center for Advanced Vehicle Electronics (CAVE) have developed a number of important methodologies related to electronics assembly with lead-free solder alloys. This research has international significance due to the ban on the element lead (Pb) enacted in the EU and Japan during 2006. A full world-wide ban of lead in electronics is expected by 2010. CAVE has become one of the first organizations to intensively study the materials science, mechanical behavior, and solder joint reliability of leading candidate Pb-free solder alloys formulated from tin, silver, and copper. An innovative approach for lead free solder prognostics has been established, which allows the user to estimate the remaining useful life of a solder joint. In addition, fundamental studies have been performed on the structure of unwanted tin whiskers that can emanate from the pure tin connector pin platings used with lead free electronics. Finally, CAVE is leading the efforts to characterize aging effects in lead free solder alloys that result in unexpected degradation of lead free solder joints in extreme environments. The developments in these projects have helped the Center's industrial partners stay ahead of their competition in their respective technological areas. The research has demonstrated not only what will work but, more importantly, what will not work. By not wasting a lot of time on dead-end research, CAVE has helped its member companies narrow the options to cost-effective and reliable alternative solders that can be used in commercial, industrial, and military electronics. For more information, contact Jeff Suhling, Auburn University, 334.844.3332, jsuhling@eng.auburn.edu.
Above: Tin whiskers that can lead to short circuits in lead free electronics.

# Center for the Built Environment (CBE)

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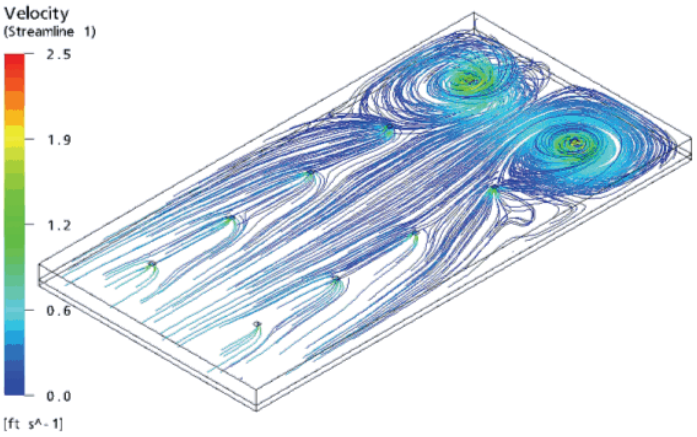
Center website: http://www.cbe.berkeley.edu/

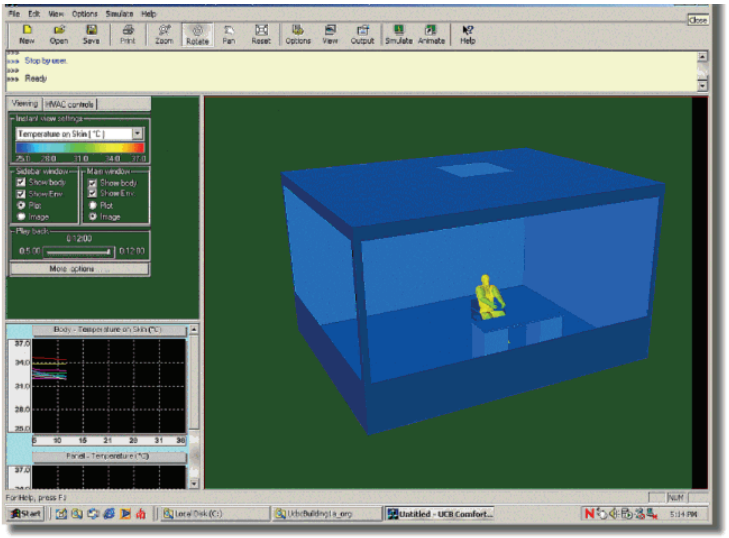
## Engineering and Design Guidelines for Underfloor Air Distribution (UFAD) Technology




Underfloor Air Distribution (UFAD) technology has experienced rapid growth in North America because of the broad range of important benefits it offers over conventional ceiling-based air distribution.

Correctly designed UFAD systems can: (1) reduce life-cycle building costs, (2) improve occupant comfort and productivity, (3) improve ventilation efficiency, indoor air quality, and health, and (4) reduce energy use. Until recently there was no standardized design protocol available to the building industry. A comprehensive design guide accessible to the design and engineering community was needed to support the continued development and growth of this promising technology. Responding to this need, the Center for the Built Environment (CBE) developed the Underfloor Air Distribution (UFAD) Design Guide. This guide provides guidance in the design of UFAD systems that are energy efficient, intelligently operated, and effective in their performance. The guide is written to assist design engineers, architects, building owners, facility managers, equipment manufacturers, utility engineers, and other users of UFAD technology. The design guide was published by ASHRAE (the American Society of Heating, Refrigerating and Air-Conditioning Engineers). For more information, email cbe@uclink.berkeley.edu.

## Human Thermal Comfort Model



Buildings are currently designed to achieve comfort by creating uniform interior environments. However in reality neither indoor environments nor building occupants are static. Center for the Built Environment (CBE) has developed a simulation tool to evaluate thermal comfort over an entire year for a building, similar to the way energy simulation tools are used. This model is one of the most sophisticated thermal comfort models available. It is capable of analyzing human thermoregulation in non-uniform, transient conditions, and is capable of predicting local and overall sensations in real thermal environments. The model also has an integrated physiological model that can predict the overall comfort that results from these responses. The model was developed with a detailed building interface to allow building designers and engineers to evaluate the thermal comfort impacts of various design and system options, and may be used for evaluating the comfort of an indoor environment including the effects of nearby windows, surface temperatures, and air movement. For more information, email cbe@uclink.berkeley.edu.

# Center for Building Performance and Diagnostics (CBPD)

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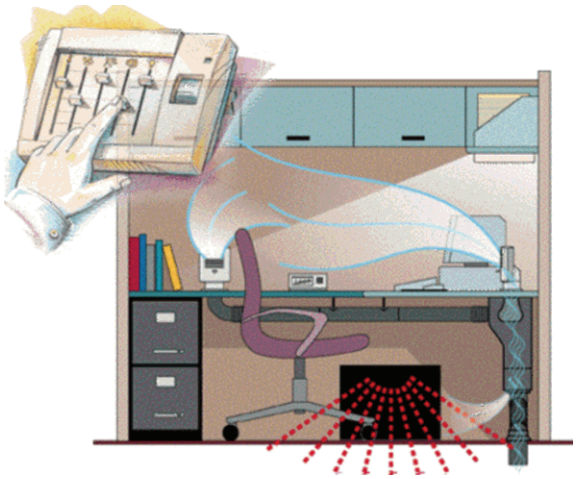
Center website: http://www.arc.cmu.edu/cbpd/index.html

Building operations (heating, cooling, lighting, and ventilation) consume almost 40% of the U.S. primary energy, and 67% of electricity. The Center for Building Performance and Diagnostics (CBPD) is dedicated to research, develop, design, engineer, demonstrate, and test, as well as apply systems, components, and materials and their integration to create built environments. These environments simultaneously increase: occupant comfort and productivity, organizational flexibility and effectiveness technological adaptability, as well as energy and environmental effectiveness. As a result, the can create a pathway towards sustainability in the built environment. The built environment is a key factor for human health. For instance, materials, component and systems choices, as well as building operations, can lead to sick building syndrome (SBS) and building related illness (BRI). The EPA estimates the annual cost to the U.S. economy to be in excess of $60 billion. In contrast, best practices can significantly enhance human health and result in increased productivity through reduced absenteeism and health costs as well as enhanced motivation, compared to standard practices. The CBPD has established the technical and economic feasibility, as well as environmental and social desirability to create win-win solutions that prove false the widely held belief that the higher the non-renewable energy consumption, the higher the quality of life. For the built environment, the opposite is largely true. For more information, contact Volker Hartkopf, 412.268.2350, hartkopf@cmu.edu.

## The Robert L. Preger Intelligent Workplace (IW)

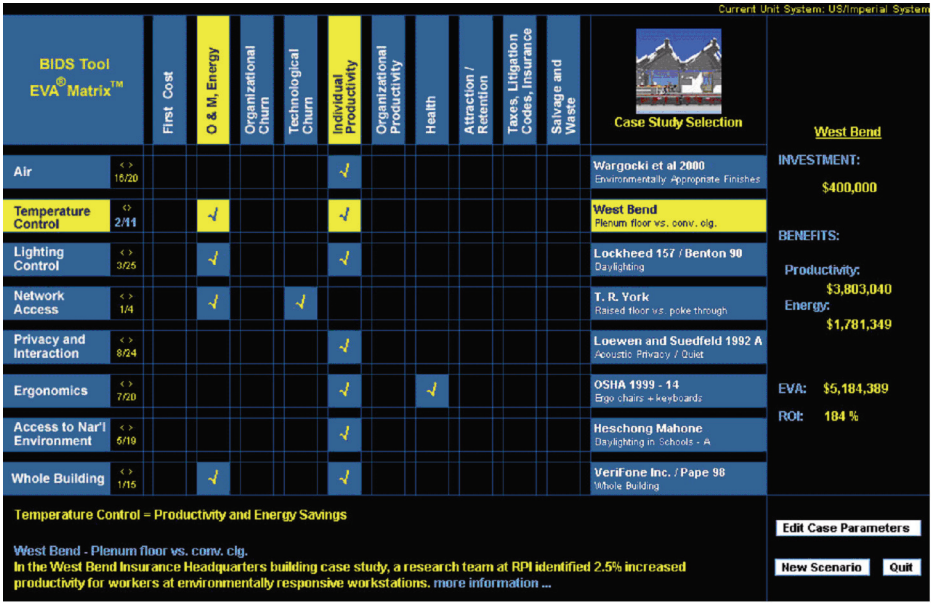


The Prefer Intelligent Workplace (IW), designed and engineered by the Center for Building Performance and Diagnostics (CBPD), in close cooperation with architects and engineers and the Advanced Buildings Systems Integration Consortium, functions as a living (frequently adapted and updated to incorporate new materials, components, and systems) and lived-in (occupied by Center faculty, staff, and students) laboratory. The integration of innovative systems (envelope, lighting, HVAC, structure and interior) demonstrates the advantages of and opportunities for integrating daylighting with artificial lighting, natural with artificial ventilation, passive and active heating and cooling strategies. These integrations resulted in high levels of energy conservation. The IW pioneered the concept of integrated horizontal load bearing structure, HVAC ducting, cabling (power, controls, communication) and excess floor technologies for floor-based infrastructures. This has resulted in unprecedented levels of user accessibility, organizational flexibility, and technological adapt-

ability, while eliminating the concept of obsolescence and material waste. The research, development, and demonstration work has resulted in numerous applications of technologies and concepts pioneered in the IW. For instance, floor based infrastructures, and flexible interiors introduced into the Owens Corning Headquarters project, Toledo, Ohio, resulted in 500 to 600 thousand dollars per year in savings in worker relocation costs within the building. The Beijing energy Efficient Office Building of the Ministry of Science and Technology, China, has a 60 percent reduced peak cooling load due to the design and engineering involvement of the Center. For more information, contact Volker Hartkopf, 412.268.2350, hartkopf@cmu.edu.

## Personal Environmental Module

Research at the Center for Building Performance and Diagnostics (CBPD) has established the importance of personal control in reaching highest levels of occupant satisfaction in thermal, visual, acoustic, air quality, and spatial ergonomic quality. The research and evaluations establish and document effect that users with personal control, for instance in thermal quality, express satisfaction far beyond the 50 to 60 percent reached by standard practices and technology. Satisfaction rates reaching up to 95 percent can be achieved. An example of a breakthrough product developed by Johnson Controls in close cooperation with the Center, is the Personal Environmental Module (PEM) which allows users to control at their workspace air speed, and direction, air and radiant temperature, as well as task lighting and background noise levels. Thousands of PEMs have been installed in major building projects. For more information, contact Dr. Volker Hartkopf, hartkopf@cmu.edu.



## Building Investment Decision Support Tool (BIDS)

A key reason for lower standard building performance is the absence of convincing economic arguments for enhanced performance. First-cost and past practices rule. The web-based interactive Building Investment Decision Support Tool, supports sound economic decision making, by providing life-cycle and return on investment based frameworks which take into account energy conservation, productivity, human health, and organizational effectiveness results of best practices. The team led by Professor Vivian Loftness, in close cooperation with researchers in industry and government has examined over 8,000 articles and distilled over 150 datasets which are now incorporated in the BIDS tool. The tool is aimed at highest-level decision-makers and resulted in providing the economic justifications for enhanced design and engineering practices, as well as advanced system choices in a number of governmental projects. Currently, a large user group, consisting of utilities, local governments, building owners, developers, architects, and engineers is examining the usefulness of this tool in their own ongoing operations. For more information, contact Dr. Volker Hartkopf, hartkopf@cmu.edu.

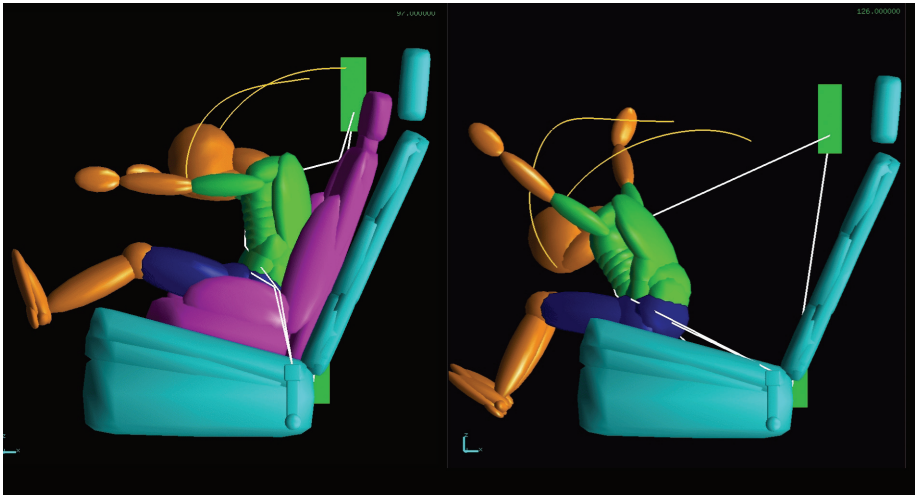
# Center for Child Injury Prevention Studies (CChIPS)

University of Pennsylvania, Flaura Winston, Director, 215.590.3118, flaura@mail.med.upenn.edu

Center website: http://www.nsf.gov/eng/iip/iucrc/directory/chips.jsp

## Child Injury Prevention (Reducing Airbag Deaths)

Consumers demand safety innovation in new vehicle models. However, much of these technologies are unproven in their safety benefits and many have unintended risks, particularly for children. Researchers at the Center for Child Injury Prevention Studies (CChIPS) discovered the first cases of airbag-related deaths in children and defined the mechanisms of injury, thus confirming the industry's research of the early 1970's. The truth about safety technology lies in actual crash performance yet there is a very limited funding pool for real world rigorous studies. The Faculty at CChIPS continue this decade-long history of informing priorities regarding safety technology development. One CChIPS study defined, for the first time, the characteristics of crashes that cause specific fatal injuries in children. This research is leading to more effective regulations, making sure that our vehicle safety systems continue to prevent injuries and death. Other CChIPS studies described injury mechanisms for children in child restraint systems and seat belts. The center's Industrial Advisory Board members use this information on injury mechanisms to develop new and enhance current safety technology. Test protocols require valid tools, but current crash test dummies for children are inadequate, developed from scaled anthropometric and biomechanical criteria of adults since much of this data is unavailable for children. CChIPS studies address the need for mechanical properties of pediatric tissues and organs to better tools including computer models. Still other studies explore the causes of crashes with teen drivers in order to inform educational and pre-crash prevention technologies to reduce the leading cause of death in our youth, motor vehicle crashes. For more information, contact Center Director, Dr. Flaura Winston, or Center Coordinator, Parvathy Menon, at CChIPS@email.chop.edu or 215.590.3118.



# Ceramic and Composite Materials Center (CCMC)

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University of New Mexico, Abhaya Datye, 505.277.0477, datye@unm.edu
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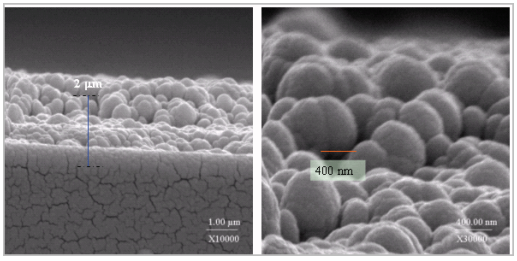
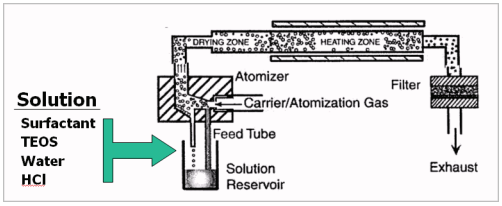
Center website: http://ccmc.rutgers.edu/

## Ambient Pressure Technology



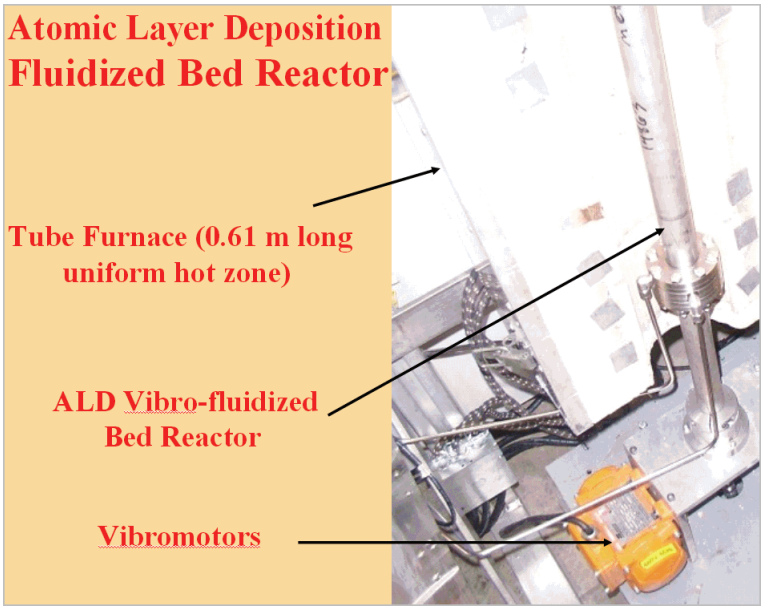

The Ceramic and Composite Materials Center (CCMC) has developed an ambient pressure process for making aerogels and xerogels. Previously these materials had to be made under critical conditions, a commercially unattractive process. This breakthrough technology spawned a spin-of company, NanoPore, which has developed into a multimillion dollar operation. The ambient pressure technology was patented and licensed to NanoPore, Hoechst, and Texas Instruments. Hoechst used it to develop a multimillion-dollar insulation manufacturing business that subsequently was sold to Cabot. Texas Instruments, TI, used the technology to develop insulation for microelectronic parts. Recently, TI reported copper wire interconnects protected with xerogel insulation for microelectronic devices. TI claims this to be a breakthrough technology that will enable copper wire interconnects to replace aluminum wire interconnects, the current industry standard. For more information, contact Professor William Koenke, 505.277.6824, yonder@unm.edu.

## Mesostructured and Nanostructured Materials




The pioneering studies of CCMC and Sandia National Laboratories to understand evaporation-induced self-assembly has led to the controlled synthesis, via self-organization processes, of mesostructured and nanostructured materials in the form of thin films and particles. These studies have developed two commercially important applications involving rapid prototyping of functional, hierarchical thin films via micropen lithography, ink-jet printing, and selective de-wetting. Two patent applications have been filed and licensing activities are in progress. For more information, contact Professor William Koenke, 505.277.6824, yonder@unm.edu.

## Atomic Layer Deposition Method to Coat Small Particles

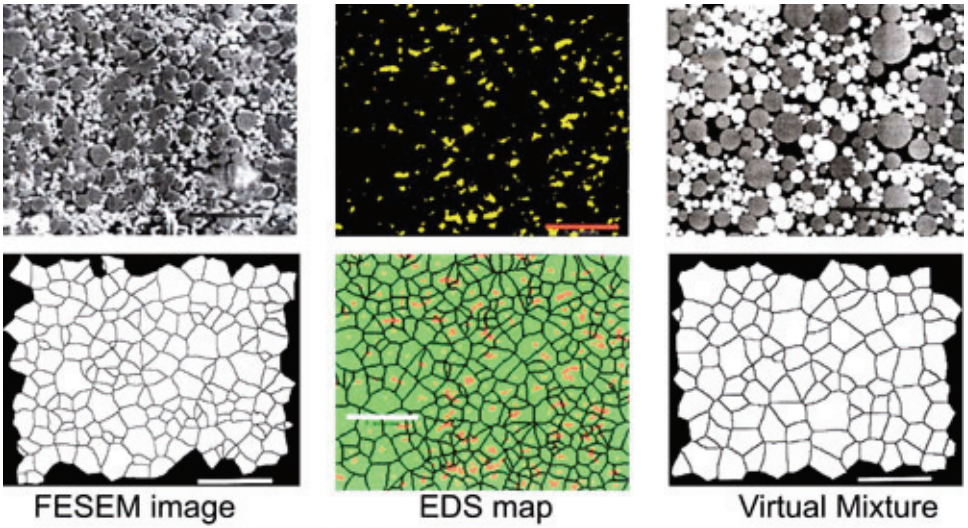



The optimum chemistry for using Atomic Layer Deposition, ALD, to conformally coat fine particles of oxides, non-oxides, and metals with metal oxides has been established under vacuum conditions. The advantage of the ALD technique over other vapor coating processes is that it permits precise deposition of one monolayer at a time until the desired coating thickness is achieved. Scale-up of the method to make it commercially viable has been accomplished by developing a vibrating fluidized bed reactor to permit atomic layer deposition. Successful scale-up has moved the technology from a laboratory curiosity to a micro-pilot plant scale capable of coating hundreds of grams of powder with selective conformal coatings in a single run. The fluidized bed ALD reactor has been used to coat metal particles with conformal coatings of metal oxides and boron nitride particles. A patent has been filed, and a spin-off company, ALD Nanosolutions, has been formed to further develop the process and bring it to a commercially attractive level of performance. For more information, contact Professor William Koenke, 505.277.6824, yonder@unm.edu.

## "Mixedness" Software for Multi-component Particulate Systems

The center has developed an approach for simulating multicomponent particle mixtures. The method can be used to diagnose mixing problems related to poor selection of raw materials and to diagnose processing problems in which changing the particle size distribution could help a process meet design specifications. The approach, which has never been done before, can be used for nano-particles as well as large-scale particulate systems. CCMC researchers can perform direct comparison of simulations with experimental mixtures, and they can design mixtures, choosing the homogeneity scale, particle contact number, or the variance in the mixture, designated on any length scale. Applications of the method range from semiconductor materials to commodities such as detergents. CCMC researchers have been able to solve a variety of manufacturing problems by recommending simple changes in the manufacturing processes. One example is the case involving piezoelectric actuators for fuel injectors, in which they recommended a

size distribution change introducing a specific size separation unit operation. This modification brought the process into the specification for the first time in 15 years. Other significant problems solved by the "mixedness" engineering approach include cutting tool materials, ferrite materials, thermal management materials, detergents, and flow of powders. Most of the simulation work has been commercially utilized. The mixedness simulation software is now in the beta-testing phase: the software has been distributed to commercial entities for evaluation and feedback prior to commercialization. For more information, contact Riman, riman@alumina.rutgers.edu or Guerman Popov, 732.445.6760, gpopov2@rci.rutgers.edu.



# Center for Coatings Research (CCR)

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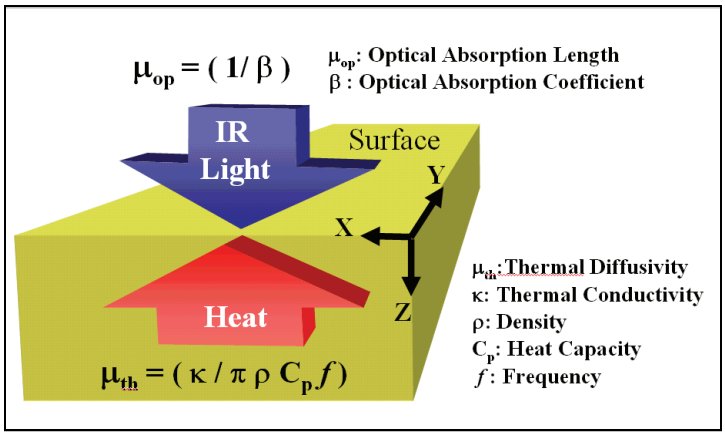
University of Southern Mississippi, Marek W. Urban, Co-director, 601.266.6868, Marek.Urban@usm.edu.

Center website: http://www.nsf.gov/pubs/2002/nsf01168/nsf01168l.htm

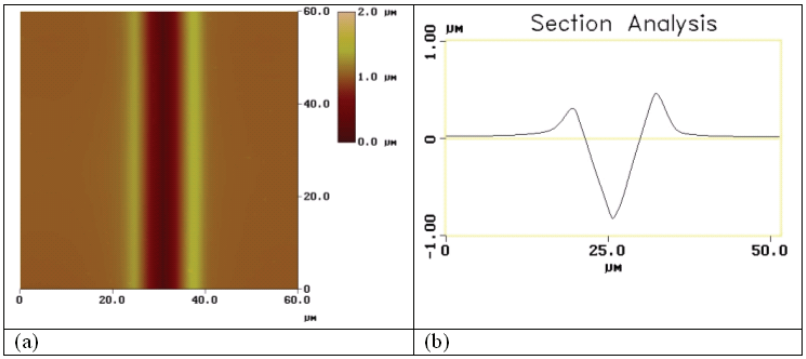
## Coating Analysis with Step-Scan Photo-Acoustic FTIR Spectroscopy




Researchers at the Center for Coatings Research (CCR) have developed a technique to analyze the chemical composition of single or multi-layer coatings. This enabling technology uses step-scan photo-acoustic Fourier-Transform Infrared (FTIR) spectroscopy to provide a means of non-destructive analysis of coatings. The chemical composition as a function of depth of the coating can be determined to provide a compositional map as a function of coating depth. The adhesion of each layer can be related to the chemical composition at the interface. In addition, Dr. Urban has developed a high-resolution FTIR imaging capability that can map out the composition of the top surface of the coating as a function of position on the surface with a spatial resolution overcoming the typical infrared detection limits. In another development, rheo photo-acoustic FTIR for stress-strain measurements provides the ability to analyze adhesion at the molecular level, particularly for plastics. The technology has been used by Ford to study degradation of coatings and by a wide range of other companies, including BASF, Bayer, Air Products, Huber, as well as government agencies such as the Office of Naval Research. For more information, contact Marek Urban, 601.266.6454, marek.urban@usm.edu.

## Scratch Resistance of Coatings Measured by Modified Scanning Probe Microscope (SPM)

Researchers at the Center for Coatings Research (CCR) have developed a technique of using a modified scanning probe microscope (SPM) with a custom-made diamond probe as a tool to measure the mar resistance of coatings quantitatively. The coating suppliers of GM, Ford and Chrysler, such as PPG, Akzo Nobel, Red Spot, etc. have utilized the technique to characterize their products and improve the mar/scratch resistance of the coatings.




As nano-tribology advances, demand for new instruments capable of carrying micro/nano indentation and scratching measurements increases. The newly developed Nano-indenters can perform both indentation and scratching tests at the micro/nano scale. The technique can not only measure the mar resistance quantitatively, but can also, for the first time, identify the responses of coatings to marring and scratching, i.e., immediate elastic recovery, plastic deformation, and abrasive wear, as well as viscoelastic creep, quantitatively. A Nano-indenter was purchased in the Surface Science and Nano-tribology lab. Now, the Nano-indenter is used for controlled damage, and SPM is used to examine the damaged surface and study the wear mechanism. The applications of the technique are extended to study adhesion of ink deposited on plastic films (Sun Chemical Company), automotive polycarbonate glazing systems (EXATEC), multilayer organic/inorganic coatings over brass surfaces (MASCO Corporation), very soft latex coatings on hard surfaces, among other applications. For more information, contact Weidian Shen, 734.487.8797, wade.shen@emich.edu, or Frank Jones, 734.487.2203, frank.jones@emich.edu.

## Solvent-less "Green Coatings"

The Center for Coatings Research has made numerous contributions in the areas of new resins for coatings and new characterization techniques. Perhaps the single most noteworthy contribution has been the synthesis of new polymers and oligomers for "green coatings." This includes the development of tailored oligomers for solvent-less liquid coatings and the use of bio-derived resins, mostly based on soybean oil. These solvent-less coatings are very good for the environment. Environmental pollutants are greatly diminished from those produced by typical solvents. For more information, contact Frank Jones at frank.jones@emich.edu or Jamil Baghdachi at 734.487.2040, jamil.baghdachi@emich.edu.

# Center for the Design of Analog/Digital Integrated Circuits (CDADIC)

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Oregon State University, Un-Ku Moon, 541.737.2051, moon@eecs.oregonstate.edu
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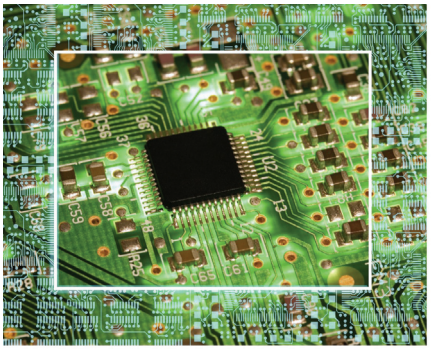
Washington State University, Joanne Buteau, University-Industry Corporate Relations, 509.335.5379, jbuteau@wsu.edu

Center website: http://www.cdadic.com/

## Low Voltage Analog Circuits in CMOS

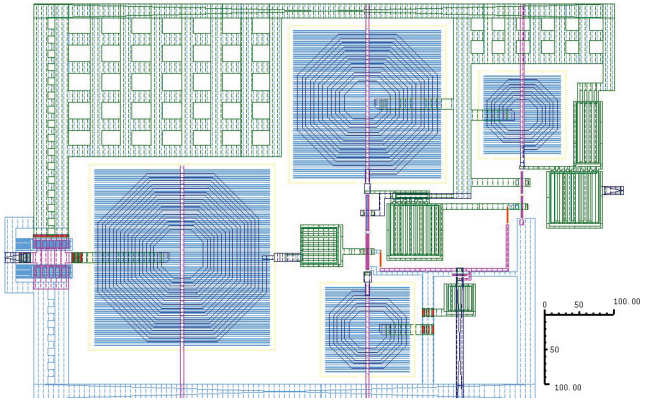
Researchers at the Center for the Design of Analog-Digital Integrated Circuits (CDADIC) have focused on ways to provide high accuracy (analog) functions in low voltage CMOS processes. Many of the existing analog techniques used in CMOS circuits at higher voltages do not work well when used in modern low voltage processes. The value of this research lies in developing new approaches to low voltage CMOS analog circuits. This advance enables modifications of existing techniques for a new environment and development of new techniques tailored to lower voltage demands. The researchers have embarked on both improving the performance of existing techniques as well as developing entirely new approaches to existing problems. Speed limitations in switched capacitor filters, which limited their usefulness at low voltages, have been overcome. New techniques for tuning of low-voltage filters have also been developed. Current work is focused on a new Switched-R-MOSFET-C approach which promises to overcome many of the challenges in low voltage linear filters. Results will make more complex "mixed-signal" CMOS integrated circuits possible. By being able to combine large amounts of digital with precision analog functions on the same chip, significant cost savings and performance improvements are being realized, as are space savings in mobile and medical devices. For more information, contact Un-Ku Moon, 541.737.2051, moon@eecs.oregonstate.edu.

## Advances in Analog/Digital Converters



An analog-digital converter (A/DC) is a mixed-mode integrated circuit, composed of both an analog and digital component. This type of circuit is essential in applications where the two different signals are required, such as in cell phones, camcorders, and hearing aids. A/DCs are needed to convert real-world analog signals, such as sound waves, into digital format, where information is represented by numbers allowing data to be stored and processed. There is constant demand to increase the accuracy and speed of A/DCs, as well as gain efficiencies in power consumption. CDADIC researchers at Oregon State University (OSU) are advancing the state-of-the-art in A/D converter technology, especially in the areas of low voltage operation, compatibility with low-cost digital CMOS processes, and high throughput delta-sigma ADCs. These are important advances that are pushing the limits of the current technology in this field. Extending the performance window for A/D converter technology will ensure that there will be A/D architectures that will be compatible with next generation IC processes. For more information, contact Un-Ku Moon, 541.737.2051, moon@ece.orst.edu, Terri Fiez, 541.737.3118, terri@ece.orst.edu, Gabor Temes, 541.737.2979, temes@ece.orst.edu.

## Modeling and Design of Integrated Circuit Protection Systems




University of Washington electrical engineering professor Bruce Darling has been developing new circuit designs and new compact modeling methods for protecting integrated circuits against the effects of electrostatic discharge (ESD) and electrical overstress (EOS). These problems have most commonly been dealt with using a trial-and-error process, but new compact models and simulation tools can now predict the current pathways on a chip that an ESD or EOS pulse will take, and then evaluate the robustness of the design to dissipate the pulse. This eliminates much of the guesswork in ESD/EOS design, and can help to bring products to market faster by evaluating ESD/EOS robustness prior to fabrication. ESD protection is also particularly difficult for sensitive RF circuits. Darling and his student, Eric Black, have also been designing new circuit protection systems for RF front-end circuits, such as those used in cell phones and other wireless systems. The design pictured below is a

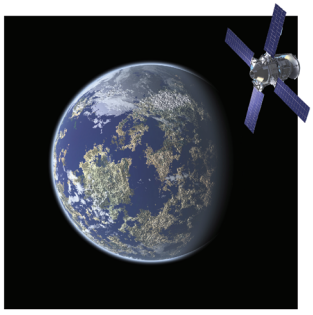
2.4 GHz low-noise amplifier (LNA) which employs an impedance-matched ESD protection system on its input which provides survivability for up to 2 kV HBM ESD pulses. For more information, contact Bruce Darling, 206.543.4703, bruced@u.washington.edu.

## PIN-Diode-Based Phase Shifter in Silicon Germanium

Phased array antennas (PAAs) are critical for next-generation satellite radios, broadband Internet, and GPS systems. A PAA consists of tens-to-thousands of individual, identical antenna elements. Each element consists of an antenna or radiator and associated electronics that amplify and phase shift the signal at each element. The primary factor limiting broader usage of PAAs has been their high cost, which is driven by the cost of the element electronics. Research conducted by Washington State University Professor Deuk Heo has successfully reduced the cost of an important electronic functional block used in each PAA element, the phase shifter. Working with one of CDADIC's aerospace partners, Prof. Heo and his students have developed and modeled a PIN diode switch in silicon germanium (SiGe) Bi-polar/Complementary Metal Oxide Semiconductor (BiCMOS) technology. They have included this switch in an integrated, high-performance phase shifter. This, in turn, has enabled the development of fully-integrated PAA electronics in a single SiGe BiCMOS integrated circuit. The result is lower cost PAAs, with higher performance. For more information, contact Deuk Heo, 509.335.1302, dheo@eecs.wsu.edu.

## Low-Cost MIMO Transceivers Using CMOS Technology

CDADIC researcher Dave Allstot is developing low-cost multiple-input multiple-output (MIMO) transmit/receive systems on monolithic microwave integrated circuit (MMIC) chips based on fine-line CMOS technology. Such systems traditionally have been implemented using gallium arsenide technology, which is more expensive and won't support putting the multiple transmitter, receiver, and control functions on the same integrated circuit. Phased array transceivers, used in aerospace and satellite communications, for example, use a radio channel for each element of the array. The cost limits how widely the technology gets used. Moreover, extensions of basic MIMO techniques are attractive for emerging cognitive radio systems. This research should help dramatically increase the use of MIMO transceivers in applications that are critical to the military for DOD's next-generation communications. For more information, contact Dave Allstot, 206.221.5764, allstot@ee.washington.edu.



# Center for Dielectric Studies (CDS)

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Pennsylvania State University, Michael Lanagan, mxl46@psu.edu
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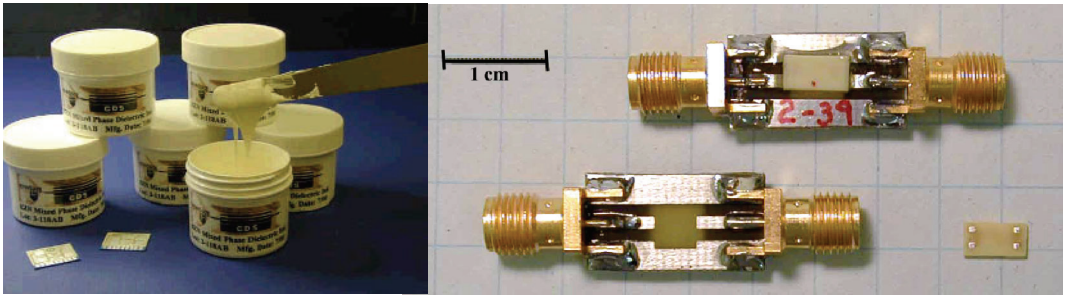
## New Products and Process Improvements for Passive Electronic Components

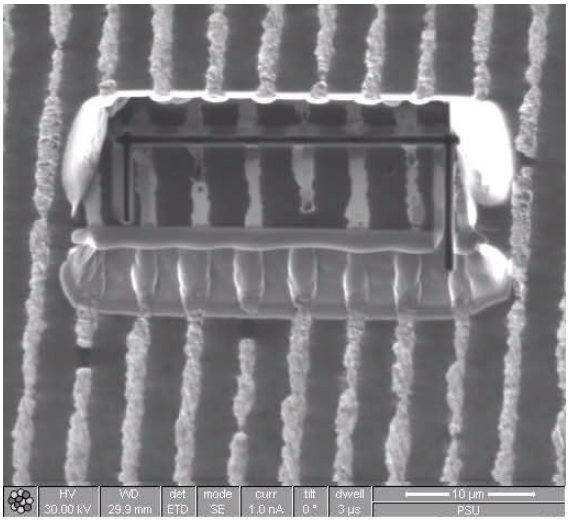
Passive electronic components have not undergone the same miniaturization as have other semiconductor components. This creates important constraints in terms of space consumption on circuit boards. Efforts have been made to make these components smaller, less expensive and generally more compatible with consumer electronics. Research at the Center for Dielectric Studies (CDS) has helped researchers at AVX Corporation better understand the materials and processes used to make electronic components. AVX is a passive electronic component manufacturing company that makes capacitors, resistors, inductors; parts that control flow of current in circuits. Specifically, this center's work has let to implementation of processes at AVX for preparation and heat treatment of capacitors; innovations that led to improvements in yield in product lines. For more information, contact Dr. Michael Lanagan, 814.865.6992, mxl46@psu.edu, Susan Trolier-McKinstry, 814.863.8348, stmckinstry@psu.edu, or Clive Randall, 814.863.1328, car4@psu.edu, all at Pennsylvania State University.

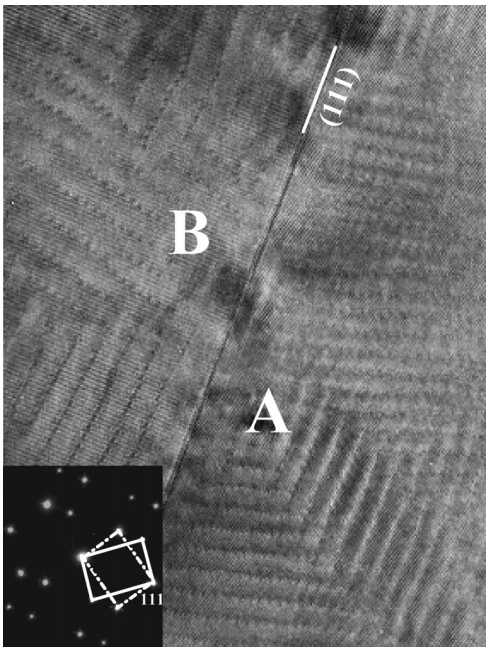



Above: (Left) shows thick film paste made from a new high permittivity, low loss dielectric for microwave passive component integration; (Right) Prototyped microwave filter components manufactured with a new high permittivity pyrochlore materials.

## Understanding Dielectric Powders

Research at the Center for Dielectric Studies (CDS) has furthered understanding of dielectric powders, including the requirements for raw materials and the properties that result from various compounds and processing approaches. One such company is Ferro Corporation, one of the largest manufacturers of barium titanate in the world. The Center's research has shed new light on understanding the defect chemistry of barium titanate, a key ingredient of many of the dielectric powders. Related center research on mechanisms of failure in multilayer ceramic capacitors, particularly capacitors with Ni electrodes, helped to improve yields using state-of-the-art microscopy techniques as illustrated in the figure below. For more information, contact Dr. Clive Randall, 814.863.1328, car4@psu.edu or Elizabeth Dickey, 814.865.9067, ecd10@psu.edu, both at Pennsylvania State University.




Figures: (Right) Local failure sites identified in a multilayer capacitive component. These regions are then removed by state-of-the-art techniques to analyze the underlying defect structures at the nanometer length scale;
(Left) A highly defective region identified from a failure site and associated with high oxygen vacancy concentrations.

# Center for Engineering Logistics and Distribution (CELDi)

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## Networking Merchandise Logistics


Research at the Center for Engineering Logistics and Distribution (CELDi) has enabled Wal-Mart to identify opportunities to streamline some of the company's processes. Center researchers collected data and conducted an in-depth analysis in areas the company could not otherwise accomplish. The work provided an opportunity to rethink how it uses some of the job activities and personnel hours in its stores and to enhance store productivity. Last year, the center helped the company do a logistics analysis that caused the network designers to rethink how the logistics network (all the systems related to moving merchandise from vendor/supplier to the store) will be organized in the future. Currently, center researchers are working on a project that will change how the company maintains inventory accuracy. In a store that has such a large flow of freight it is critical to maintain accuracy of inventory records to avoid over- or under-inventorying items in the store. Center efforts have led also to the publication of research papers on these subjects. Last year, the network analysis was published in the literature, and the company anticipates that this year's inventory analysis will lead to another paper. For more information, contact Dr. Manuel Rossetti, 479.575.6756, rossetti@uark.edu, or Dr. Russell D. Meller, 479.575.6196, rmeller@uark.edu.

# Center for Experimental Research in Computer Systems (CERCS)

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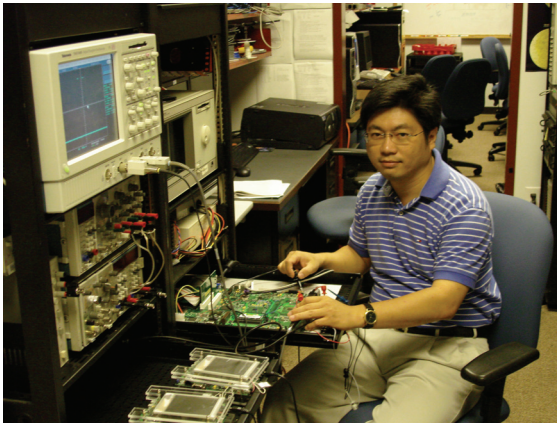
## Power-Efficient and Tamper-Proof Embedded Architectures

This research focuses on novel embedded processor architectures that provide power/thermal efficiency and tamper-proofness while without compromising the performance objective. As process technology shrinks, power and heat dissipation has become the main debacle in embedded processor design that limits their usability. On the other hand, the increasing number of physical tampering on such platforms further jeopardizes the security and privacy of their usage.



To combat the power/thermal issues, two thrusts examine low-power techniques for cache architecture. The first analyzes the memory access stream based on semantic distribution defined by programming language and isolates the higher frequency, higher locality accesses into a more power-efficient memory structure for less power consumption. The second thrust exploits bloom filters for cache hierarchies that generate the signature of observed memory addresses. Such information is used to eliminate unnecessary cache lookup's to reduce power. This work has demonstrated that the effectiveness of these CERCS techniques in power reduction. CERCS researchers are working with ARM Ltd. to evaluate how these techniques can be integrated into their embedded processors. To prevent physical tampering and compromised digital rights, researchers first devised and evaluated potential side-channel attacks via tapping on the bus interface and differential power measurement to reveal the vulnerability of current embedded platforms. For addressing these issues, researchers proposed several low-overhead integrations at the micro-architectural level to enable data protection on these devices. Hardware schemes increase the randomness of the information flow, making these embedded systems more secure. For more information, contact Matthew Wolf, 404.385.1278, mwolf@cc.gatech.edu or Karsten Schwan, 404.894.2589, schwan@cc.gatech.edu.

## Insights from High Performance Computing Service Augmentation

Service augmentation is a new concept developed by researchers at the Georgia Tech Center for Experimental Research in Computer Systems (CERCS) to benefit high performance, I/O intensive applications. Receiving the "Best Paper" award at the 2006 Conference on Cluster Computing, service augmentation uses runtime binary code generation to augment complex codes with new functionality, as and when needed by these applications. Originally intended for and applied to enable the online visualization of high performance simulations running on supercomputers, this concept is now showing promise for commercial applications. For retail forecasting, for instance, the concept can be used to efficiently extract data from the complex internal structures used by these codes to make it useful for display to managers and planners. Ongoing work with a startup company is exploring this use of the idea.
For more information, contact Matthew Wolf, 404.385.1278, mwolf@cc.gatech.edu or Karsten Schwan, 404.894.2589, schwan@cc.gatech.edu.

## Automated Performance Characterization (APC) During Staging

As the complexity of large-scale enterprise applications increases, providing performance verification through iterative staging becomes an important part of reducing business risks associated with violating sophisticated service-level agreements. Staging is the deployment and validation of the entire application in a controlled testing environment. Currently, performance verification during the staging process is accomplished through either an expensive, cumbersome manual approach or ad hoc automation. Researchers at the Center for Experimental Research in Computer Systems (CERCS) have developed an automated approach for supporting the monitoring and performance analysis of distributed multi-tiered applications. The process uses code generation and machine learning to automatically determine service level agreement satisfaction and to locate bottlenecks in candidate application deployment scenarios. The intent is to detect bottlenecks and enable the system to self-tune by addressing the detected bottlenecks through redesign; thus using iterative staging until a satisfactory system is designed. Evaluation tools are used to examine and illustrate the effectiveness of the APC monitoring and analysis process in successfully locating performance limitations as part of automated iterative staging. For more information, contact Karsten Schwan, 404.894.2589, schwan@cc.gatech.edu.

# Center for Glass Research (CGR)

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Penn State University, Carlo Pantano, 814.863.2071, pantano@ems.psu.edu

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## New Insights Glass Surfaces

Understanding the detailed physical and chemical nature of glass surfaces is key to the development of stronger and more durable glasses as well as to advancements in adhesion and performance of coatings used in many types of glass products and glass fiber based composites. Research at the Center for Glass Research has identified and energetically quantified specific chemical sites on the surfaces of various glass types that are responsible for adsorption and bonding of water and various organic molecules that are critical to these qualities. Using this information, it is now possible to develop more hydrophobic glass surfaces, better coatings and stronger interfaces. Previous improvements in glass surface properties have been accomplished largely through either through trial and error or through statistically designed experiments without specific technical knowledge of bonding or adsorption sites on the glass. Understanding glass surface site chemistry allows more technically intelligent design, e.g., of protective coatings and interfaces to maximize product performance. Glass producers and coating designers now have new and more powerful information that can enable "surface engineering", i.e., building specific properties such as strength into the surface and the interface rather than relying on the intrinsic properties of the bulk glass itself to define those surface features. Initial applications will be to the production of glass fibers with improved coatings for better protection, better dispersion in processing, and better coupling with various polymeric matrices in a variety of composite applications. Eventual applications may extend to protective and strength-enhancing treatments or coatings for containers or glass panels. For more information, contact Carlo Pantano at the Pennsylvania State University, 814.863.2071, cgp1@psu.edu.

## Higher Strength Glass

Stronger, lighter weight glass products, whether they are automobile windows, architectural glazing, or beverage bottles, have the potential to benefit much of society. Continuing research, over the past ten years or more, on methods by which to strengthen glass has put the CGR at the forefront of this technical area. Knowledge gained related to chemical (ion-exchange) strengthening is enabling lighter, higher strength glass products to be manufactured. CGR researchers received a Department of Energy Office of Industrial Technologies grant (DE-SC02-97CH10875) to continue these studies and to demonstrate practical applicability of their ideas to producing stronger, yet lighter weight, glass windows. While there are economic (cost) barriers for some applications, for others these should be surmountable. Pilot production of such strengthened glasses is imminent. For more information, contact Dr. Tom Seward, 607.871.2432, seward@alfred.edu.

## Redox (Oxidation State) Studies

Major insights have been gained into the understanding of the oxidation state of glass melts. Research conducted by Dr. Henry D. Schreiber under CGR and NSF funding at the Virginia Military Institute has greatly extended our ability to ascertain the degree and mechanisms of mutual interaction of important redox (reduction-oxidation) couples (for example, Fe/Cr, Fe/Ce, and Fe/Mn) in soda-lime-silica glasses and glass melts; to develop in situ electrochemical procedures for soda-lime-silica and borosilicate glass melts and understand and control the melt's redox state; and to correlate in situ electrochemistry to the redox state of glass-forming melts. These research findings are important to processes involved in the melting and fining of glass and for controlling color in commercial glass. One CGR member company, Visteon Corporation, the automotive glass producing subsidiary of Ford Motor Company, claims that nine (9) U.S. patents in the areas of manufacturing processes, glass color (tint) and glass quality were stimulated by this CGR-sponsored research. For more information, contact Dr. Tom Seward, 607.871.2432, seward@alfred.edu.

## Glass for Toxic Waste Encapsulation

Specialized glasses and glass melting processes are at the heart of toxic waste vitrification, particularly of low-level and high-level radioactive waste, for long-term storage. Research sponsored by the CGR at Alfred University and the Virginia Military Institute has led to major insights into understanding the oxidation state of such glass melts, including the degree and mechanism of mutual interactions (oxidation-reduction reactions) among the many multivalent elements present. This is at the heart of understanding and predicting chemical durability of the glass, which is important for assuring long-term stability during underground storage. This information has been found extremely valuable by at least one of our member companies, the Westinghouse Savannah River Company, and several national laboratories involved with nuclear waste vitrification. For more information, contact Dr. Tom Seward, 607.871.2432, seward@alfred.edu.

## Energy Efficiency, Modeling and Glass Melt Properties

Glass manufacturing involves some of the country's most energy-intensive industrial processes. Mathematical modeling is a useful approach toward improved, less energy-consuming processes. However, predictions of models are no better than the quality of data on which they are based. Between 1996 and 2003, with additional funding from the DOE Office of Industrial Technologies (Grant #DE FG07-96EE41262), CGR researchers studied and measured high temperature glass melt properties of six commercially important families of glass: window and architectural glass ("float glass"), container glass, textile and insulation fiberglass, low-expansion automobile headlamp and laboratory glass, and color television picture tube glass. This was done to the high degree of reliability needed by the modelers. Some properties, such as the photonic contribution to high temperature heat conductivity, had never before been measured for these types of glass. At least 8 member companies have testified to the value of this database and 4 (U.S. Borax, Visteon Corporation, Guardian Industries and Techneglas) are actively using the information it contains. For more information, contact Dr. Tom Seward, 607.871.2432, seward@alfred.edu.

# Center for Health Management Research (CHMR)

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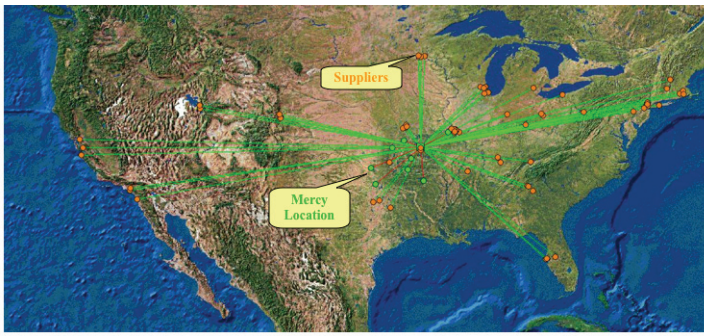
## Strategic Inventory Alliance in the Healthcare Industry




Researchers at Center for Health Management Research have collaborated with researchers from the Center for Engineering Logistics and Distribution at the University of Arkansas to evaluate ways that hospital organizations can better manage their vertical chains of production. The research contrasts and compares completely outsourced models of healthcare supply chains with in-house management models using a case study approach with two healthcare supply chain strategies. Simulation models have been used to replicate the supply chain operations of both strategies. Alternative supply chain networks have been used to develop best practices from both strategies. The process culminates in performance measures to assist in making decisions regarding "make versus buy" and inventory stocking policies, thus providing health care managers with information that enables them to make better strategic decisions about inventory and distribution that may improve organization performance. For more information contact, Manuel Rossetti, 479.575.6756, rossetti@uark.edu or Russell Meller, 479.575.8431, rmeller@uark.edu.

# Center for Infrastructure Engineering Studies (CIES/RB$^2$C)

Repair of Buildings & Bridges with Composites
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University Missouri-Rolla, Reza Zoughi, 573.341.4656, zougnir@umr.edu
North Carolina State University, Sami Riskalla, 919.513.4336, sriskal@unity.ncsu.edu
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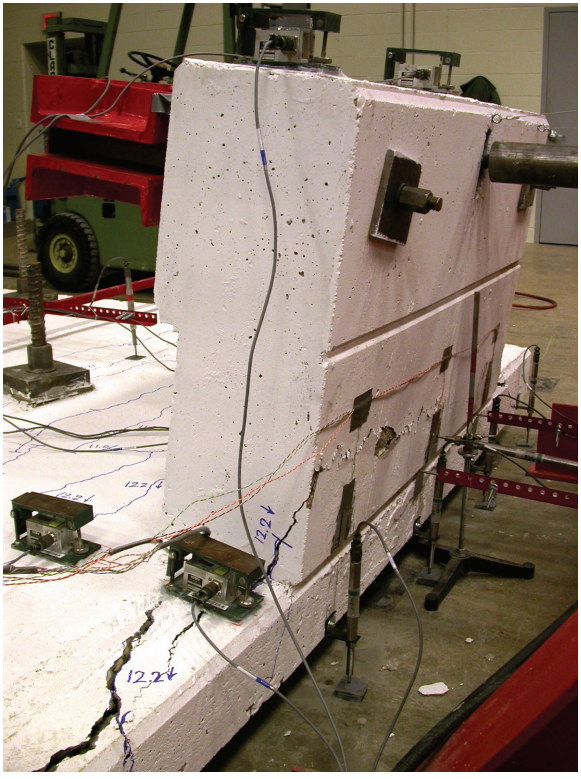
Center website: http://www.cies.umr.edu/ & http://www.rb2c.umr.edu/

## Concrete Structure Reinforcement Enhancement:

### Bridge Rehabilitation



Synergism through the RB$^2$C center has resulted in the adoption of fiber-reinforced polymer (FRP) internal reinforcing for concrete structures. Much existing infrastructure is falling to disrepair due to simple corrosion of the reinforcing steel embedded in concrete. Each year the effects of corrosion on essential infrastructure divert billions of dollars of public funds to renewal of bridges and other structures. A number of efforts are being taken to mitigate this problem but most are superficial compared to getting at the root of the problem and utilizing a non-metallic reinforcing material that will not corrode. Lightweight, high strength materials have been demonstrated to be useful in restoring structural capacities to existing buildings and bridges extending their useful life. The adoption of FRP materials for the repair and new construction will benefit everyone by making our infrastructure last significantly longer freeing public resources for other pursuits. NSF funding has facilitated basic research in the area of FRP reinforcement and repair and has resulted in codification for use in the civil infrastructure and demonstration projects that can be leveraged for broader use enabling participating industry part-

ners to be involved in the early stage development of a growing industry aimed at producing FRP rebar and repair materials. It should be noted that the civil engineering community is becoming more aware of the existence of such materials and that building design and construction codes are now being updated to facilitate their use. Documentation is being developed on how bridges should be selected for various FRP-strengthening procedures along with associated cost estimates of competing scheme, and predicted life expectancies of strengthened bridges. For more information, contact Dr. Antonio Nanni at the University of Miami-Florida, 305.248.3461, nanni@miami.edu.

## Preformed Fiberglass Grating Panel Systems (GRIDFORM)

GRIDFORM consists of fiberglass grating panel systems with fiber-reinforced polymer (FRP) plate for stay in place use. These FRP grating panels replace steel rebar in reinforced concrete bridge decks on vehicular bridges. The grating panels are shop fabricated and shipped to the job site ready for installation on the steel bridge girders and the concrete pour. Field installation time for the GRIDFORM panels including the concrete pouring is approximately 25% of normal steel rebar installation and concrete pour. This reduced installation time results in lower field installation costs and less disruption of service for people needing access to the bridge for travel. Additionally, reduced field installation time translates into a lower rate of construction workplace injuries. GRIDFORM grating panels have become recognized as a viable alternative to traditional steel reinforced concrete bridge decks. The use of GRIDFORM panels meets the Federal Highway Administration's initiative of "Get In and Get Out." The emphasis by FHWA is to reduce the amount of construction time and the concurrent disruption to the traveling public by utilizing new technologies and methods for rapid construction of bridges and roads. The new technology will result in producing the FRP grating panels at the manufacturing site of the FRP grating. This new breakthrough technology has resulted in a new product line for the Strongwell plant located in Chatfield, Minnesota. Strongwell is promoting this new product line to county and state transportation officials as a time saving alternative to traditional construction materials. For more information, contact Dr. Antonio Nanni at the University of Miami-Florida, 305.248.3461, nanni@miami.edu.

# Center for Intelligent Maintenance Systems (CIMS)

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## Watchdog Agent for Assessing Equipment Performance


Since machine or process breakdowns severely limit their effectiveness, methods are needed to predict products' life expectancy. Information about the remaining life of products and their components is crucial for their disassembly and reuse, which in turn leads to a more efficient and environmentally friendly usage of product and resources. Development of the Watchdog Agent by researchers at the Center for Intelligent Maintenance Systems (CIMS) answers the aforementioned needs. The Watchdog is essentially software that can be applied to just about any product or system for which it would be beneficial to predict when and why the product or system is going to fail, from a simple valve to a complex system. Watchdog Agent™ assesses and predicts the process or equipment performance based on the inputs from the sensors mounted on it. Performance-related information is extracted from multiple sensor inputs through signal processing, feature extraction and sensor fusion techniques. Historical behavior of process signatures is utilized to predict their behavior and thus forecast the process or machine performance. Researchers developed the Watchdog Agent toolbox to include tools for a wide variety of applications. These tools can then be customized to meet the needs of the particular industry or processes involved. Most of previous systems are limited to few tools. In today's competitive market, production costs, lead time and optimal machine utilization are crucial values for companies. The watchdog agent's continuous assessment and prediction of product's performance enables collaborative product life-cycle management in which products are followed, assessed and improved throughout their life-cycle. Watchdog software has been used in test-beds for Harley-Davidson, Tongtai Machine, TechSolve, and it is in the process of being applied at Omron, Toyota, GE and other companies. For more information, contact Jay Lee at the University of Cincinnati, 513.556.2493, jay.lee@uc.edu.

# Center for Integrated Pest Management (CIPM)

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## Novel Insect Repellent

CIPM researchers have developed a novel insect repellent from a compound found naturally in certain types of tomato plants. As an EPA category 4 compound, the new repellent is regarded as potentially safer than DEET, which is an EPA category 3 compound. The novel compound, which is safe enough to be approved as a food additive, may help meet consumer demand for an alternative to DEET as an insect repellent. The invention received national media coverage during the summer of 2003. It has received a U.S. patent and has been licensed to a private company. For more information, contact R. Michael Roe, 919.515.4325.

## Molecular Transfer System as Insecticide

CIPM has developed a molecular transfer system for proteins, nucleic acids, and small molecules that might be used as insecticides. The invention permits the movement of insect-specific compounds across the insect digestive system and possibly the cuticle, and allows for specific targeting of organs within the insect system. Other possible applications include the development of a novel transformation system for general applications where genetic material can be incorporated into cells. The technology has been submitted for patenting and has been licensed to a private company. For more information, contact R. Michael Roe, 919.515.4325.

## Assay for Monitoring Insect Resistance to Transgenic Crops

CIPM researchers have developed a diagnostic assay technology for monitoring insect resistance to transgenic crops. The invention has other applications, including monitoring insect susceptibility to transgenic crops, monitoring resistance to traditional insecticides, high-throughput screening for insecticides, and rearing of insects on a large scale more efficiently. Two U.S. patents have been awarded and the technology has been licensed to a private company. Products are currently on the market and have generated significant income. For more information, contact R. Michael Roe, 919.515.4325.

# Center for Identification Technology Research (CITeR)

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Center website: http://www.citer.wvu.edu/

## Fingerprint Liveness Detection

It has been shown that fingerprint biometric scanners, used for secure authentication, can be deceived very easily, using simple, inexpensive techniques with fake or dismembered fingers, called spoofing. In this CITeR breakthrough, it has been demonstrated that perspiration can be used as a measure of liveness detection for fingerprint biometric systems. As a result, the potential for spoofing biometric fingerprint devices, one major vulnerability in the industry, in being minimized. Unlike cadaver or spoof fingers, live fingers demonstrate a distinctive spatial moisture pattern when in physical contact with the capturing surface of the fingerprint scanner. The pattern in the fingerprint images begins as 'patchy' areas of moisture around the pores spreading across the ridges over time. Image processing and pattern recognition algorithms have been developed to quantify this phenomenon using wavelet and statistical approaches. Previously, commercial biometric devices did not have a mechanism to prevent spoofing. Prior to the Fingerprint Liveness Detection (FLD) research the main approach to spoofing prevention was to combine the biometric with additional hardware to measure liveness signals such as the electrocardiogram, pulse oximetry or temperature. Disadvantages included the need for additional hardware combined that was bulky and inconvenient and possibility spoofable by a live (un-authorized) finger in combination with the spoof finger. The advantage of the new CITeR approach is that the biometric itself is naturally integrated with the liveness measure, requiring only an additional software algorithm to protect from spoofing. This research has raised the visibility of these major security issues through presentations, publications, and main stream media (Discovery Channel, New York Times, National Public Radio) featuring FLD. As a result, industry has moved towards developing biometric devices that incorporate liveness, as well as other anti-spoofing measures. These CITeR developed algorithms are being considered by major biometric companies. Researchers have submitted and is continuing to develop patents for the liveness algorithms. The center universities are in the process of licensing the patents to a start-up company, called NexID Biometrics, LLC, incorporated and owned by the researchers. The company will develop and license the technology to the biometric device industry and system integrators for integration with their devices. For more information, contact Stephanie Schuckers at Clarkson University, 315.268.6536, sschucke@clarkson.edu or Lawrence Hornak at West Virginia University, 304.293.0405, lawrence.hornak@mail.wvu.edu.

## Multimodal Biometric Toolset

The design of multi-biometric systems has become significantly easier. Researchers at the Center for Identification Technology Research (CITeR) have developed the MUBI Toolset which addresses the growing interest in the prediction and evaluation of performance of systems that integrate multiple biometric devices and/or modalities. The toolset brings together more than a dozen algorithms from the research literature. It includes an embedded tutorial on multimodal biometric systems and fusion techniques. These algorithms represent all major types of biometric score normalization and fusion techniques. The toolkit presents performance curves from multiple biometric devices. Then, it calculates ranges of performance characteristics (genuine accept vs. false accept rates) of different multi-biometric system configurations. It assists users with the selection of individual device performance characteristics such that they meet the desired application-specific performance goal. No such tool existed before the MUBI became publicly available as an open source software product, downloadable at no charge from CITeR's Web site. The toolset supports biometric systems designers, system evaluators, students and all others interested in performance analysis and integration of biometric systems. For the developers of multi-biometric systems, MUBI significantly reduces the time needed to analyze and define the most suitable combination of biometric devices/modalities. The toolset has been downloaded hundreds of times, mostly by students studying information fusion techniques in biometrics software engineering and sensor networks. At the time that MUBI was being developed by CITeR researchers, major biometric systems in the US government (FBI's New Generation Identification system, DoD's Automated Biometric Identification System, etc.) moved towards adopting such multimodal identification techniques. It is being used by CITeR members to investigate and develop optimal combinations of biometric modalities for clients. Center developers are receiving numerous inquires about specific tool features from companies and federal agencies. CITeR is committed to keeping MUBI available free of charge through an open source software license. For more information, contact Bojan Cukic or Arun Ross at West Virginia University, 304.293.0405, bojan.cukic@mail.wvu.edu, arun.ross@mail.wvu.edu.

# Center for Microcontamination Control (CMC)

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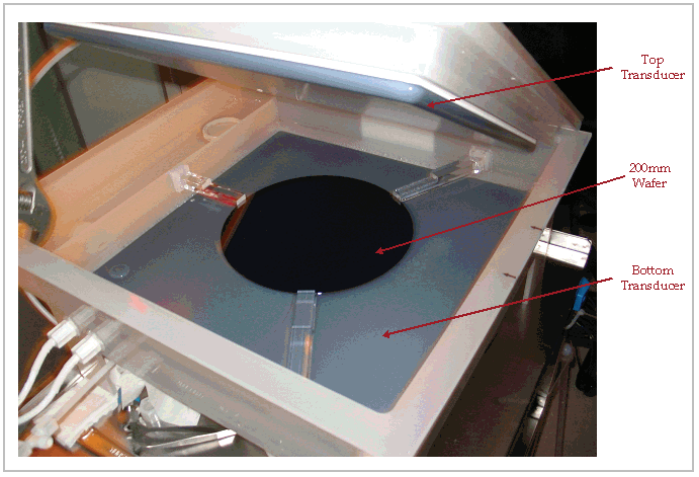
University of Arizona, HG "Skip" Parks, Director, 520.621.6180, parks@ece.arizona.edu

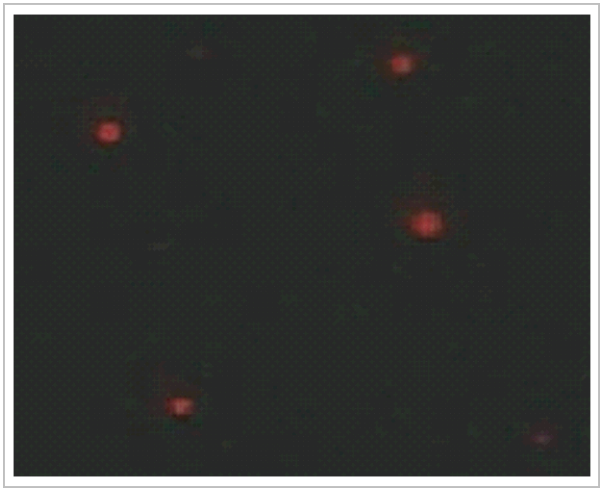
Center website: www.ece.arizona.edu/~cmc/ or www.cmc.neu.edu

## Physical Removal of Nanoscale Particles from surfaces and trenches




Researchers at the Center for Microcontamination Control (CMC) have developed a substrate independent technique for the removal of nano particles (down to 26 nm) from large areas in a very short time (less than a minute). The technique uses high frequency acoustic streaming in a specially designed tool by the center. The technique has also been shown to be capable of efficiently removing nanoparticles from deep trenches (as deep as 500 microns). This is also the first time that such removal from trenches has been directly demonstrated. The technique has been applied to semiconductor wafers, hard disk media and head, flat panel display, mask, etc. This is the first demonstration of substrate independent removal of nanoparticles. The techniques enable companies to remove nanoscale particles without any effect of sensitive substrates and allows them to use the same process for a variety of substrates. The techniques is based the reduction of the boundary layer thickness from thousands of microns to submicron which allows even low velocity to remove nano particles. It opens the field to many other applications that requires a high shear velocity near the surface. A patent has been filed and a member company (PCT Systems) already made two prototypes. Another member company (Seagate) is ordering an additional prototype to evaluate for their fabrication development based on our results in removing manufacturing defects. For more information, contact Ahmed Busnaina, 617.373.2992, a.busnaina@neu.edu

## Detection and Scanning of Nanoscale Fluorescent Particles



There is a need to scan and count submicron particles on structured surfaces. No commercial instruments are available for the metrology of submicron and nano particles on structured surfaces such as trenches. Center researchers have developed a simple technique for detecting and counting nanoscale fluorescent particles using an optical microscope. The microscope can count particles as small as 26 nm in areas as large as 100 million square microns. This technique has been used to detect particles on flat substrate and deep trenches and has been instrumental in verifying the surface cleaning technologies on flat and structured substrates. The technique has been applied to semiconductor wafers, hard disk media and head, flat panel display, mask, etc. The technique can give an accurate estimate of the cleaning efficiency of nanoscale particles on any surfaces or microstructures. For more information, contact Ahmed Busnaina, 617.373.2992, a.busnaina@neu.edu. Above: 28 Nanometer PSL Fluorescent Particles.

## Software for the Design of Silicon Wafers Particle Detector

A software was designed by Prof. Andreas Cangellaris in a project funded by Tencor (Now KLA-Tencor.) This software mapped the signal scattered from a particle located on a bare or oxidized silicon wafer. This software allowed fast plots of the scattered light intensity vs. angle from a particle on a wafer for a given light frequency, angle of illumination. Prior to this development in sparse matrix calculating, super-computers were required to perform these calculations. This knowledge led to the development of the tool. This tool has enhanced signal-to-noise ratio. That is, by locating the detector at its new angle, the ratio of signal to noise was greater. That allowed the detector to locate and identify particles on the rough, backside of a silicon wafer. Tencor engineers used this software to design the optimum location for the illumination source and the scattered light detector in a then-new generation of scanners--the first of which was the Tencor Surfscan (r) 6420. For more information, contact Prof. Andreas Cangellaris, now of the ECE Department, University of Illinois, 217-333-6037, cangella@staff.uiuc.edu.

## Observing the Nucleation of Bacteria on the Inside Walls of Ultrapure Water Pipes

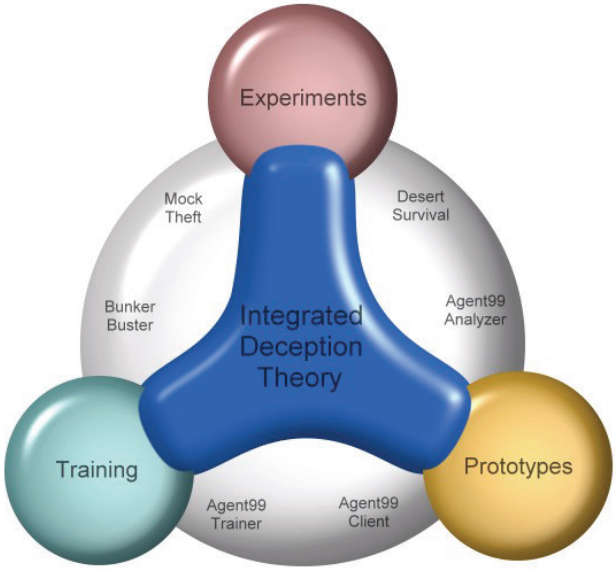
A decade ago, the Center for Microcontamination Control sponsored work that lead to Polymerase-Chain-Reaction amplification of DNA in ultrapure-water-born bacteria. Eventually, a process was developed that would measure one bacterium in one liter of water. However, it was then realized that most of the bacteria reside on the walls of the ultrapure water piping in concentrations of 10,000 to 1,000,000-times greater. Semiconductor process contamination results when small areas of the bacterial colonies or biofilms, are released from the surface at infrequent and random intervals. Once this concept was understood, it was realized that the primary issue is detecting the nucleation and growth of bacterial films on the piping materials used in the distribution of ultrapure water. The breakthrough was the development of a new and novel technology that can monitor and detect growth of surface bacterial films. This technology can be made so sensitive that it can detect the protein substance that must deposit before the first layer of bacteria attaches to the piping walls. It can also be made less sensitive for less demanding applications. This device will be of most use in the drug industry, where bacterial monitoring is now coming under more scrutiny and is more serious than in the semiconductor industry. The CMC is currently working with a small business to develop and manufacture this detector. For more information, contact Prof. Jon Sjogren, University of Arizona, jsjogren@ece.arizona.edu.

# Center for Management of Information (CMI)

University of Arizona, Jay F. Nunamaker, Director, 520.621.4475, nunamaker@cmi.arizona.edu

## Detecting Deceptive Communications

Working with the U.S. Air Force and two other universities, the Center for the Management of Information (CMI) at the University of Arizona is investigating how to detect deception in various communication modes and identify the types of information processing tools needed to improve homeland protection. A key goal is to develop hardware and software tools to screen electronic communications traffic and automatically flag potentially deceptive methods, using indicators of deceit incorporating text, voice, and visual cues. For more information, contact Dr. Judee Burgoon, 520.621.5818, jburgoon@cmi.arizona.edu.



## Networkcentric Warfare


Working with the U.S. Navy, the Center for the Management of Information (CMI) at the University of Arizona developed CommandNet, a collaborative logging tool designed to shorten the decision-making cycle and to increase situation awareness. CMI's research, development and deployment of CommandNet for intelligence is showing the way to what the U.S. Navy deems Network-Centric Warfare has increased the Navy's war fighter situational awareness and has improved operational decision-making. An article in the Arizona Daily Star stated, "The key to CommandNet is to provide a systematic methodology of organizing information and present it in a manner that makes sense. This technology shortens the decision-making cycle to increase situation awareness." For more information, contact Jay Nunamaker, 520.621.4475, nunamaker@cmi.arizona.edu.

# Center for Machine Tool Systems Research (CMTSR)

University of Illinois, Urbana-Champaign, Shiv Kapoor, Director, 217.333.3432, sgkapoor@uiuc.edu

Center website: http://www.scitechresources.gov/Results/show_result.php?rec=2419

## Machining Software to Improve Part Quality and Production

Computer software to simulate machining and machine tool systems developed by the center has yielded improvements to parts' quality and production. The Center members that have been using the suite of machining simulation software developed by UIUC Professors Richard DeVor and Shiv Kapoor in engineering design, manufacturing, and diagnostic activities within their corporations include General Motors, Ford Motor Company, Caterpillar Inc., Kennametal, Inc. and Delphi Automotive. Specifically, the process simulation work has helped companies to develop re-configurable fixtures for rapidly changing part designs and fault diagnosis work in machining processes that employ a control cycle and exercise control over product, processes, and resources. A joint venture that happened because of center I/UCRC research work on process simulation is a new company called "Pre-con." For more information, contact Ed De Chazal, 313.821.5897, edechazal@webcradle.net.

## Constant Velocity Joint Wear Measurement and Analysis

Professor Mike Philpott at the University of Illinois, Urbana-Champaign, working with Center member Rockford Acromatic, Rockford, Ill. on the Constant Velocity Joint Wear measurement and analysis research received two U.S. patents. The research addressed the problem facing the Constant Veloity (CV) rebuilder of evaluating the specific component, or components, in the driveline needing to be replaced or refurbished. The economics of CV joint rebuilding is dependent on the rebuilder's ability to accurately evaluate component degradation and serviceability. The primary invention relates to the mathematical models of measuring and quantifying wear in the complex profiles of CV joints, without prior knowledge of the nominal or designed geometry. The instrument provides a direct quantitative method of CV joint track wear. The second patent deals with the development of a handheld device for measuring certain important parameters of splines. The patents were U.S. Patent No. 128,992 on "Method and Means for Measuring Wear in Constant Velocity Joints" Oct 15, 1996; and U. S. Patent No. 315071 on "Spline Counting Mechanism" Nov. 21, 1995. For more information, contact Shiv Kapoor, 217.333.3432, sgkapoor@uiuc.edu.

## Feature-Based Costing Software

A company named FBC Systems was created based on feature-based costing technology work funded by Center for Machine Tool Systems Research. The company has developed the first feature-based costing software that allows engineers to determine the cost during the early conceptual design stage of product development. The focus of this research has been on developing cost models based on key cost drivers in the designers' knowledge domain. The software is designed to help engineers make choices that minimize the cost of parts before one gets further into the product development cycle. For more information, on FBC

Systems, contact Dr. Mike Philpott at mphilpot@fbcost.com or Eric Hiller at ehiller@fbcost.com, FBCost.com.

## Ceramics Machining Technology

Technology for machining ceramic materials has led to joint patents between the University of Illinois (Professor P. M. Ferreira and his students) and the Nashua Company. A hybrid process that combines conventional grinding with ultrasonic grinding was developed for machining ceramic materials. An experimental test rig, consisting of a modified milling machine fitted with an ultrasonic spindle and a constant pressure feed worktable, was developed to demonstrate the feasibility of the new technology. The research has been shown to improve the productivity of machining ceramic components, including machining of ceramic disks used by computer industry, and possible suppression of tool glazing to make the process more widely acceptable ("Rotary Ultrasonic Grinder," U. S. Patent Number 08,447,780, 1997). For more information, contact Placid Ferreria 217.333.0639, pferreir@uiuc.edu.

## Tetrahedral Tripod Type Machine Tool

A functional Tetrahedral Tripod Type machine tool, which is based on the use of hybrid serial-parallel schemes, has been designed, constructed, and delivered to Center member Caterpillar, Inc. for applications in ceramic machining. It has spatial positioning capability that positions the platform in space with no rotations. The design is modular, and possesses speed, accuracy, and high stiffness. It is reconfigurable so that it can be tailored to manufacturer needs, including 3-axis milling. It also addresses the complex issues of precisely controlling the machining process, the need for high machine stiffness in grinding of structural ceramics, and issues involving precise tool-workpiece engagement by employing a hybrid position/force controller. For more information, contact Shiv Kapoor, 217.333.3432, sgkapoor@uiuc.edu.

## Micromechanical Test Apparatus

Prof. Sottos at the University of Illinois Urbana-Champaign (UIUC) and Dr. Andrew Skipor at Motorola Labs, Motorola Advanced Technology Center (MATC), have established a successful record of research and tech-transfer. Their first Motorola sponsored project (1994-1999) investigated bending reliability and dimensional stability of plastic ball grid array (PBGA) packages. This research resulted in the development of a unique capability to test small-scale electronic components. A micromechanical test apparatus was designed specifically to investigate the response of area array electronic packaging to both thermal and flexural loading. For more information, contact Shiv Kapoor, 217.333.3432, sgkapoor@uiuc.edu.

## Self-Healing Polymers to Improve Microelectronic Components

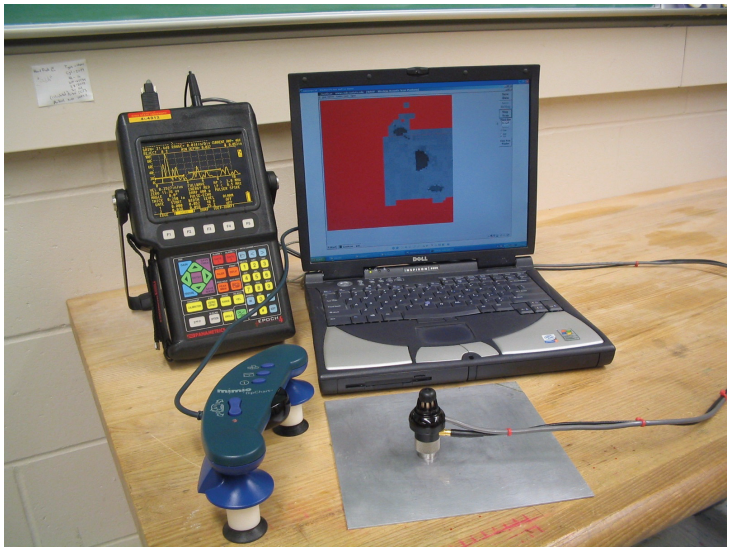
The Machine Tool Systems Research Center's Motorola sponsored project (2001-2004) seeks to improve the reliability of microelectronic components through the use of self-healing polymers. A comprehensive experimental program is in progress to assess the fatigue behavior of self-healing polymers for potential use in printed circuit board (PCB) laminates. Excellent progress has been made at the Center for Machine Tool Systems Research (CMTSR) on characterizing the fatigue characteristics of self-healing epoxy. A self-healing PCB laminate test vehicle was designed and fabricated for on-site testing at Motorola by Dr. Andrew Skipor. For more information, contact Shiv Kapoor, 217.333.3432, sgkapoor@uiuc.edu.

# Center for Nondestructive Evaluation (CNDE)

Iowa State, Bruce Thompson, Director, 515.294.7864, thompsonrb@cnde.iastate.edu

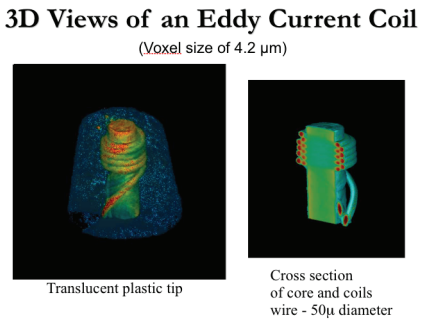
Center website: http://www.cnde.iastate.edu/

## Generic Scanner to Image NDE Data



The Generic Scanner or "GenScan" has demonstrated the ability to take off-the-shelf, relatively inexpensive nondestructive evaluation (NDE) flaw detectors and combine them with non-encumbering position encoding devices and newly developed software. This creates semi-automated NDE scanners with far greater capability than the previously available. This CNDE research was initially funded by the Federal Aviation Administration to develop improved methods for inspecting composite aircraft structures. The main advantage of the generic scanner is that it allows inspectors to create images which can provide a more intuitive and thorough inspection of relatively large areas of commercial aircraft, e.g., composite control surfaces. The system has been designed to mate with a number of portable NDE devices used throughout the aviation industry. It is inexpensive, portable, and user friendly in its setup and operation. GenScan effectively makes traditional point-by-point inspection methods much more capable by adding tracking of the NDE signal with its position. Image scans made by the scanner can be readily saved and transmitted electronically for further off-site analysis. GenScan has been successfully coupled with several eddy current and ultrasonic flaw detectors. A number of scanner prototypes have been assembled and beta site tested at several aviation maintenance facilities in the civil and military sectors. GenScan can increase the inspection capabilities of a variety of existing NDE devices. It allows maintenance organizations to extend the use of instruments and mitigate the need to purchase more expensive, specialized NDE instruments with built-in imaging systems. The generic scanner will provide more robust inspections, particularly of relatively large featureless areas encountered such as those on composite aircraft. It is being actively reviewed by the US Navy and US Air Force for its ability to increase existing inspection capabilities and can be easily adapted for inspection applications in other industries aside from aviation. For more information, contact David K. Hsu, 515.294.2501, dkhsu@iastate.edu or Dan J. Barnard, 515.294.9998, both at Iowa State University.

## High Resolution 3D CT




This breakthrough extends the ability of radiographic computer-aided tomography (CT) to industrial applications at the micron resolution level. The breakthrough utilizes corrections for beam hardening and for low contrast associated with the radiographic interrogation of metallic components that enhance CT algorithms to achieve high resolution. These algorithm enhancements coupled with a micro focus x-ray source provide higher resolution 3D image resolutions. Such structure resolutions on the micron level allows for non-destructive characterizations that previously were not possible. This is particularly beneficial in characterizing structures with cracks displaying a three-dimensional morphology. For more information, contact Dr. Joe Gray at Iowa State University, 515.294.9745, jgray@cnde.iastate.edu.

## Dripless Bubbler: Portable Scanner for Aircraft Inspection

Researchers at the Center for Nondestructive Evaluation (CNDE) have developed a field able ultrasonic scanning system for aircraft inspection. Developed by the center's Composite Group, the "Dripless Bubbler" is the first portable ultrasonic scanner with a closed-cycle water couplant and uses high frequency focused ultrasonic beam. It is a portable ultrasonic scanner designed and developed for aircraft inspection. It can be attached to the fuselage of an aircraft and inspect it for hidden corrosion. It uses a unique closed-cycle pump/vacuum water handling system that uses focused transducers. The focused ultrasonic beam leads to superior image resolution and more accurate determination of the metal loss due to corrosion. It has the unique capability of scanning over protruding rivets on the aircraft skin. The closed-cycle water handling feature makes it compatible with the safety requirements of maintenance hangars. Because this device performs ultrasonic inspection with a focused beam, it provides much improved resolution and sensitivity compared to previous methods. The resolution afforded by the focused transducer makes it a useful tool for mapping out the depth profile of corrosion. The Dripless Bubbler received an R&D 100 award. It was licensed to and commercialized by Sierra Matrix, Inc. of Fremont, California. The technology was also used in addressing the corrosion problem of KC135 wing skins around fasteners. For more information, contact David K. Hsu, 515.294.2501, dhsu@cnde.iastate.edu.

## Simulation Tools for Nondestructive Evaluation

Researchers at the Center for Nondestructive Evaluation (CNDE) have developed simulation tools that make it possible to predict the results of nondestructive evaluation (NDE) measurements to detect and to characterize flaws in structural materials. These incorporate rigorous, physics-based models, and procedures to determine the necessary input parameters to describe the measurement situation and user interfaces. The tools include simulators for ultrasonic, eddy current, and x-ray NDE. The tools result in considerable industrial cost and time-savings, since the need to construct expensive samples and make time-consuming measurements on them is greatly reduced. Many possible inspection scenarios can be quickly evaluated, leading to a down-selection of a few for final experimental evaluation. The technology has been transferred to a number of major entities with large industrial impact. A major, land-based gas turbine manufacturer saved $500K per year in avoiding the manufacture of curvature correction blocks. A consortium of aircraft engine companies are using these tools to design the ultrasonic probes used to inspect billet and forging materials for critical defects. One aerospace company has estimated that a particular ultrasonic application saved them $1M in the first year alone and is investing a like amount at CNDE to develop other possibilities. Eddy current simulators are being used in the nuclear, aircraft engine and general aviation industries to evaluate the capabilities of a wide range of inspection techniques. A small business, NDE Technologies, was formed in 1997 to commercialize the technology. A joint agency group (Air Force, FAA, NASA) has recognized the important potential of this technology to replace, to a large degree, costly and time-consuming experimental programs for assessment of NDE reliability. For more information, contact R. Bruce Thompson, 515.294.7864, thompsonrb@cnde.iastate.edu.

## Time-Proven “Coin Tap” Automated


The hearing-based, manual tap test, practiced widely by aircraft inspectors, was computerized and automated to give it quantitative and imaging capabilities and to take the "human factor" variation out of the inspection procedure. The tapping action was automated with the invention of a magnetic cam-action cart. Equally-spaced and uniform taps were made as the cart was pushed over the part's surface. The simple encoding method gave the system a previously unavailable imaging capability. Computer-aided tap tester (CATT) has proven effective for the inspection of both composite structures and metal honeycomb structures on a wide variety of control surfaces on aircraft. It also provided the quantitative inspection results in the form

of images that can be archived electronically. The technology was patented and licensed to a start-up company, Advanced Structural Imaging, Inc. in 2001. Two of the original inventors of the CATT participated in the company. Aircraft manufacturers and R&D organizations in NDE have purchased ten units from the company so far. For additional information, contact David K. Hsu, 515.294.2501, dhsu@cnde.iastate.edu.

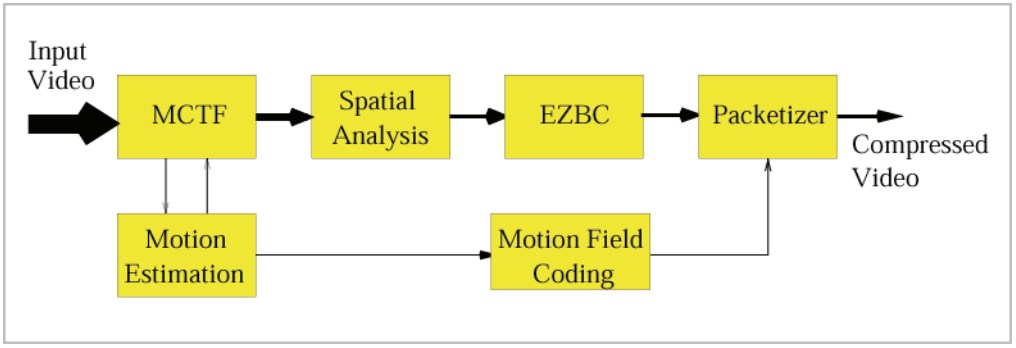
# Center for Next Generation Video (CNGV)

Rensselaer Polytechnic Institute, John W. Woods, Director, 518.276.6079, woods@ecse.rpi.edu

Center website: http://www.ecse.rpi.edu/CNGV/

## Scaleable Video Coding

Researchers at the Center for Next Generation Video have developed a technique for scalable video coding, or data compression, called MC-EZBC. The technique can accommodate different video resolutions, frame rates, and quality at the same time and is flexible enough to serve many users with different systems and network link capabilities. The research has provided the basis of an effort to develop standards for video coding for transmission over the Internet by MPEG (Motion Picture Experts Group, a committee of the International Telecommunications Union, the official international body that defines the standards for DVD, digital broadcasting, and video). The center's work was the impetus for this standardization effort of MPEG. For more information, contact John W. Woods, 518.276.6079, woods@ecse.rpi.edu.

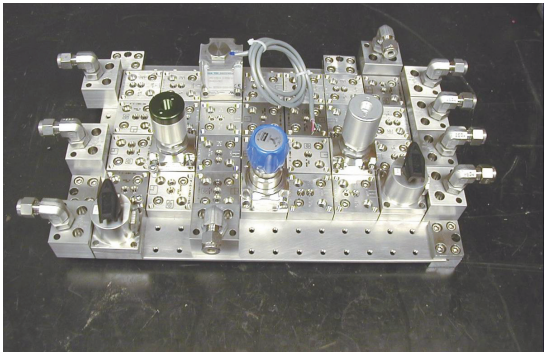


# Center for Process Analytical Chemistry (CPAC)

University of Washington, Mel Koch, Executive Director, 206.616.4869,
mel@cpac.washington.edu

Center website: http://www.cpac.washington.edu/

## New Sampling and Sensor Initiative (NeSSI™)



Although process analyzers have undergone great technological advance, the systems that deliver samples to them have hardly changed in the last fifty years. The initiative, launched in 2000 by the Center for Process Analytical Chemistry (CPAC), is primarily concerned with the treatment and continuous analysis of samples extracted from process equipment. NeSSI™ provides specifications, guidelines and a forum for the on-going development of a Lego®-style building block approach for analytical systems. It is being specified on major new-build projects.

It also provides networked connectivity for all components of Process Analytics systems, opening the door to smart diagnostics and improved remote technical support. NeSSI™ is now used for process analytical measurements in the petrochemical, chemical and oil refining industries and are being explored in the pharmaceutical related industries. In 2006 it was widely recognized that CPAC's leadership has developed NeSSI™ into a valuable global ad hoc initiative comprised of end users and suppliers and is resulting in permanent changes on process analysis. The New Sampling and Sensor Initiative provides an entirely new platform which reduces costs (up to 40% off the cost to build and 30% off the cost to own) with increasing reliability, and hence the credits delivered by process analyzers. The combined benefits to industry will be measured in tens of millions of dollars per year. For more information, contact Mel Koch at the University of Washington, 206.685.2326, mel@cpac.washington.edu or Dave Veltkamp, 206.543.6364, veltkamp@cpac.washington.edu.

## Non-Destructive Spectroscopic Measurement: Inline Octane Sensor

The Center for Process Analytical Chemistry (CPAC) pioneered a revolutionary approach to octane determination in oil refineries. The new method uses a non-destructive spectroscopic measurement followed by multivariate calibration techniques to predict diverse physical, chemical, and consumer properties of fuel. The now commercially available "octane sensor" is now used by oil companies worldwide because it quickly, accurately and in real time predicts octane levels from the near-infrared vibrational spectrum of the inline sample. This is possible because the spectrum of the material clearly reveals the number and types of functional groups (e.g., methyls, methylenes, olefins, aromatics). These together determine gasoline's physical, chemical, and consumer properties. This octane determination method represents a vast improvement over previous octane determination methodologies because octane levels were determined by a specially designed, ASTM-CFR test engine, where the sample's performance was compared to reference fuel blends. The instrumentation required for the measurement was very expensive (over $100,000), required constant maintenance, needed frequent standardization, consumed approximately one pint of gasoline per test and, most importantly, required 20 minutes to produce results. As a bonus, the octane sensor can simultaneously predict a number of important properties of gasoline such as density, vapor pressure, and percent aromatics. All of these measurements are made nondestructively on one cc of sample. Results are available instantaneously. The approach has proven an invaluable adjunct to process analytical chemistry. It literally saves the oil gasoline refinement industry many millions of dollars per day. For more information, contact James Callis at the University of Washington, 206.543.1208, callis@u.washington.edu.

## Process Chemometrics

Through the efforts of the Center for Process Analytical Chemistry (CPAC), the tools of chemometrics were introduced to the chemical industry, allowing important process and product performance quantities to be obtained from indirect chemical measurements. An important example is the calculation of the fuel performance standard, such as the octane number of gasoline, from infrared and near infrared spectroscopic data obtained on-line during the blending process. Another is the estimation of product performance at an early state in the manufacturing process such as elongation strength of finished polymer fibers. For the first time, Multivariate Statistical Process Control (MSPC) allowed manufacturing processes to be controlled using all of the process measurements together as opposed to the old methods of Statistical Process Control (SPC) which demanded the analysis of control charts for each process variable. Chemometrics methods have allowed industrial chemists and engineers to extract all of available information from data acquired during the manufacturing process. Additionally, it has provided tools to determine the actual value of process measurements and/or control parameters leading to a major cost savings by discontinuing the acquisition of useless information. Today, a number of new companies are available to help chemical and material companies learn to use chemometrics tools developed at CPAC. Many of the mathematical methods are so useful that industry has developed protocols for their use that are approved ASTM standards. Finally, most medium to large chemical, material, pharmaceutical, food, and fuel companies employ at least one chemometrician and several have chemometric groups who do exploratory and routine analysis of process and product data as well as train others to use chemometrics tools to, in general, improve manufacturing processes.

For more information, contact Bruce Kowalski, bskowalski@mydurango.net or Mel Koch at the University of Washington, 206.616.4869, mel@cpac.washington.edu.

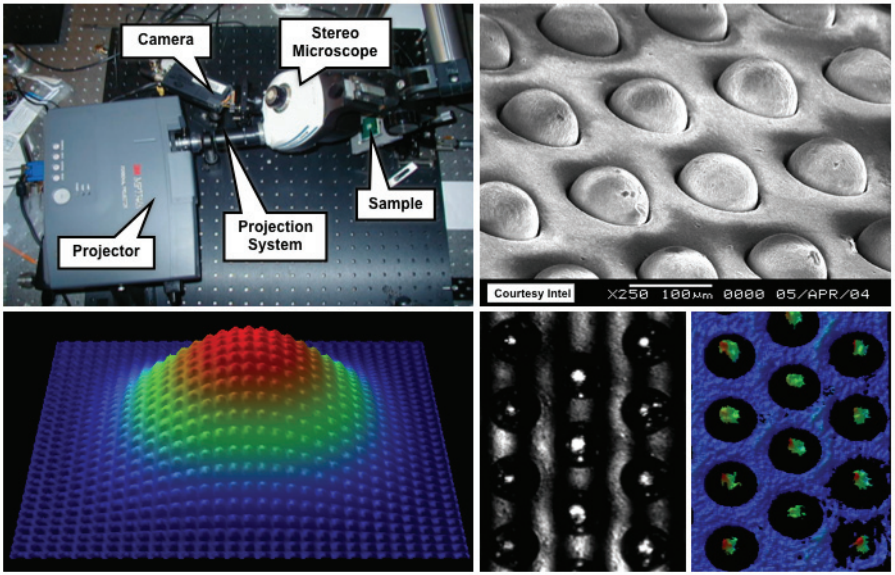
# Center for Precision Metrology (CPM)

University of North Carolina Charlotte, Robert Hocken, Director, 704.687.8496, hocken@uncc.edu

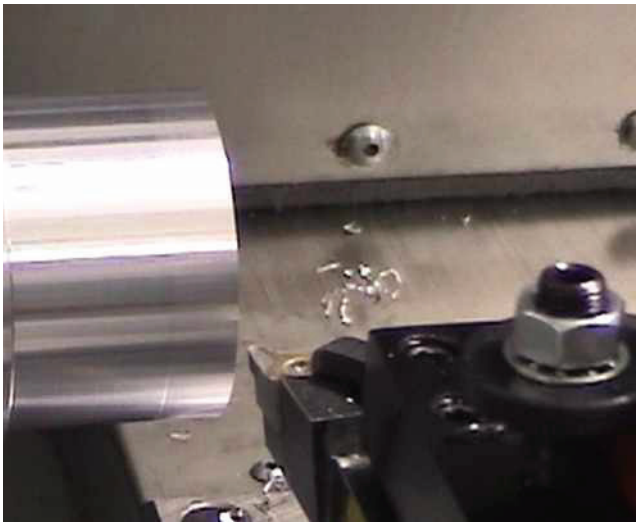
Center website: http://www.cpm.uncc.edu/

## CPM Moiré Fringe Metrology

Researchers at the Center for Precision Metrology have developed a system that uses structured white light to make dimensional measurements on any surface that can be sufficiently illuminated. As a metrology technique for measuring first level interconnect features in the semi-conductor packaging industry this method has proven to be about twenty five times faster than the historic white light interferometry technique. This new method has allowed the semi-conductor industry to maintain quality control of the first level interconnect as customer requirements continue to demand higher bump densities. Extensions to this technology have shown it to be versatile enough to make macro level form measurements as well as roughness. Current substrate metrology capabilities may be extended to support additional features of interest such as substrate shape and/or solder resist roughness. The easy availability of this type of data may allow for improved substrate manufacturing and improved yield during assembly. For more information, contact Angela Davies, 704.687.8135, adavies@email.uncc.edu or Faramarz Farahi, 704.687.8136, ffarahi@uncc.edu, both at the University of North Carolina at Charlotte.

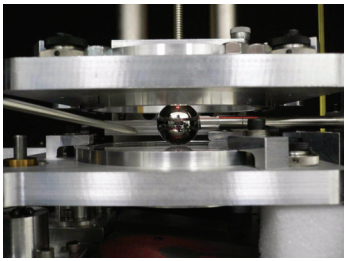


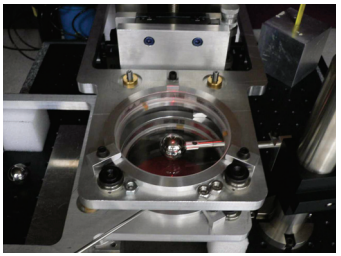
## Chip Breaking



Special materials requiring machining operations with no physical operator interaction often form springy chips which interfere with the process and may force expensive parts to be scrapped late in the manufacturing cycle. By choosing non-traditional tool paths that are now possible with computer-controlled machines, small chips can be reliably produced enabling operation without human monitoring or intervention.
For more information contact Scott Smith, 704.687.8350, kssmith@uncc.edu.

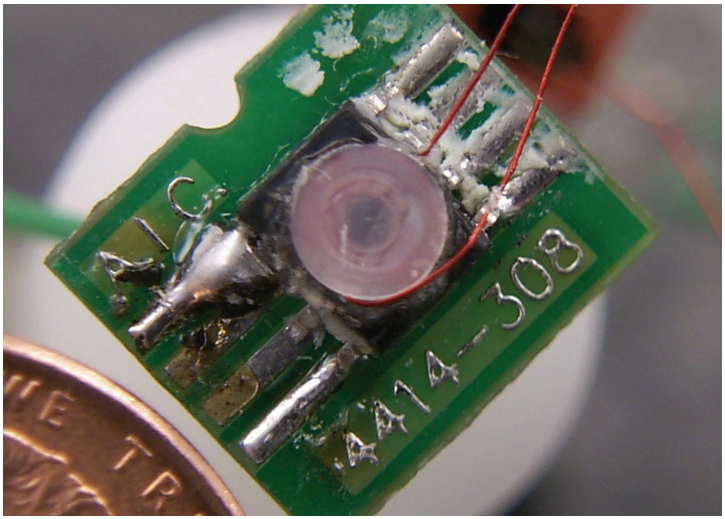
## International Dimensional Assessment with Nanometer Scale Agreement





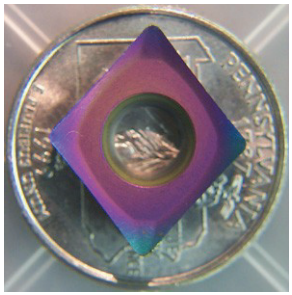
With the realization of global economics and nanometer-scale toleranced manufacturing for meso-scale part dimensions, it is necessary to expand, compare, and confirm techniques for the realization of low uncertainty measurement. Measurement capability for the diameter measurement of nominal 25.4 mm spheres was developed with international round-robin agreement with less than one part in a million (the order of nanometers) with the US and German National Laboratories, the National Institute of Standards and Technology and the Physikalisch-Technische Bundesanstalt. For more information, contact Robert Hocken, 704.687.8496, hocken@uncc.edu.

## Giant Magneto-Resistive Eddy Current Sensor




These miniature sensors utilize the Giant Magneto-Resistive (GMR) property that has been demonstrated in some materials. The GMR property is present when an external magnetic field significantly alters the resistance of a conductor. The device produces a magnetic field and then measures it using a GMR device. When the sensor is scanned near a material, the structure of that material influences the magnetic field. If there is the presence of a micro-crack (surface or subsurface) in the nearby material, eddy currents are generated which are clearly discernible to the sensor. By enabling the detection of subsurface cracks, catastrophic failure of materials can be predicted which was hitherto impossible. The device has applications in aerospace where cracks near bolted joints are a problem and also in rail systems where defective tracks can be replaced before there is a problem. The project resulted in U.S. Patent 6,504,363 and was the lead technology for a spin-off company. For more information, contact Robert Hocken, 704.687.8496, hocken@uncc.edu.

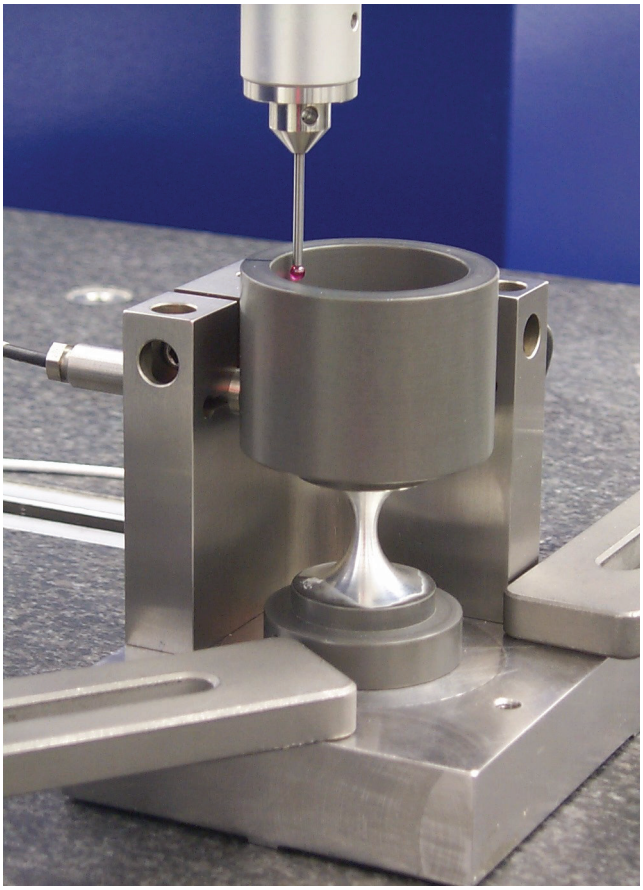
## Diamond Thin Films



The development of techniques for depositing thin diamond films on surfaces was advanced for the purpose of producing wear-resistant machine tooling. Diamond has two very useful properties. It is extremely hard and it is an excellent thermal conductor. Results of diamond research conducted at the Center for Precision Metrology (CPM) has yielded coating tools that have greater wear resistance and better removal of heat from tool/workpiece interfaces. The latter may increase the material removal rate for materials such as titanium which have traditionally been machined at very slow rates in order to prevent flash combustion and material softening due to near melting temperatures. Additionally, less coolant may be required resulting in a more environmentally friendly processes. The processing techniques have provided the basis for the development of technologies for a pending patent. A company is refining the techniques studied and is producing nanocrystalline diamond coatings with characteristics that offer increased durability, transparency, and protective characteristics with possibilities for anti-icing and abrasion protection for aircraft surfaces. The company is also looking at uses for artificial joints. For more information, contact Robert Hocken, 704.687.8496, hocken@uncc.edu.

## Standards for Tight-Tolerance Manufacturing Machines

Researchers at the Center for Precision Metrology (CPM) had several projects directed toward developing performance evaluation standards for coordinate measuring machines (CMMs). These are machines critical for verification of tight-toleranced manufacturing in the U.S. Along with the development of the standards. A device for performance evaluation of these machines was patented (U.S. 6,434,845) and licensed to a major U.S. supplier of metrology equipment. The device is capable of measuring probing forces, which may be sufficient to damage a component that is to be measured. Additionally, it is capable of assessing the ability of CMM's to scan parts for reverse engineering purposes. For more information, contact Robert Hocken, 704.687.8496, hocken@uncc.edu.



# Center for Research on Information Technology & Organizations (CRITO)

University of California, Irvine, Vijay Gurbaxani, Director, 949.824.5215, vgurbaxa@uci.edu

Center website: http://www.nsf.gov/eng/iucrc/directory/crito.jsp

## The Net-Enabled Organization


The forces of globalization and networking technologies are affecting the ways that companies work and do business. The commercial airplane unit of Boeing, for example, is partnering with a large number of groups around the world to build the new Dreamliner 787 airplane. Behind that network of organizations is a backbone of infrastructure for an information-rich environment. In such an environment, information needs to be available anywhere and anytime to anyone who needs it. To make this happen most efficiently, hierarchical organization structures are needed wherein decisions are made, then information flows up and down and needed approvals can be obtained. Simultaneously, everyone can look horizontally across multiple organizations to build teams, to complete tasks and to solve problems when within their scope of responsibility. With the help of CRITO, Boeing is working to improve understanding of how to orchestrate networks with internal and external partners. Center research is providing the theoretical basis as Boeing transforms itself into a different kind of organization. The underlying hypothesis is that those companies that are best at orchestrating these networks and at using them to provide most value to their customers will be the most successful. One important dimension of the solution is better understanding what companies need on order to keep tight internal control versus what it can or should safely network. Benefits of this approach are less inventory, fewer facilities and services that are market driven instead of internally driven. Profitability can be increased and companies can be more responsive. In the case of Boeing, airplanes can be built more efficiently. Using the tools of social science and business research, including case studies, interviews, surveys, modeling and analysis, CRITO researchers are working on the conceptual aspects the networked business model and helping to create the processes and tools to work more effectively in these new structures. For more information, contact Vijay Gurbaxani at the University of California, Irvine, 949.824.5215, vgurbaxa@uci.edu.

# Center for Surface Engineering and Tribology (CSET)

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Georgia Tech, Steven Danyluk, 404.894.9687, steven.danyluk@marc.gatech.edu

Center website: http://www.csetr.org/

## Design of Energy-Saving Lubricants

Research at the Center for Surface Engineering and Tribology (CSET) has solved a problem that has eluded tribologists for 40 years: the prediction of elastohydrodynamic traction (friction) from measured properties of a lubricating liquid. This development has great industrial significance since it should enable the design of lubricants that provide large savings in energy. Determination of lubricant parameters and behavior under pressure is important to the determination of the lubricating film between rolling element-bearing components. Understanding bearing lubrication permits determination of the mechanism of fatigue and bearing degradation that is likely to occur and how long the bearing surface will last. Experimental results and computer software from CSET have been used to improve lubrication in commercial products by several companies, including Timken, manufacturer of roller taper bearings; Eaton, automotive parts manufacturer; and Lubrizol, manufacturer of lubricant additives for heavy machinery applications. For more information, contact Leon Keer, 847.491.4046, l-keer@northwestern.edu or Michael Hoeprich, hoeprich@timken.com.

## High-Speed Surface Stress Analysis

CSET researchers have developed a high-speed numerical method of surface contact stress analysis. It was based upon programs from Northwestern University that led to evaluations of the effect of lubricant debris dents on reduction of fatigue life of rolling element bearings. By mapping bearing surfaces that have been dented with various sizes of debris particles and then analyzing these dented surface geometries with the stress analysis programs, the researchers developed a predictive tool for lubricants of various cleanness levels. This work has been used on customer applications. DuPont EKC Technology says that CSET research resulted in advances in numerical approaches to solving shaft seal, ring seal, and mechanical wear problems. For more information, contact Leon Keer, 847.491.4046, l-keer@northwestern.edu.

## Nanolayered Super-Lattice Coatings for Tribological Applications

Enhanced performance capabilities in terms of lifetime and wear were achieved through design of nanolayered coatings. These coatings also appear to have promise in use for cutting tools. In October 2001, the Tribology Division of the American. Society of Mechanical Engineers awarded to Y.W. Chung and L.M. Keer of the tribology center their Innovative Research Award. For more information, contact Leon Keer, 847.491.4046, l-keer@northwestern.edu.

# Center for the Study of Wireless Electromagnetic Compatibility (CSWEC)

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Center website: http://www.ou.edu/engineering/emc

## Avionics Research

There have been many reports questioning the potential interference that cellular phones could cause to aircraft avionics. To address this serious potential problem, a study was undertaken to provide valuable information on the spurious emission levels of wireless phones and the possible effect of those emissions on several of the more critical aircraft navigation equipment. It was designed to be an initial exploratory study to identify any significant problems that may exist. None of the phone technologies investigated exhibited a power level greater than a 38 dBm path loss level above the maximum sensitivity of the aircraft system antennae when tested one meter away from the antenna. Results indicated that, for the aircraft systems tested, the antenna of these systems would not have detected the emissions of the phones used in this study. For more information, contact Hank Grant, 405.325.2429, emc@ou.edu.

## Gas Station Research

A number of reports were circulated in the news media and on the Internet suggesting that cell phones could cause a fire or explosion if used at gas stations. In response to such potentially catastrophic events, a study was initiated. The cell phone/gas station issue is centered on claims that the cell phone battery could spark and ignite gas fumes, or that the electronic impulses or electromagnetic (RF) waves emitted by the phones might trigger fire and/or explosions of gas fumes. The Center performed a subjective assessment of the potential for a cell phone to cause an explosion, based on historical evidence and expert opinion. To add some perspective, comparison was made against the chances that an explosion could occur due to other sources. A matrix was developed that contains subjective ratings indicating the probability that a fire or explosion would occur under specified conditions. The matrix shows the fire/explosion probability from cell phones to be negligible. Thus, while it may be theoretically possible for a spark from a cell phone battery to ignite gas vapor under very precise conditions, realistically there is virtually no evidence to suggest that cell phones pose a hazard at gas stations. For more information, contact Hank Grant, Director, 405.325.2429, emc@ou.edu.

## Hearing Aid Research

The issue of the compatibility of hearing aids and wireless phones has been a "hot" issue for nearly a decade and continues to be a major issue. The Wireless EMC Center has been involved in this area throughout this time and has conducted several studies looking both at objective (performing laboratory measurements and developing laboratory protocols) and subjective (performing clinical studies by bringing in hearing aid wearers for evaluations) studies. The results of these studies were critical in the creation of a hearing aid compatibility standard that the Center was commissioned to validate. The Center is currently working with the wireless phone and hearing aid industries to evaluate proposed changes to a compatibility standard. For more information, contact Hank Grant, 405.325.2429, emc@ou.edu.

## Implantable Cardioverter Defibrillator (ICD) Research

The Center developed a test protocol to evaluate whether there were any interactions between wireless phones and implantable cardioverter defibrillators (ICDs). The EMC Center found that interaction occurred between a small number of wireless phones and small number of ICDs. The phones were tested in close proximity to the ICD to represent the phone being carried in a chest pocket or being held adjacent to the chest. The Wireless EMC Center concluded that more effective electronic filtering and shielding of the ICD would be a viable solution to mitigate the interaction. The study confirmed the recommended "safe" distance that a wireless phone should be kept to prevent any potential interaction with an ICD implanted in a body. Following the study several of the worst offending devices were modified. Re-testing showed drastic improvements were made due to the modifications. For more information, contact Hank Grant, 405.325.2429, emc@ou.edu.

## Pacemaker Research

The Center for the Study of Wireless Electromagnetic Compatibility at the University of Oklahoma conducted two large-scale in-vitro investigations of interaction between wireless phones and cardiac pacemakers to address major concerns that wireless phones could interact with implanted pacemakers. All testing was conducted under the most extreme conditions, with the phones at their highest power and the pacemaker sensitivity set to the maximum value permitted. The testing showed that a variety of solution approaches are possible to eliminate the potential for interaction between the phone and the pacemaker. These solutions include various types of Electromagnetic Interference (EMI) filtering at the input stages of the detection circuitry. The studies confirmed the recommended "safe" distance that a wireless phone should be kept to prevent any potential interaction with an ICD implanted in a body. These studies helped pacemaker companies to better understand how to design devices to reduce the risk of interference from wireless devices. Newer models of pacemakers are virtually immune from wireless phones. The Center continues to test pacemakers with new wireless technologies as is needed. For more information, contact Hank Grant, 405.325.2429, emc@ou.edu.

## Electromagnetic Interference Management in the Hospitals

The Center has developed several items to provide important information to hospital personnel to assist in managing electromagnetic compatibility (EMC) issues in hospitals. The reports contain articles and information on research activities in the area of EMC in health care. The reports give an introduction to electromagnetic interference (EMI) and electromagnetic compatibility, discussing general terminology, types of interference, and the ambient electromagnetic environment. There is information for administrators, medical professionals, biomedical engineers, and general hospital personnel. By properly managing the electromagnetic environment in a medical center, administrators can better assure compatibility between wireless and medical devices. This translates into safer environments, improved health care and gains in productivity, as advances in wireless technology are applied to medical applications. For more information, contact Hank Grant, 405.325.2429, emc@ou.edu.

# Center for Tree Genetic Research (CTGr)

Purdue University, Charles Michler, Director, 765.496.6016, michler@purdue.edu
Oregon State University, Steven Strauss, 541.737.6578, steve.strauss@orst.edu

Center website: http://www.nsf.gov/eng/iucrc/directory/tger.jsp

## Exponential Nutrient Loading


A new approach referred to as "exponential nutrient loading" has been developed by researchers at the Center for Tree Genetic Research (CTGr) to pre-condition black walnut grafts in the greenhouse for field planting. The technique increases the morphological and nutritional quality of grafted plants, as well as store nutrients in root plugs for later utilization to benefit early plantation establishment success. This protocol, allows for a higher growth rate of the grafts in their first year after planting in the field. Black walnut grafts that have been grown exponentially will be used in intensively cultivated plantings. In intensive cultivation, this is important because the response to fertigation and weed control is higher and rotation age will be decreased, which brings substantial financial benefits. In extensive cultivation, the rapid growth and competitiveness exhibited by exponentially nutrient loaded grafts will accelerate plantation growth to reach free to grow status sooner, which increases the chances of crops to escape damage from animal browsing and weed competition. Intensively cultivated clonal black walnut plantings under are currently being offered as a financial opportunity for long-term investors. For more information, contact Francis Salifu, HTIRC, Purdue University, 765.494.9780, fsalifu@purdue.edu.

## Method for Identifying Genes Controlling Growth of Trees

Manipulation of plant stature has long been a major goal in agronomy, horticulture, and silviculture. Trees of short stature can provide substantial benefits for urban forestry and wood products industries. CTGr researchers have established a method for identifying genes that affect the growth and development of trees. This research has resulted in the first identification of a gene underlying an unusual tree form and size. The difficult biology and genetics of trees, including their long generation time, has impeded such efforts in the past. Control of plant stature and form previously required the use of plant growth regulators or classical plant breeding. It is difficult to obtain through classical breeding the healthy dwarf plants of the variety needed for large-scale commercial deployment. The new method, using "activation tagging," allowed CTGr to circumvent several roadblocks. Center research on creating an activation-tagged poplar population is finding application, according to a Weyerhaeuser representative. This work is expected to provide numerous new genes for exploring and manipulating the development and physiology of trees. Furthermore, CTGr researchers identified a gene that controls tree size in a dominant manner, enabling the size of any tree to be reduced via over-expression of this gene. This result could provide a valuable new way to reduce tree size for uses in urban and orchard environments, and can be used as a tool to provide a high degree of biosafety to linked transgenes that derive from other species. This work appears to be the first case of successful forward genetics— where a gene has been isolated based on a mutant phenotype—in a tree. For more information, contact Steven Strauss at Oregon State University, 541.737.6578, Steve.Strauss@orst.edu.

## Precocious Flowering in Populus

Federal regulators have made it clear that a transgene confinement system is likely to be needed before genetically engineered trees can be deployed commercially. Center researchers are attempting to genetically engineer flowering control as a way to satisfy this requirement. In order to test the efficacy of the genetic constructs inserted in the poplar genome for their ability to affect floral development, researchers must wait for plants to acquire the competence to produce flowers. The long delay before the onset of flowering in poplars (they have a juvenile period of five to seven years) and their resistance to various conventional flower-induction treatments have been serious impediments to engineering sterility. CTGr obtained a genotype of *Populus alba* from a colleague at the University of Tuscia (Viterbo, Italy) that flowered nine months from when the seed was sown. Vegetative propagules from this line

remained true to type (i.e., they flowered in nine months). However, this genotype had to be regenerated *in vitro*, and grown under aseptic conditions, before APHIS would allow it to be imported into the U.S. The regeneration process caused this genotype to lose its ability to flower early. CTGr experimented with a variety of inductive treatments and discovered one that restored the early-flowering phenotype. Center researchers have also obtained a genotype of *Juglans regia* that is capable of producing flowerings on nine-month-old plantlets and have identified conditions required to induce flower formation on *Prunus serotina* grown *in vitro*. Thus, CTGr scientists now have a variety of effective model systems for testing flower-control constructs, without having to conduct lengthy, expensive field trials. For more information, contact Rick Meilan at Purdue University, 765.496.2287, rmeilan@purdue.edu.

# Center for Virtual Proving Ground Simulation (CVPGS)

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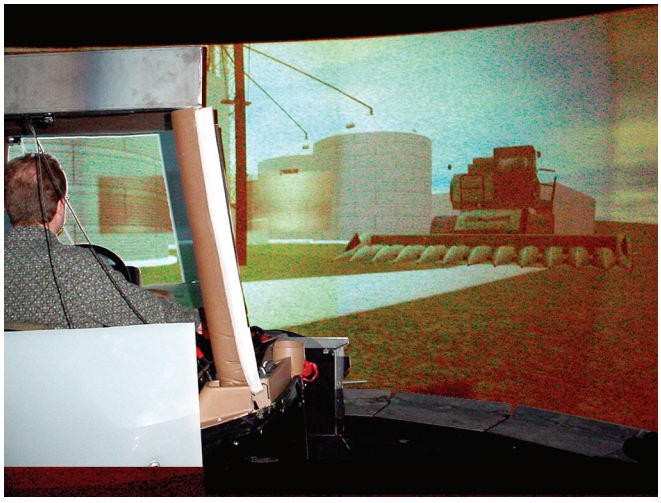
University of Texas Austin, Raul Longoria, 512.471.0530, r.longoria@mail.utexas.edu

Center website: http://www.nsf.gov/eng/iucrc/directory/vpg.jsp

## National Advanced Driver Simulation Facility



Researchers at the Center for Virtual Proving Ground Simulation (CVPGS) at the University of Iowa and the University of Texas at Austin have developed enabling technologies that use the world-class facility, National Advanced Driving Simulator (NADS), for operator/driver-in-the loop simulation for vehicle designs and for driving safety research. The NADS facility, completed in 2002, has been used by Deere & Co., Caterpillar Inc., Continental-Teves, Bosch, etc. for "virtual proving" experiments, and by the National Highway Traffic Safety Administration for highway safety studies. The National Advanced Driving Simulator is the only driving simulator in the world in which such activities can be carried out in a full 360º immersive virtual environment with a high fidelity motion cues in all six degree-of-freedom of vehicle motion. For more information on enabling technologies using NADS, contact L. D. Chen, 319.335.5674, ldchen@engineering.uiowa.edu.

# Connection One - Center for Communication Circuits & Systems Research Center (CCCS)

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University of Arizona, Jeff Rodriguez, 520.621.8732, Rodriguez@ece.arizona.edu
University of Hawaii, Magdy Iskander, 808.956.3434, iskander@spectra.eng.hawaii.edu
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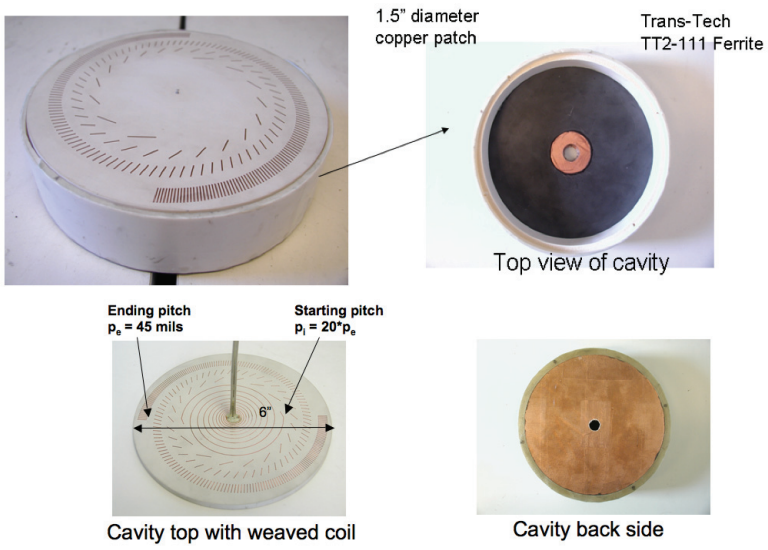
Ohio State University, John Volakis, 614.292.5846, volakis.1@osu.edu

Center website: http://www.connectionone.org/

## Meta-Ground Plane for Airborne Radar and Electronic Warfare Systems

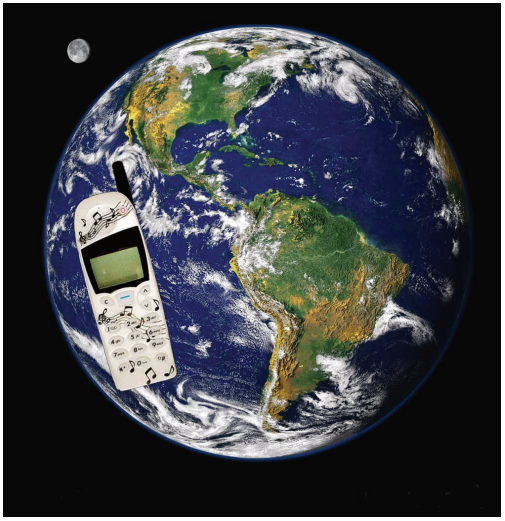



Researchers with the Center for Communication Circuits & Systems Research Center (CCCS - Connection One) have developed a meta-ground plane for Ultra low-profile UHF wide-band sensors used in airborne radar and electronic warfare systems that require wide-band, low frequency (UHF) antennas for roadside mind detection. These sensors offer a small, light weight and low loss solution to an ever growing problem. TV and cell-phone base station antennas can be glued on the fuselages, rooftops, or sidewalls of buildings. An application of this small UHF antenna is for sensors capable of locating targets concealed under trees and forests. The meta-ground plane will drastically reduce the profile of such bulky antenna systems on UAVs, thus, increasing their ability to accomplish their missions. No prior art existed to solve this problem without penalties in weight, gain, and efficiency. For more information contact John Volakis at The Ohio State University, 614.292.5846, volakis@ece.osu.edu.

## Cellular PA Bandwidth & Efficiency Improvement

As mobile wireless communication devices evolve from voice-centric to data-centric, the data rate expectations have increased dramatically. The resulting signal processing, done primarily in the digital domain, has benefited greatly from semiconductor advances following Moore's Law. However the RF power amplification function has experienced extreme pressure for increased linearity to support more complicated modulation, wider bandwidths due to higher data rates. All this while maintaining or improving power efficiency. Researchers the Center for Communication Circuits & Systems Research Center (CCCS - Connection One) have produced breakthroughs in terms of the balance among these three key parameters. The result has been significantly improved PA bandwidth and efficiency. Future cellular PA architectures will utilize some of these techniques for 3G (UMTS) and future (3GPP-LTE) systems.
For more information, contact Sayfe Kiaei, 480.727.7761, sayfe.kiaei@asu.edu, Bertan Bakkaloglu, 480.727.0293, Bertan.Bakkaloglu@asu.edu, or Jennifer Desai Kitchen, jennifer.desai@asu.edu. All are at Arizona State University.

## Universal Wireless Transceiver for World Phones



The ultimate goal in cellular communications is ubiquity: a world phone that is adaptable to all systems, such as GSM and WCDMA, as well as distinct frequency bands. In order to implement this phone, a highly efficient monolithic power system is needed in transceivers of continuously decreasing size. Two major components in transmitter architecture are the power amplifier and its modulator, because they dominate over 70% of the power consumption in handsets and consume a significant portion of the handset's volume. Therefore, altering the power amplifier topology to lower the demand on their bulky passive filters while simultaneously increasing the efficiency and linearity is essential when realizing high-efficiency monolithic transmitter architectures. A new method using a noise shaping technique to modulate the controller integrated circuits in switched-mode converters and power amplifiers reduces the demand on the output filters of the structures. High efficiency and linearity is accomplished with a novel power amplifier topology using a combination of either signal noise or pulse shaping and the Kahn technique. The new architecture for a switch-mode power amplifier has higher efficiency than other techniques. It eliminates the need for a filter in the supply modulator by switching the drain of the PA and pushing the noise of the switching modulator to higher frequencies. The new topology presents a multimode, monolithic, highly efficient, linear power amplifier for use in future wireless handsets as well as other RF communication devices requiring minimum power dissipation. For more information, contact Sayfe Kiaei, 480.727.7761, sayfe.kiaei@asu.edu.

# Cooling Technologies Research Center (CTRC)

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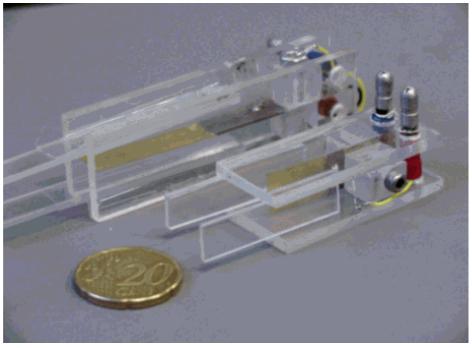
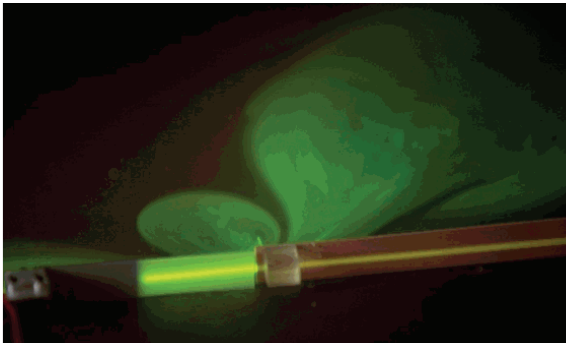
Center website: http://widget.ecn.purdue.edu/~CTRC/

## Miniature Piezofan Arrays for Cooling Electronics

Innovative, miniature piezoelectric fans have been developed in this CTRC project (by Suresh Garimella and Arvind Raman) into a viable technology for meeting a variety of cooling needs in portable and small-scale electronic devices. These fans are small, noiseless, extremely low-power devices, and can easily be fabricated to suit specific applications. They are well suited to providing supplemental cooling in hot spots and other stagnant areas in devices such as laptops and cell phones where rotary fan action is ineffective. In smaller devices, where rotary fans are not practical and electronics are pushed to the limits of their heat dissipation capacities, piezoelectric fans offer the only realistic cooling solution while meeting the noise and power constraints of portable devices. Analytical tools have been developed for modeling the flow field, heat transfer, and fan structure; flow-structure interaction is currently being investigated, to allow the design of optimal cooling systems. Interactions between multiple fans are being studied; coupling effects between the fans can cause the amplitude to increase by up to 40% over that of a single fan. The images show the fan and the heat transfer distributions brought about by two fans vibrating in front of a heated surface.



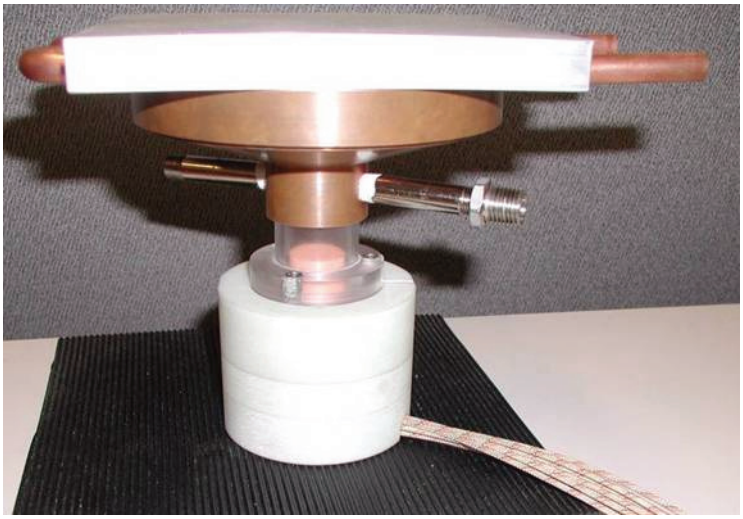


The Center's research has advanced the science to a stage that it is now possible to use them in small form factor applications. This technology is lower cost, lower noise and has better reliability compared to existing rotary fans. Center members have new products aligned to use this technology in ways that will give them a marketing edge. Small form factor boxes and cell phones will be using this breakthrough. For more information, contact Suresh Garimella, 765.494.5621, sureshg@ecn.purdue.edu.

## Validated Models for Particulate Thermal Interface Materials

Thermal Interface Materials (TIMs) continue to be a bottleneck for developing the next generation of micro-processors with smaller chip sizes and increased power. Development of better TIMs is imperative to ensure efficient heat removal from the microelectronic systems, which in turn improves the system reliability and performance. Accurate modeling of thermal interface materials requires either complex 3-D computational simulations or improved analytical models. Most existing models do not consider particle-particle interactions, Many fail when volume loading exceeds 30%. Numerical modeling of realistic three-dimensional microstructures (at high filler volume loadings) considering inter-particle interactions was performed using full-field meshless simulations and random particle network simulations. The developed models are validated with experiments on representative systems. The models can be efficiently used to accurately predict the effect of varying: 1) the filler particle conductivity; 2) the base polymer matrix conductivity, and; 3) size-distribution and arrangement of the filler particles, on the composite thermal conductivity of TIMs. These models are expected to provide critical help in the design of high performance TIMs. For more information, contact Suresh Garimella, 765.494.5621, sureshg@ecn.purdue.edu.

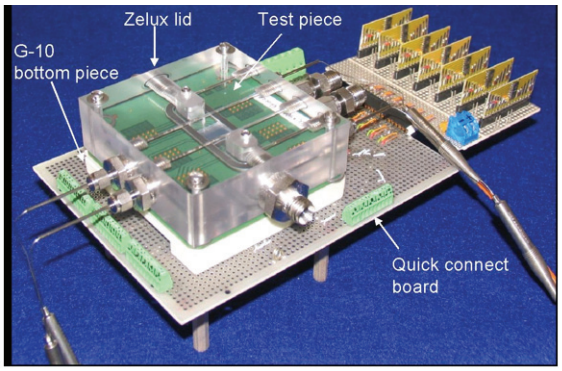
## Transport Properties of Wick Structures



Heat pipes are commonly used in electronics cooling applications due to their ability to move large amounts of heat over reasonable distances with only small drops in temperature. Porous wick structures imbedded inside heat pipes provide the interfacial tension necessary to passively drive the working fluid. For most electronics cooling applications, a balance between capillary pressure head and the corresponding permeability at this pore density determines whether a heat pipe will meet temperature rise and heat flux requirements. Also of increasing interest is the presence of boiling inside the wick, and the required removal of vapor bubbles. Discrepancies in operating limits reported in the literature due to inadequate test procedures are being resolved. Improved measurements and observation of transport processes will aid in the design of miniaturized heat pipes and novel improvements to existing wick structures that are becoming more relevant as heat flux levels increase. CTRC has developed two dedicated heat pipe wick-testing facilities. One measures mass transport in a variety of flat wick structures such as sintered and grooved materials, to support modeling efforts for heat pipe operating limits.

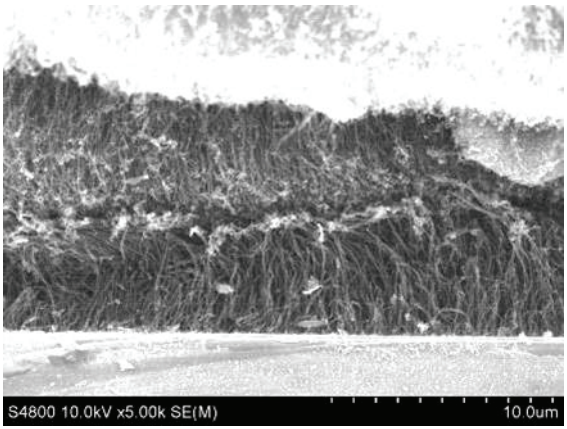
The second facility is an instrumented thermosyphon test bed to measure conductivity values for wick structures under varying degrees of wick saturation. Initial tests have shown interesting results at low power. Analytical models are being formulated to relate observed transport characteristics to measured properties. For more information, contact Suresh Garimella, 765.494.5621, sureshg@ecn.purdue.edu; or Jayathi Murthy, 765.494.5701, jmurthy@purdue.edu.

## Two-Phase Transport in Microchannels



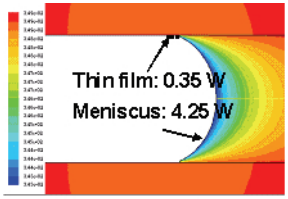

Researchers at the Cooling Technologies Research Center are exploring boiling and two-phase flow in microchannels. Transport through microchannels that range in width from 100 to 400 micrometers in copper and silicon substrates has been experimentally characterized. Experiments include high-speed flow visualization, and local and global temperature and pressure measurements. A predictive model has also been formulated to aid in the design and optimization of micro-channel heat sinks. Previous work has been done for single phase cooling using water as the cooling liquid and using relatively small channel sizes (<100 micrometers). Direct cooling of silicon chips at low cost will require larger more robust channel and fin widths and the use of dielectric fluids to prevent ionic contamination and parasitic electrical conduction paths. Major strides are being made in this CTRC project to better understand transport in microchannels, and hence in rendering microchannel heat sinks implementable in electronics cooling applications. Several novel experimental and modeling tools have been developed. Infrared Particle Image Velocimetry (IR-PIV) is being developed as a tool to make measurements inside silicon microstructures (with no optical access), capitalizing on the transparency of silicon to infrared light. System-level analysis of microchannel cooling systems, with an emphasis on design for energy efficiency and manufacturability, is now possible through a software tool developed in the Center. The Purdue CTRC research has characterized two phase liquid (dielectric fluids and water) cooling performance in copper and silicon channels and has developed models to enable the use of this technology in cost sensitive and very high power electronic applications. Anticipated power densities for direct cooling of silicon chips using dielectric fluids are anticipated in the 200-300 Watts/sq. cm range. Anticipated applications include high power density processor and high power switching transistor cooling for high end PC and workstation, server, military and high power automotive electronics. For more information, contact Suresh Garimella, 765.494.5621, sureshg@ecn.purdue.edu.

## Enhanced Thermal Contact Conductance Using Carbon Nanotube (CNT) Interfaces




Research at the Cooling Technologies Research Center (CTRC) investigates the thermal contact conductance enhancement with directly synthesized carbon nanotube arrays. A tri-layer catalyst configuration has been developed for well anchored and vertically oriented CNT arrays direct synthesized on various substrates (e.g., bare silicon, metals, dielectric materials) with plasma-enhanced chemical vapor deposition and different catalyst metals. Results demonstrate that the CNT arrays can exhibit resistances below 10 $mm^2$ K/W that are comparable to the resistance of an ultra-thin soldered joint. A test rig for thermal contact resistance measurement (adapted from ASTM D 5470) has been established in a high-vacuum environment. Temperature measurements are accomplished with an infrared imaging system. Important and relevant capabilities that have been developed include: a) anchoring of CNT arrays to substrates, b) control of CNT wall type, diameter, density, length, and alignment, c) synthesis at moderate and low temperatures using catalyst-containing dendrimers, and d) conductances of dry interfaces that are comparable to soldered interfaces and that exhibit good mechanical robustness. For more information, contact Tim Fisher, 765.494.5627, tsfisher@purdue.edu.

## Thin Film Evaporation



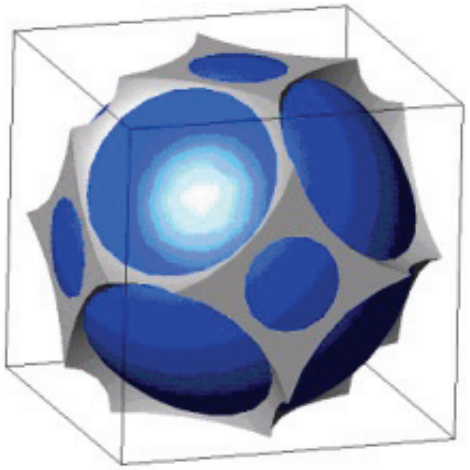

Temperature Contour

An evaporating meniscus forms the basis for all two-phase heat transfer devices; a comprehensive understanding of the underlying physical mechanisms is critical for miniaturization of heat pipes, cold-plates, and other thermal solutions. This CTRC project aims at a comprehensive investigation of the fluid mechanics, the heat and mass transport in an evaporating meniscus and development of validated models. Thin-film evaporation or evaporation taking place near the small solid-liquid-vapor junction is thought to be the dominant mode of heat transfer in a liquid-vapor phase change process. The experimental work characterizes the effect of thermocapillary convection and thin-film evaporation on the total heat transfer of the system. Micro-PIV experiments are performed to study the flow pattern near an evaporating meniscus. A 3-dimensional computational model of an evaporating meniscus has been developed which includes the thermocapillary and gravitational effects. Experimental results and models allow, for the first time, a comprehensive understanding of the transport in different regions of thin liquid films.

Improved designs of micro heat pipes and other two-phase heat transfer devices are expected to result from this work. For more information, contact Suresh Garimella, 765.494.5621, sureshg@ecn.purdue.edu or Jayathi Murthy, 765.494.5701, jmurthy@purdue.edu.

## Transport in Porous Structures and Metal Foams

A novel computational methodology for detailed modeling of open-cell foams and heat pipe wick structures has been developed at the Cooling Technologies Research Center (CTRC). This comprehensive model predicts the thermal and flow characteristics in foams and particle beds in excellent agreement with the published experimental measurements. Current work focuses on developing better understandings the thermal dispersion effects in open-cell foams and on extending the developed methodology for a wider range of foam structures. The methodology developed presents opportunities to explore foams for a wide range of heat transfer enhancement applications, including in advanced heat sinks and compact heat exchanger designs. For more information contact: Suresh Garimella, 765.494.5621, sureshg@ecn.purdue.edu or Jayathi Murthy, 765.494.5701, jmurthy@purdue.edu.



# Industry/University Center for Biosurfaces (IUCB)

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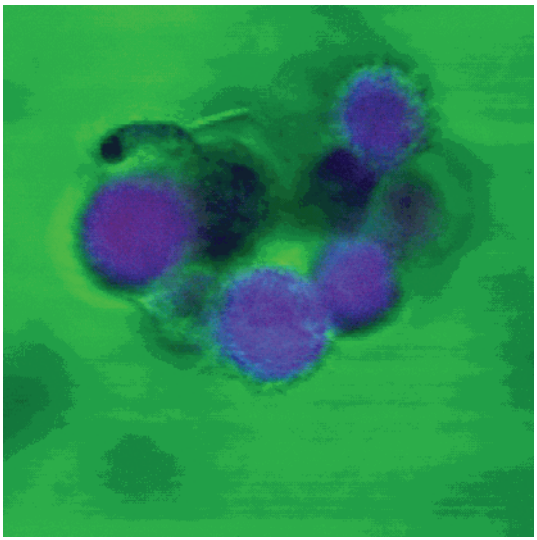
## Superior Relief From Dry Eye Problems

Many people suffer from "dry eye" problems, or a "gritty" sensation when blinking in a dusty environment. A significant improvement in the lubricity of in-the-eye comfort formulations has been achieved with the introduction of a borate-buffered solution of HP Guar containing active demulcents polyethylene glycol and propylene glycol. Researchers at the Industry/University Center for Biosurfaces (IUCB) developed a new tissue-on-tissue testing protocol that demonstrated the superior reduction of "blinking" friction associated with addition of this novel solution compared to the normal saline-wetted tissue surfaces. Previously available test methods that employed synthetic materials lubricated by various formulations, while moving back and forth over one another, did not reveal the clinically relevant superior lubricity for the borate-buffered HP Guar formulation. Synthetic materials articulated with preserved tissue surfaces did not exhibit the very low coefficients of friction actually obtainable in the tissue-on-tissue test system. The scientific lesson is that if results are to be predictive of actual clinical outcomes, then laboratory simulations of biological joints, and of other situations where bioadhesion is important, must adequately replicate the complex natural tissue surfaces involved. The new measurement technology revealed the superior reduction of friction obtained with tissue-on-tissue articulating ("blinking") lubricated with just a small droplet of a solution containing a particular gellable polymer. This same solution showed superior protection of living eye-surface cells from damage by desiccation and chemicals and gave excellent clinic comfort to patients using this new "artificial tears" formulation. Alcon Laboratories of Fort Worth, Texas has brought this new formulation to market, under the trade name SYSTANE. By the end of calendar year 2006, annual commercial sales of the SYSTANE "artificial tears" solution were approaching $80,000,000. For more information, contact Robert Baier at the University at Buffalo, 716.829.3560, baier@buffalo.edu.

## Allergy Friendly Room Program

Previously, there have only been specific individual products available to improve indoor environments. Pure Solutions LLC has developed a patent pending process that is now being tested at the University at Buffalo's Industry/University Center for Biosurfaces (IUCB). The process provides pre-packaged allergy friendly rooms to the hospitality market, as well as commercial and residential markets. Pure Solution's allergy friendly rooms process offers multiple interventions to substantially improve an indoor environment and has added a quarterly maintenance program that will maintain the hygienic conditions over a 24-month period. The process substantially reduces particles, bacteria, mold spores and fungi in indoor environments. An added benefit is energy savings of 25% or more through the cleaning and sanitization of heating and cooling coils in an air-handling unit. The company has developed a worldwide licensing program and has partnered with companies in the U.S., Canada, Dutch Caribbean, Barbados, United Arab Emirates, Singapore, Scandinavia, Malaysia and China to provide its allergy friendly room technology to markets around the world. For more information, contact Robert Baier at the University at Buffalo, 716.829.3560, baier@buffalo.edu.

## Inadvertent Implants? Visualizing Lung Cell pH



Inhaled particles and pollution can stress lungs, causing asthma and other diseases. Indigestible fibers, too long to be engulfed, cause lung disease. Most difficult to remove are long, thin asbestos-like fibers. Researchers at the Industry/University Center for Biosurfaces (IUCB) have shown how the body protects itself against safe insulation glass fibers, and how to select formulations for new, safe building materials. A surprise has been the discovery of a new use for the insulation fibers, as scaffolds for regenerating body tissues. "Chemistry in action" is recorded and displayed using laser photonics combined with confocal microscopy to take "visual slices" through living cells. Living cells take in a dye that gives off fluorescent rays of two different colors, red for acid production and blue for alkalinity. Lung cells digest away respirable fiberglass by an acid attack that shortens them, and an engulfment into the cells that allows them to be digested and carried away before disease processes can be triggered. For more information, contact Robert Baier at the University at Buffalo, 716.829.3560, baier@buffalo.edu.

# Center for Lasers and Plasmas for Advanced Manufacturing (LAM)

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Center website: http://www.nsf.gov/eng/iucrc/directory/lam.jsp

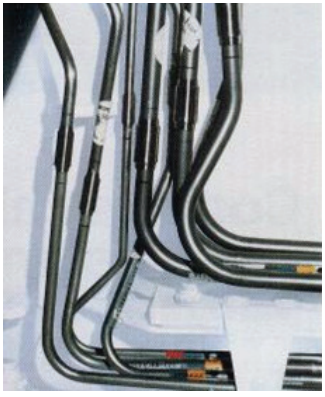
## Field Portable Welding of Titanium Tubes

Welding titanium tubes in military aircraft is an exceedingly critical and very difficult task. Ordinarily this process is accomplished by manufacturing in super clean operational environments using high-skilled personnel. The U.S. military not only would like to develop the capability to take this process aboard ships and into austere, remote areas, but it would also like to avoid using some of the chemicals traditionally used to clean titanium tubes prior to welding. Working with the Center for Lasers and Plasmas for Advanced Manufacturing, the U.S. military has demonstrated that surfaces of titanium tubes can be successfully cleaned using lasers instead of caustic and environmentally harmful chemicals, thus successfully removing the oxidation layer and any contaminants on the outside of the tube. This laser technology provides a very accurate method of controlling the depth of oxide removal layer. Now that the feasibility of this approach has been demonstrated work is underway to package the system in a portable, maintainable system for deployment in the field. For more information, contact Dr. Mool Gupta at the University of Virginia, 757.325.6850, mgupta@virginia.edu.

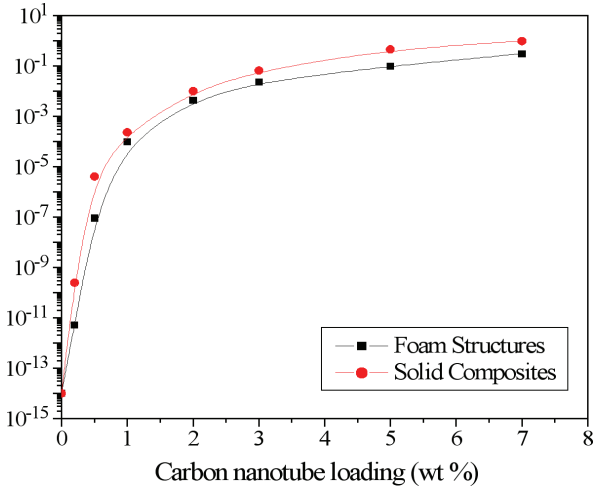
## Extending Damage Limits of Hydraulic Systems in Military Aircraft

Titanium tubing provides the critical arteries of hydraulic systems in military aircraft. The tubing is comprised of thin-walled tubes capable of withstanding high pressures in the range of 5,000 psi. Research at the Center for Lasers and Plasmas for Advanced Manufacturing (LAM) at the University of Virginia has helped in assessing the ability to expand the damage limits of the tubing; that is, how much sustained damage can be safely tolerated. Expanding the damage limit can reduce maintenance man hours and reduce operational support costs.

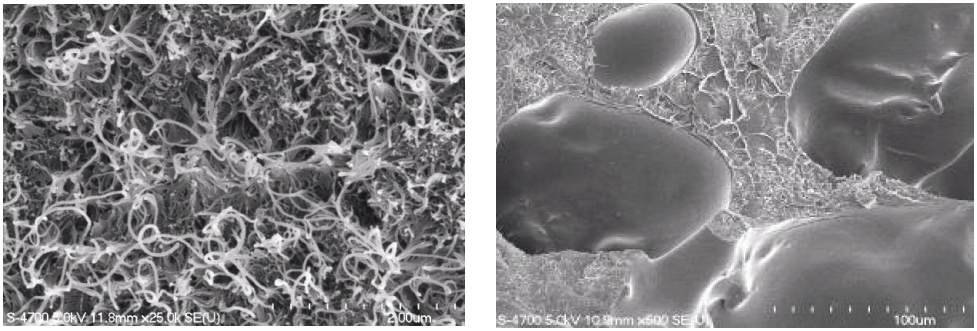
Research results have demonstrated that there were additional margins in some areas that translated into expanded damage limits. As a result of this work, aircraft are performing much better from a maintainability standpoint. This should result in considerable savings to the military over the next 15-20 years. For more information, contact Dr. Mool C. Gupta at the University of Virginia, 757.325.6850, mgupta@virginia.edu.



## Ultra light weight structures using carbon nanotubes

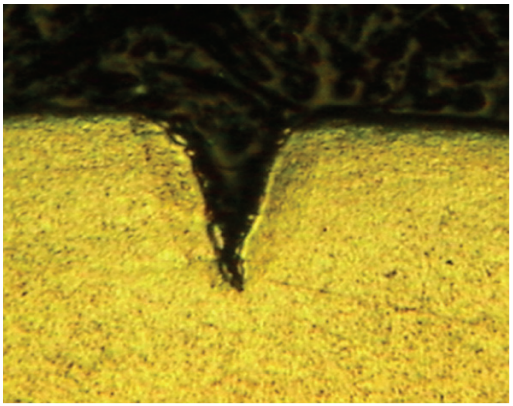



Ultra light weight materials capable of electronic conduction are needed by NASA and the military. Ultra light weight electrically conducting materials would provide structures for Electromagnetic Interference (EMI) Shielding applications for commercial and space applications, development of advanced sensors, lower cost canopy for aircrafts, lightening protection, electronic packaging, printed circuit boards etc. Research at the Center for Lasers and Plasmas for Advanced Manufacturing (LAM) at the University of Virginia has shown that ultra lightweight electrically conducting materials can be obtained by incorporation of lightweight carbon nanotubes in polymeric materials. Research has demonstrated that the weight of the nanotubes can be further reduced by conversion to foam structures. Density of 0.56 gm/cm$^3$ was obtained. These kinds of flexible conductive composites may be used for typical antenna systems, lightning-protected aircraft composite panels, avionics line replaceable unit (LRU) enclosures, connector gaskets, electrostatic and space charge dissipation materials, and different types of electronic pressure sensitive switches or sensors. The University of Virginia has filed a patent application on this technology due to its large commercial and defense application potentials. For more information, contact Dr. Mool C. Gupta at the University of Virginia, 757.325.6850, mgupta@virginia.edu.

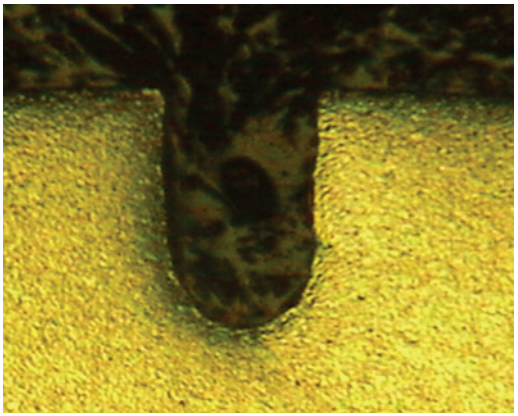



Above: SEM images of CNT nanocomposite.

## Lasers for Damage Detection and Study

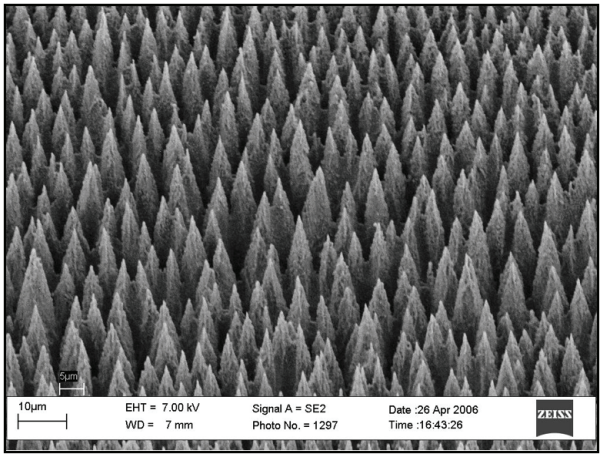


Research at the Center for Lasers and Plasmas for Advanced Manufacturing (LAM) involving the use of lasers for damage testing and analysis is being applied in several sponsor organizations. Lasers have been used to control the depth and width of micro features in titanium tubes in the context of military aircraft. The purpose is to conduct controlled experiments on damage detection. The sponsors are looking at using what is akin to off-the-shelf barcode technology scanners to develop less expensive, more portable, and most importantly field-deployable damage detection systems. In addition, Framatome (AREVA Group) has leveraged this work to use a similar approach in the nuclear industry.



Sponsors have used lasers to induce small cracks and features into reactor vessels in order to conduct experiments that should extend the service life of nuclear reactor equipment. For more information, contact Dr. Mool C. Gupta, 757.325.6850, mgupta@virginia.edu

## Laser Texturing of Surfaces and Commercial Applications




Laser processing provides a unique method of modifying materials surfaces by depositing large amounts of energy onto the surface of a material in an tightly controlled manner. Research at the Center for Lasers and Plasmas for Advanced Manufacturing (LAM) at the University of Virginia has helped to develop enhanced textured surfaces on metals and semiconductors. The laser treatment causes pillars to form on the treated surface. The method may be performed in a gaseous environment, so that laser assisted chemical etching will aid in the texturing of the surface. These pillars provide for greater light absorption for solar energy conversion, enhanced light detection, improved tissue growth for body implants, higher catalytic activity, and better heat sinks. This research is leading to the formation of a new high technology company for commercial products and defense applications. Because of its large commercial and defense application potentials, the University of Virginia has filed an industry supported patent application. For more information, contact Dr. Mool C. Gupta at the University of Virginia, 757.325.6850, mgupta@virginia.edu.

# Membrane Applied Science and Technology Center (MAST)

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University of Cincinnati, William Krantz, 513.556.2762, william.krantz@uc.edu

University of Cincinnati, Stephen Clarson, 513.556.5430, stephen.clarson@uc.edu

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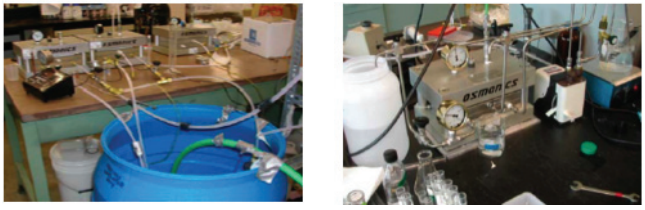
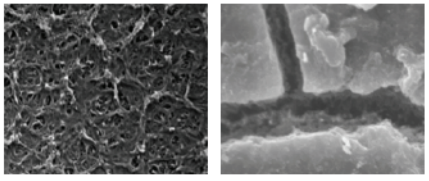
## Reducing Membrane Fouling in Water Treatment Processes

The problem of membrane fouling by natural organic matter is critically important in the production of potable water from surface waters such as rivers and streams. Many such waters have a brown or tan appearance due to the natural organic matter they contain (humic and tannic substances). Those materials tend to bind to the surface of water treatment membranes in reverse osmosis and nanofiltration processes. Researchers at the Membrane Applied Science and Technology Center have evaluated and characterized several kinds of membranes to determine their fouling characteristics. In addition to published research, the Dow Chemical Company has evaluated the technology and is in the process of launching new products that benefited from the knowledge gained from this Center project. For more information, contact Dr. Alan R. Greenberg at the University of Colorado at 303.492.6613, alan.greenberg@colorado.edu.



Above: Bench-scale experimental system for measuring membrane flux decline (left) and membrane rejection (right).



Above: SEM micrographs showing representative surfaces of clean (left) and fouled (right) membrane.

# Photopolymerizations Center (PC)

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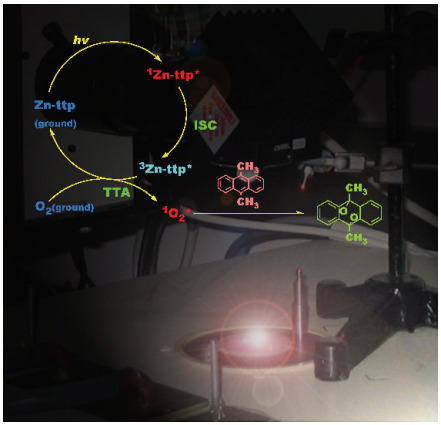
## Improved UV Curable Systems

Progress on Thiol-ene-acrylate UV Curable Systems has been made via fundamental research conducted at the Photopolymerizations Center on the kinetics and relative polymerization ratios of the three chemical components in thiol-ene-acrylate UV curable systems. The work has led to a greater understanding of competing reactions. Kinetics studies conducted at the center using model systems have been relevant to proprietary technology under development in the R&D facility of National Starch and Chemical Company. These insights have enabled the company to enhance the performance of their opto-electronic adhesive products.
For more information, contact Dr. Christopher Bowman at the University of Colorado, 303.492.3247, Christopher.Bowman@colorado.edu.

## Improvement in Photo-Cured Acrylate Coatings




At the University of Iowa's Photopolymerizations Center, a photochemical method to eliminate oxygen inhibition in free-radical photopolymerizations has been developed. This work provides a unique and practical solution to a major problem in photo-cured acrylate coatings: that curing is inhibited by air at the coating surface; the Henkel Corporation expects this technology to be of significant commercial value. The company attributes commercial successes to research at this center. For more information, contact Alec Scranton, 319.335.1414, alec-scranton@uiowa.edu.

## Ultra-Rapid Photopolymerization Method

Novel (meth)acrylate monomers for ultra-rapid photopolymerization have been developed by researchers at the Photopolymerizations Center (PC). This program has identified and characterized several new monomers that provide highly photosensitive acrylate compositions with excellent physical and mechanical properties. These materials have potential for the design of improved structural adhesives in engineering applications. One application noted by UCB Chemicals is that of inks used in printing on food packages. Fast-reacting monomers can reduce both cost and food contamination. The fast-reacting monomers result in inks that dry faster and in packaging that is not as slippery, thereby improving the ability to stack packages. These two effects help reduce packaging costs.

An added benefit to the fast-drying ink is that it does not seep through the packaging, and therefore does not contaminate food contained in the package with chemicals. For more information, contact Christopher Bowman, 303.492.3247, christopher.bowman@colorado.edu.

## Dental Restorative Materials

Research at the Photopolymerizations Center (PC) in the field of dental restorative materials has recently received a great deal of attention and numerous accolades. The research group has applied their expertise to address the ongoing issues associated with the high degree of polymerization shrinkage with highly cross-linked dental composites. The substantial shrinkage of these materials generates interfacial stresses between the restorative and the tooth structure. These stresses may lead to micro cracking of the restorative and tooth structure, microleakage at the tooth/restorative interface, and occasionally catastrophic failure of the restorative. Seminal efforts from the group using a unique photoiniferter technique has shown that there is a direct correlation between the physical properties of the "cured" restorative and the degree of methacrylate conversion of the restorative--independent of the methodology used to achieve a given degree of conversion. Development of an instrument to simultaneously measure degree of conversion and polymerization shrinkage stresses of polymerizable materials is underway. This key effort will likely direct future shrinkage reduction efforts away from light exposure protocols and towards new chemical strategies. For more information, contact Christopher Bowman, 303.492.3247, christopher.bowman@colorado.edu

## Moisture Effects on Cationic Cure of Adhesives

The chemistry of cationic cure is critically important for pressure sensitive and laminating adhesives and also in some UV curable systems. Research at the Photopolymerizations Center has established that the mechanical and physical properties of the cured materials are even more directly related to moisture content during cure than was heretofore thought to be the case. Microscopy work on this project has helped the National Starch and Chemical Company to better understand the chemical effects of moisture and to determine steps necessary for enhancement of the performance of pressure sensitive laminating and opto-electronic adhesives. For more information, contact Julie Jessop, University of Iowa, 319.335.0618, Julie-Jessop@uiowa.edu, Jeffrey Stansbury, the University of Colorado Health Sciences Center, 303.724.1044, Jeffry.Stansbury@uchsc.edu, or Alec Scranton, the University of Iowa, 319.335.1414, Alec-Scranton@uiowa.edu.

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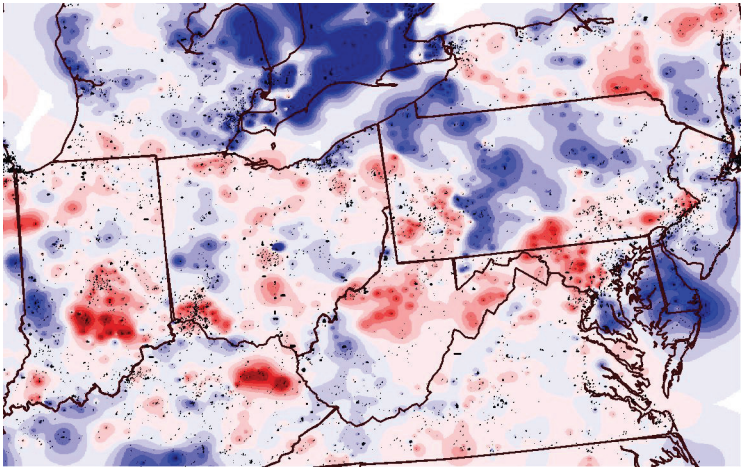
Center website: http://www.pserc.wisc.edu/

## Advanced Power System Visualization Tools



PSERC research has integrated new visualization techniques with power system modeling methods to create visual insights for the user into the condition of power systems. With visualization tools, industry can "see" what is happening without disruption of the actual energy production. Using two- and three-dimensional plotting capabilities coupled with power system animation, the technology gives the user a picture of the power system that synthesizes thousands of pieces of

information. Coupling economic data with engineering data allows not only the display of important data for economic and reliable power system operation, but also visualization of the data in the form of plots, contours and animations. The technology shortens the time between observing power system problems and identifying appropriate corrective actions, thereby making power systems more reliable. Furthermore, it integrates visualization of economic and engineering data, thereby informing decision-making for economic and reliable power system operation. The technology enables power systems engineers and operators to better communicate with non-technical audiences that often include business and regulatory policy-makers. It serves as a training tool for technical and non-technical audiences. The technology has been successfully commercialized, and is being used in software that is sold worldwide. The technology has also been installed in several utility control centers. The graphic figure contours the normalized voltage levels at about 8000 different 100 kV to 300 kV power system "buses" (nodes where two or more electric devices join together) in the eastern portion of North America for a hot summer afternoon. Such figures could be used to allow power system operators to quickly monitor the voltage levels over a wide geographic area. In the figure areas shaded red indicate locations of potential voltage problems. For more information, contact Tom Overbye, overbye@ece.uiuc.edu.

## Methods to Test Power Market Designs and Policies

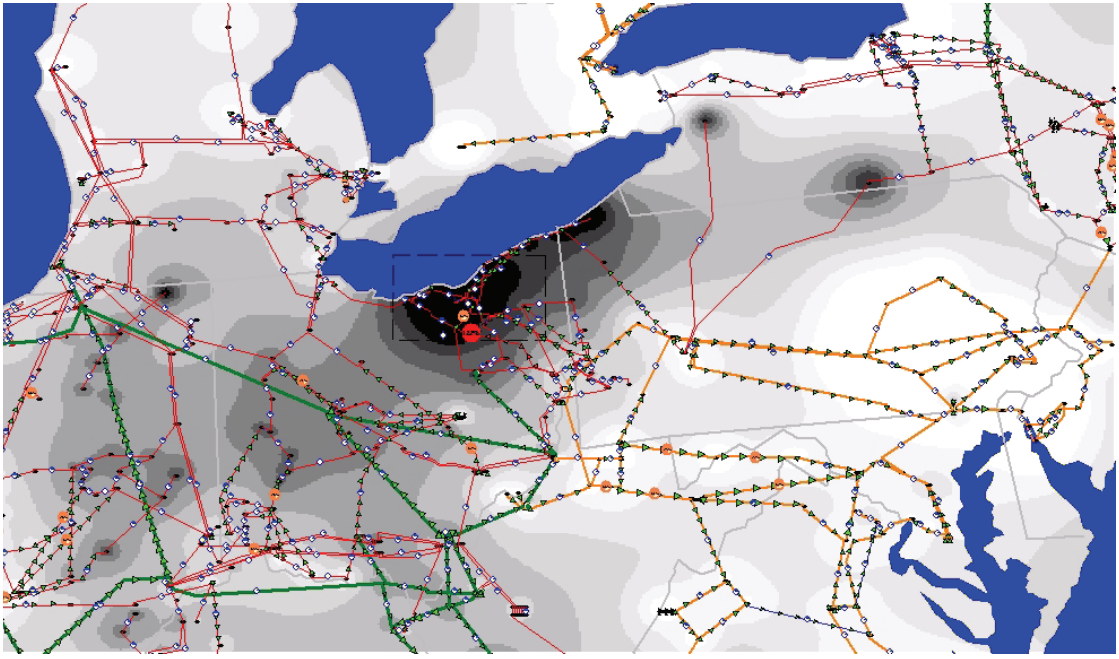
PSERC has successfully been using the institutional concept of testing electric power market designs and policies to verify and validate that anticipated market outcomes would be consistent with policy objectives. In the past, industry and regulatory policy-makers largely believed that it was not possible to test, verify, and validate specific market designs. As a result, market designs with unappreciated or unknown weaknesses were introduced as an "experiment of the whole." This posed high risks to consumers and sellers of electric services. PSERC's ability to demonstrate the power of experimental economics, integrating economic and engineering knowledge, is being applied to complex electricity market design are contributing to new methods for market design policy developments that are beginning to influence decision-making in the industry. PSERC has used this approach to help policymakers test market policies, to illuminate reasons for markets failures such as in California, and to develop and test innovative approaches for solving difficult market design issues unique to power systems. In so doing, PSERC has had an influenced on regulatory agency decision-making. For more information, contact Robert J. Thomas, 607.255.5083, rjt1@cornell.edu.

## Improvements in Power System Reliability

Power system reliability is increasingly a concern to the power industry and society at-large. PSERC researchers have played leading roles in studying reliability problems and suggesting solutions. PSERC researchers contributed to an important study that was published in May, 2002 for the U.S. Department of Energy, entitled the "National Transmission Grid Study." PSERC researchers contributed to this DOE report prepared in response to the President's National Energy Policy directive to the Secretary of Energy to study the Nation's transmission system, identify transmission bottlenecks, and identify measures to eliminate those bottlenecks. They also played an important role in an earlier report from DOE entitled "Report of the Department of Energy's Power Outage Study Team." This report provided findings and recommendations to enhance reliability after a team of experts (including PSERC researchers) who studied power outages and other system disturbances that occurred in the summer of 1999. Finally, PSERC helped the U.S. DOE establish the Consortium for Electric Reliability Technology Solutions (CERTS), formed in 1998 to research, develop, and commercialize new methods, tools, and technologies to protect and enhance the reliability of the U.S. electric power system. CERTS is conducting research for the U.S. Department of Energy's Transmission Reliability Program and for the California Energy Commission's Public Interest Energy Research Program. PSERC faculty are working with researchers at Lawrence Berkeley National Laboratory, Oak Ridge National Laboratory, Pacific Northwest National Laboratory, Sandia National Laboratories and several energy businesses. For more information, contact Robert J. Thomas, 607.255.5083, rjt1@cornell.edu.

## Responding to the Blackout of 2003

PSERC has made significant contributions to understanding and developing solutions to electric power system reliability issues. PSERC researchers, working through the Consortium for Electric Reliability Technology Solutions, are developing solutions to transmission reliability concerns and are assisting the U.S. DOE in the blackout investigation. The center is providing resources to help people understand blackouts. PSERC created the "Blackout of 2003" web page, which has become a recognized portal to information about the blackout, ongoing investigations, and power systems in general. For more information, contact Robert J. Thomas, 607.255.5083, rjt1@cornell.edu.



Above: Using power system visualization tools, PSERC helped promote a better understanding of the blackout. This picture illustrates the seriousness of the system condition before the final cascading outages began. This visualization is based on 1998 data.

# Queen's University Environmental Science and Technology Research Centre (QUESTOR)

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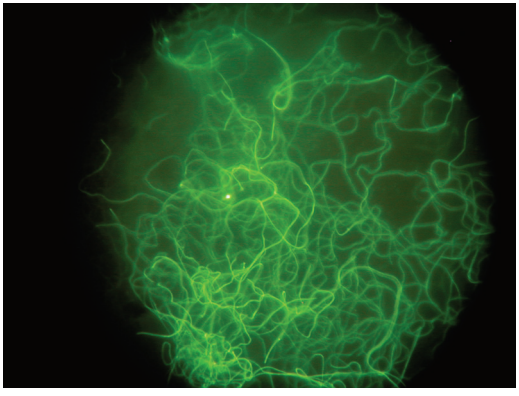
Center website: http://questor.qub.ac.uk/webpages/qcindex.html

## Prevention of bulking at Sludge Wastewater Treatment Plants

Sludge bulking is a serious problem for wastewater treatment operators. Sludge bulking, when it occurs, is a very expensive problem to eradicate. One of the prime causes is the filamentous bacteria, *Microthrix Parvicella*, which exists at low levels in many treatment plants without causing problems. When concentrations rise above a threshold level, however, bulking and foaming is the all too common result. It occurs in the settling tanks of activated sludge plants and results in a reversal of the settling process whereby solids float to the top of the tank rather than settling to the bottom. Researchers at The Queen's University Environmental Science and Technology Research Centre (QUESTOR) have developed a diagnostic test for the detection of *Microthrix Parvicella*. The test prevents the occurrence of foaming or sludge bulking at activated industrial and municipal sludge wastewater treatment plants. The technology enables operators of treatment plants to monitor the concentration of *Microthrix* and take remedial action before the serious problem of sludge bulking or foaming occurs.



Previously there had been no effective means for operators to monitor the concentration of *Microthrix Parvicella*. As a result sludge bulking occurred randomly and without warning. This new technology allows operators of treatment plants to detect and prevent the occurrence of sludge bulking and to take more economical remedial action before the problem occurs. This technology has resulted in a new commercial product known as SLUDGEGUARD, a powerful ELISA test kit that quantifies and allows small changes in the concentration of *Microthrix Parvicella* to be detected. A one-step test kit for rapid detection is also under development.

For more information, contact William McGarel, 44 (0) 28 9097 5577/8, w.mcgarel@qub.ac.uk.

# Software Engineering Research Center (SERC)

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Center website: http://www.serc.net/web/index.asp

## Provably Secure Software Systems Development through Security Typed Languages

This work has extended security-typed languages from the realm of theoretical programming language tools to an apparatus for building secure software systems. Researchers at the Software Engineering Research Center have developed software engineering practices and tools that allow mapping of high-level security goals into the applications that must realize them in a secure-typed language. These tools have been used to develop provably secure large-scale security-labeled email systems, as well as other secure systems. Past software security techniques have attempted to isolate applications (as seen in sandboxing techniques), introspect possible vulnerabilities (as in static and dynamic analysis tools), or apply formal analysis to achieve high assurance applications. However, such approaches are often ad hoc, incomplete or difficult to use.

This work has addressed these past limitations by identifying, formalizing, and automating the complex processes of identifying security relevant data and its potential for leakage or corruption. In so doing, usable infrastructures are available for defining and developing provably secure software. This work advances the state of the art in software systems development by providing guaranteed compliance with security goals. Further efforts have identified new algorithms for important problems such as security level inference and credentials discovery. Such discoveries are being used not only in security typed languages, but are also helping the operating systems community to define policies and services tailored to the security requirements of applications. This will significantly enhance the capabilities of commercial software developers to articulate and realize security goals. The researchers are working with Motorola to evaluate how the tools can be used to make applications of embedded devices such as cellular phones more secure. For more information, contact Dr. Patrick McDaniel at The Pennsylvania State University, 814.863.3599, mcdaniel@cse.psu.edu.

# Silicon Wafer Engineering and Defect Science Center (SiWEDS)

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Center website: http://www.mse.ncsu.edu/siweds/

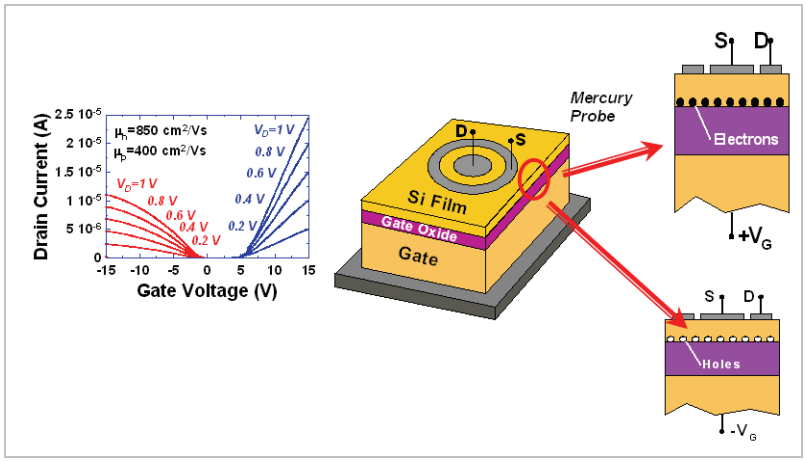
## Convergent Electron Beam Diffraction (CBED)

Control of a number of transistor properties, such as enhanced mobility through either substrates with stressed surface layers or process induced stressed channels, present long standing and difficult challenges. With device size decreasing, local strain variation on a nanoscale level is critical for device performance. Convergent electron beam diffraction (CBED) can provide strain information with a nanoscale spatial resolution and precision. Characterization of local strain information with CBED also can be a challenge due to HOLZ lines splitting and broadening. Researchers at the Center for Silicon Wafer Engineering and Defect Science (SiWEDS) representing three different universities have developed improved quantitative analysis of this HOLZ line splitting and residual strain measurements. Popular strain measurement techniques like Raman spectroscopy and X-ray diffractometry cannot satisfy current requirements for spatial resolution and precision as well as CBED technique does. HOLZ line splitting profile with CBED is a fast evaluation tool for initial strain state on different strain enhanced heterostructures.The experimental data and simulation results match well. This advance represents an important new method for reliable determination of strain in device structures with combinations of residual strain and elastic deformation. For example, improved direct measurement of stress in nanosized, buried areas such as the stressed channel have been demonstrated. For more information, contact G. Rozgonyi, North Carolina State University, 919.515.2934, rozgonyi@ncsu.edu, Eicke Weber, the University of California, Berkeley, 510.642.0205, weber@socrates.berkeley.edu or Moon Kim at the University of Texas-Dallas, 972.883.6635, moonkim@utdallas.edu.

## Nondestructive Characterization of Silicon-on-Insulator Wafers

Silicon-on-insulator (SOI) is a preferred technology for leading edge, small devices in future integrated circuits. However, one of the challenges is the measurement of the thin silicon layers that make up the active portions of the circuit. Such measurements should be simple and be nondestructive so that wafers can be measured upon receipt. Arizona State University, a participant in SiWEDS Center research, has developed in conjunction with Four Dimensions, Inc., the manufacturer of the mercury probe, a technique using this probe to serve as source and drain of the MOSFET. Measurement of the thin silicon layers are now simple and non-destructive so wafers can be measured upon receipt. The device allows the current to be measured from which one extracts the carrier mobility, a very important device parameter, the threshold voltage, defect information, and the doping concentration. The technique is used by some of the SOI wafer producers, e.g., Gritek, MEMC, Komatsu, and LG Siltron. For more information, contact Dieter K. Schroder, Arizona State University, 480.965.6621, schroder@asu.edu.

Right: Schematic of *Hg* probe pseudo MOSFET and typical $I_D$-$V_G$ curves. Both *n*-channel and *p*-channel parameters can be characterized.




## Comprehensive model of properties of copper in silicon

The copper interconnect technology has become the mainstream technology for the manufacturing of high performance chips. This requires development of procedures and tools for contamination control of copper in silicon wafers and for removal of Cu from reclaim wafers. University of California at Berkeley, a participant of the SiWEDS Center, studies diffusion, electrical properties, and gettering of copper in bulk silicon. In the framework of this research, several breakthroughs were achieved in the area of understanding the fundamental physical properties of copper in silicon. It was demonstrated that the diffusion barrier for copper is silicon is not 0.43 eV, as it was thought for nearly forty years, but only 0.18 eV. Correspondingly, the diffusivity of Cu at room temperature is about three orders of magnitude higher than it was thought. This allows copper to diffuse substantial distances in silicon at room temperature and explains the kinetics of the phenomena of Cu contamination during chemomechanical polishing and of its outdiffusion to the

surface during storage at room temperature. This data was provided to SiWEDS member companies, which used it for improving their technological processes. The ongoing collaborative effort between Intel and several wafer suppliers to develop a standard metrology of Cu contamination control relies to a large extent on this data. For additional information, contact Andrei Istratov, 510.486.6634, istratov@socrates.berkeley.edu or Eicke Weber, 510.642.0205, weber@socrates.berkeley.edu.

## Process of Interfaceless Oxynitride Thin Layer

Dr. A. Karoui and Prof. Rozgonyi's team at the NC State University have developed methods for growing shallow oxynitride layers with unique properties on silicon wafers. The starting material is nitrogen doped commercial Czochralski Si, with an initial nitrogen level of about 1E15 $cm^{-3}$, lower levels can be used for growing shallower layers. The strong N segregation enriches the subsurface zone, which results in oxygen gettering. Unlike deposited oxynitride layers, the new layers are grown from the bulk with a smooth N and O concentration gradients. At a few microns away (or less) from the surface, N and O concentrations are increasing and peaking at the surface. The layers grown with this method are crystalline, continuous and interfaceless thus do not have interface states, known to be harmful for charge carriers. In addition, no charge center exists in these crystalline oxynitride unlike the amorphous ones grown by chemical vapor deposition. Knowing that interface states and charged centers found in add on oxynitride layers can be detrimental for devices, the new oxynitride layer are of interest for IC technology. Depending on the layer thickness and the [N] to [O] ratio, three novel processes are used: 1) Fine sliced N doped Si wafers are grinded to generate submicrometer roughness while exerting mechanical stress on the surface, then finely polished by chemical and mechanical polishing process (CMP). The thickness of the layer is in the nanoscale range, up to 0.5 microns. The nitrogen concentration reaches eight times and oxygen twice their respective solubility limits. 2) Anneal N doped wafers at 650°C for 8 hours, then at 1050°C for 10 hours. This process results in N and O concentrations up to 1E18 $cm^{-3}$ and 2E20 $cm^{-3}$, respectively. The maximum breadth of this layer is 1.5 microns. 3) Anneal at 650°C for 16 hours, NCZ silicon wafer. For N doping level of 5E14 $cm^{-3}$, this process gives the maximum layer breadth, about 2 microns. For more information, contact Abdennaceur Karoui, NCSU, 919.515.7217, nas_karoui@ncsu.edu.

# Safety, Security and Rescue Research Center (SSR-RC)

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Center website: http://www.nsf.gov/eng/iip/iucrc/directory/ssr_rc.jsp

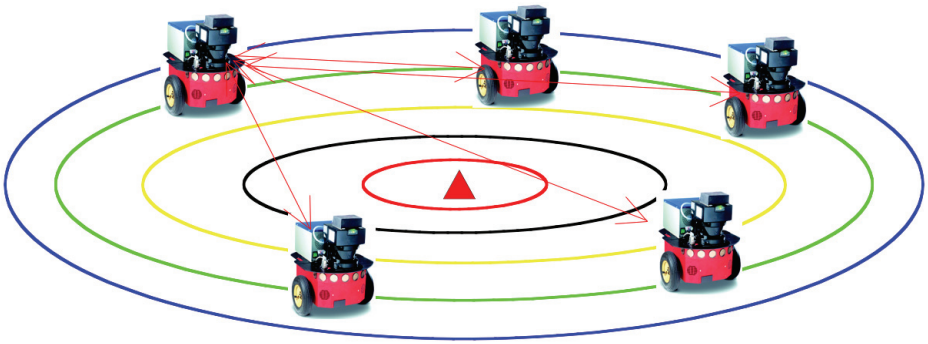
## Scout Robot Platform: Urban Search and Rescue

The development of large-scale robot teams has been prohibitive for a number of reasons. The complexity of such systems has been hard to simulate, especially in the case of a many to one relationship between a marsupial robot and the robots it can deploy. Additionally, the construction of physical systems can be expensive to implement and maintain. However, there is a number of scenarios in which large scale distributed teams are advantageous such as urban search and rescue, biological or chemical release monitoring, or distributed surveillance and reconnaissance. Distributed robot teams are often able to leverage the power, computational, and locomotive capabilities of a larger system to transport, coordinate, and control miniature robots which may carry more specialized capabilities into areas that are spatially restrictive. Research at the Safety, Security, Rescue Research Center has resulted in the development of the Scout Robot Platform currently utilized by the U.S. Army and several police departments for search and rescue missions. It has a cylindrical shape that allows it to be deployed by launching it from an appropriate barreled device. Once deployed, it moves using a unique combination of locomotion types. Each Scout is provided with a sensor suite, which may vary with the Scout's mission. Scouts may contain some combination of a CMOS camera, a passive infrared sensor, a microphone, and other sensors. For more information, contact Sunil Saigal, 813.974.3780, saigal@eng.usf.edu.

## Plume Tracking with a Reconfigurable Computing Platform

Robotic teams are envisioned to assist or even replace humans in search and rescue operations such as when dealing with a chemical leak. The objective researchers at the Safety, Security and Rescue Research Center (SSR-RC) is to develop algorithms and reconfigurable hardware that will allow distributed groups of

robots to search an area and determine the source, type and quantity of dangerous gases released in the atmosphere due to an accident or malicious act. In order for robots to achieve this goal, they must be able to determine their position, create detailed representations of the area they search, and coordinate in their distributed detection and estimation task. Additionally, robots must deal with mobility issues when navigating in unstructured environments or need to climb stairs. To this end, the center has designed adaptive sensing algorithms that allow robots to determine the optimal locations where they need to move in order to receive the most informative measurements for the detected chemical. Additionally, stair-climbing estimation and control algorithms have been implemented that allow safe and precise navigation inside buildings. These dynamic re-configurable processes allow re-tasking of hardware and software resources, thus making adaptations to varying operating conditions possible. For more information, contact Stergios Roumeliotis, 612.626.7507, stergios@cs.umn.edu or Richard Voyles, 612.624.8306, voyles@cs.umn.edu.
Below: Robot team searching for the source of a gas leak.



## Terrain Analysis for Human-Computer Interaction (TAH-RI)

TAH-RI is a software package that reasons about terrain and spatial relationships. It is intended for use onboard autonomous robots and in other software systems used by humans (e.g., Intelligent Tutoring Systems, decision aiding systems, navigation systems). Roles performed by SSR-RC researchers at the University of South Florida on the Distributed Field Robot Architecture (DFRA) component of TAH-RI AI software include: Driver, Navigator, Cartographer, and Scout. Additional roles include: Terrain Analyst, Staff, and Mission Leader. The software improves human-robot interaction by enabling robots to better understand and use terrain representations, terrain analyses and reasoning, in a software system organized by the roles the software is to play in performing required functions on teams. The first application of TAH-RI is a six-month feasibility assessment and proof of concept demonstration of a novel robotic teammate system design for DARPA. Relative to comparable alternatives, systems for helping humans to understand terrain and its impact on their intended activities and plans can be built very economically by adapting TAH-RI, with most applications requiring only changes to XML-based cognitive agent representation of expertise, and addition or modification of a very few C++ software components which use a plug-in architecture. Most of the existing components can be reused in a variety of applications without changes. Visualization of terrain and terrain analyses results are readily available in TAH-RI STAFF configuration (the only configuration supporting GUIs for direct human use) which can also be reused in new domain-specific applications in a host of domains where terrain matters. For more information, contact Robin Murphy at the University of South Florida, 813.974.4756, murphy@cse.usf.edu.

# Wireless Internet Center for Advanced Technologies (WICAT)

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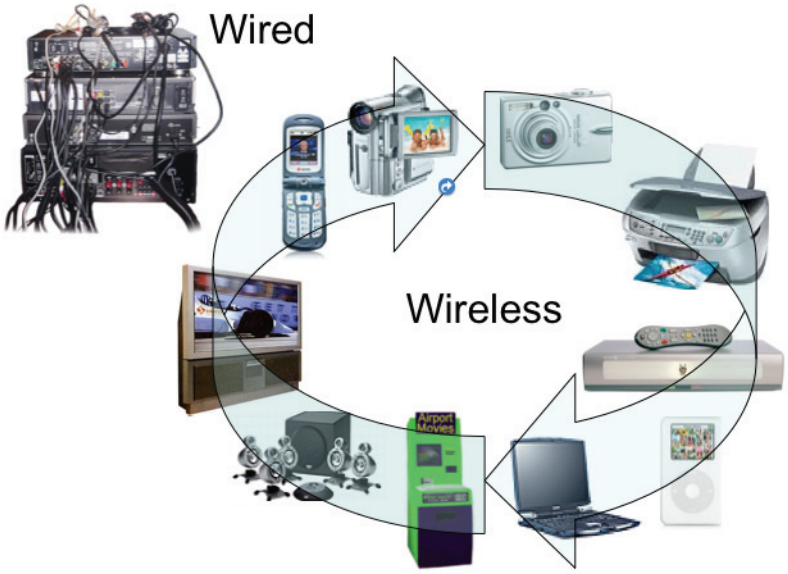
Center website: http://wicat.poly.edu/

## High Speed Wireless Personal Area Networks

Wireless personal area network (WPAN) technologies will be embedded in future consumer products to enable high-speed distribution of video and downloading of audio/video files among these products within the home and office. Industry and consumers will be able to move huge amount of pictures, audio, video wirelessly from one device to another device quickly; example: one could move one hour of high quality home video from the camcorder to the media center wirelessly in about 1 minute. Researchers at WICAT have worked to create a computer-based simulator that has been used to debug and validate these WPAN technologies. Work is underway to further develop these technologies and to determine the best way to incorporate these technologies into future consumer and electronic products. For more information, contact Dr. Shiv Panwar at Brooklyn's Polytechnic University, 718.260.3740, panwar@catt.poly.edu.



# Water Quality Center (WQC)

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Arizona State University, Mortesa Abbaszadegan, 480.965.3868,
morteza.abbaszadegan@asu.edu

Center website: http://wqc.arizona.edu/

## Land Application of Biosolids

The University of Arizona biosolids long term land application study has been ongoing for 20 years. Biosolids application is a low cost method of utilizing treated sludge materials. The study has provided extensive data on appropriate applications of Class B biosolids, and the long term effects on soils, aquifers, and agricultural yields. This extensive long term study evaluates biosolids land applications and its effect on cotton crops. Data are being used nationally and globally as new concepts and rules are evaluated. Recent research has evaluated potential hazards including: aerosols, endotoxin, and endocrine disruptors. Better understanding of the aerosol challenges of biosolids applications has resulted in a significant education of communities nationally, with respect to the low potential hazards of aerosolized viruses and bacteria. This information is being used by EPA, biosolids state coordinators, and academic institutions, to teach communities about the benefits of biosolids applications, while minimizing exposure to potential hazards. Benefits include the addition of crop nutrients to soil as well as improved soil structure and physical properties. Research on biosolids applications is documenting the sustainability of long term land application and providing data that is critically important for proper land management and public education. For more information, contact Ian Pepper at the University of Arizona, 520.626.3328, ipepper@ag.arizona.edu.

Left: Avra Valley. A Water Quality Center-supported graduate student samples a biosolid solar drying bed for *Salmonella*.

## Effects of Water Recharge Treatment in Tucson

In response to dwindling ground water supplies, the Central Arizona Project was undertaken to bring water by canal from the Colorado River to Tucson, Ariz. When this 20-year, $3-billion effort was completed, the water quality was determined to be inadequate and therefore the water unusable. The remedy was to "recharge" the water—sending it from the canal into filtration basins in the ground prior to use. Researchers at the Water Quality Center played a role in this solution by evaluating the effects of recharge treatment on removal of natural organic matter and the subsequent potential for formation of disinfectant by-products, which are undesirable for human health. Center research demonstrated that the quality of the recharge water in these respects was adequate for consumption. For more information, contact Ian Pepper, 520.626.3328, ipepper@ag.arizona.edu.

## HPC Bacteria in Water

Heterotrophic plate count (HPC) bacteria are a certain class of organisms that in the past have been considered undesirable in the water supply. It was thought that point-of-use filtration devices such as filters on faucets--many of which are used in third world countries to purify water--provide a breeding ground for such bacteria. Research at the Water Quality Center showed that regardless of the source of water, and of the type and extent of water treatment, HPC bacteria proliferate as biofilms. Furthermore, center research showed that these bacteria are not harmful and can even inactivate pathogens--they may actually provide a beneficial effect. As a result of this research, the World Health Organization redefined limits for HPC bacteria. This development has a broad impact since it not only enhances public acceptance of point-of-use treatments, but also, for companies who sell these devices, enhances the marketability of point-of-use technologies. For more information, contact Ian Pepper, 520.626.3328, ipepper@ag.arizona.edu.

## Endocrine Disruption Activity In Waters and Wastewaters

Endocrine disruptors or hormonally active agents can result in declining human sperm counts, malformed genitalia, aberrant mating behavior and other behaviors anomalies. Pharmaceutically active agents are known to be present in waters particularly wastewaters. This project evaluated the fate and transport of endocrines following dispersion of treated effluent in dry river bottoms. The project showed that soil aquifer treatment reduced estrogenic activity by up to 90%. These data have been of enormous value to the Arizona Department of Environmental Quality, to wastewater treatment facilities, and to the community at large. For more information, contact Ian Pepper at the University of Arizona, 520.626.3328, ipepper@ag.arizona.edu.

## Occurrence and Control of Emerging Waterborne Pathogens

Molecular method development for emerging pathogens including protozoan parasites (*Naegleria fowleri* and *Microsporidia*) and *Norwalk* virus was the focus of this research. The project has had state and national implications. At the state level, two young boys swimming in a surface recreational lake close to Phoenix, Arizona were later found to be infected with *Naegleri fowleri*. This parasite enters through the nose, swims to the brain and causes death. Both boys died, causing a local panic in Maricopa County. The project was in immediate and direct response to the Arizona Department of Environmental Quality plea for help. *Norwalk* virus gained recent national notoriety as the causative agent of gastroenteritis on cruise ships. For more information, contact Ian Pepper at the University of Arizona, 520.626.3328, ipepper@ag.arizona.edu.