Compendium of Technology Breakthroughs of NSF Industry University Cooperative Research Centers

National Science Foundation

Engineering and Education Centers Division
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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 source for identifying the breakthroughs was 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 the accomplishments of 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 an extraordinary technological breakthrough:

An extraordinary technological breakthrough was defined as leading to significant process improvements, new processes or techniques, and new or improved products or services.

Up to six IAB member/scientists from each center were invited to participate in structured interviews or online surveys between August of 2003 and April of 2004.

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.

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Biomolecular Interaction Technologies Center (BITC)

University of New Hampshire
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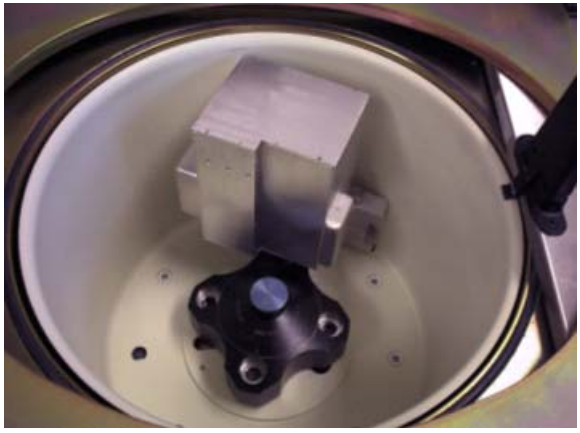
Fluorescence-Based Detector for the Analytical Ultracentrifuge



The Center for Biomolecular Interaction Technologies has partially funded the research that led to the commercial production of a fluorescence-based detector for the analytical ultracentrifuge. The analytical ultracentrifuge is the principal method for measuring the molecular weights of biomolecules in solution. The new instrument will allow one to analyze biomolecules (e.g., DNA, proteins) and their assemblies at much lower concentrations than ever before and to perform these analyses in very complex media, like cell lysates. This advance may permit the characterization of complex assemblies of biomolecules under conditions that much more closely resemble those in a living organism, and will aid drug discovery and development programs in pharmaceutical companies as well as quality control/quality assurance procedures. The first commercial instruments are being developed by Aviv Biomedical.

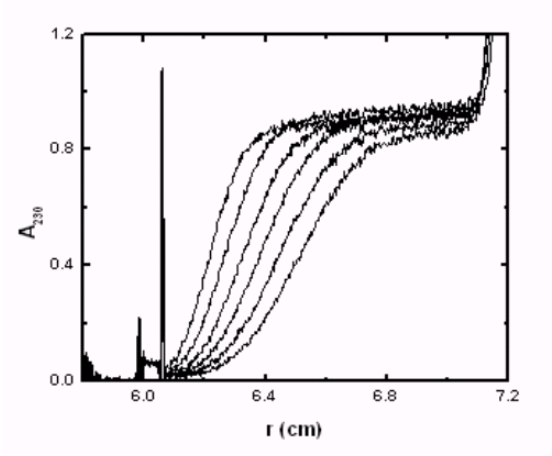
For more information, contact Dr. Thomas M. Laue, 603-862-2459; e-mail: tom.laue@unh.edu.

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. Center research 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; e-mail: tom.laue@unh.edu.

Absorbance Optical System and Data Acquisition Software for the Analytical Ultracentrifuge

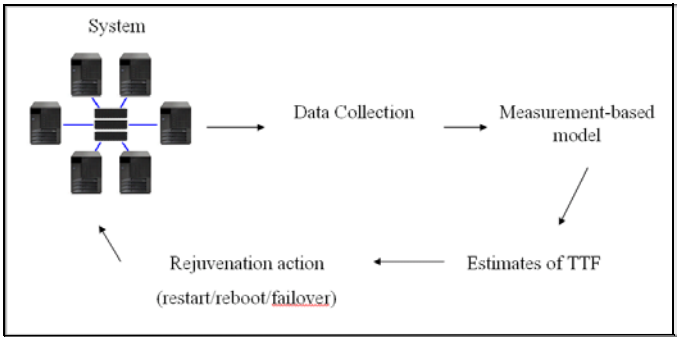
A new high-precision absorbance optical system and data acquisition software for the analytical ultracentrifuge developed by BITC will improve the throughput of analytical ultra-centrifugation. Without Dr. Laue's effort, this advance would not be possible: Beckman, the company that developed the analytical 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; e-mail: tom.laue@unh.edu.



Center for Advanced Computing and Communication (CACC)

North Carolina State University and Duke University
Dr. Dennis Kekas, Director (N. Carolina State University)
Dr. Kishor Trivedi, Director (Duke University)

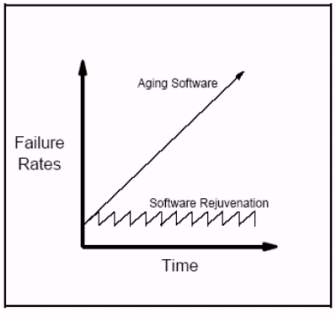
Software Rejuvenation



CACC researchers led by Duke professor Kishor Trivedi 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; e-mail: kst@ee.duke.edu.



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

University of Colorado at Boulder
Dr. Roop Mahajan, Director
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Atomic Layer Deposition

Atomic Layer Deposition (ALD) on MEMS contacting surfaces for increased reliability. Work done a CU indicates ALD indicates this will increase the switch life of MEMS devices and 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; e-mail: 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; e-mail: roop.mahajan@colorado.edu.

Center for Advanced Polymer & Composite Engineering (CAPCE)

Ohio State University, Florida State University, University of Wisconsin-Madison
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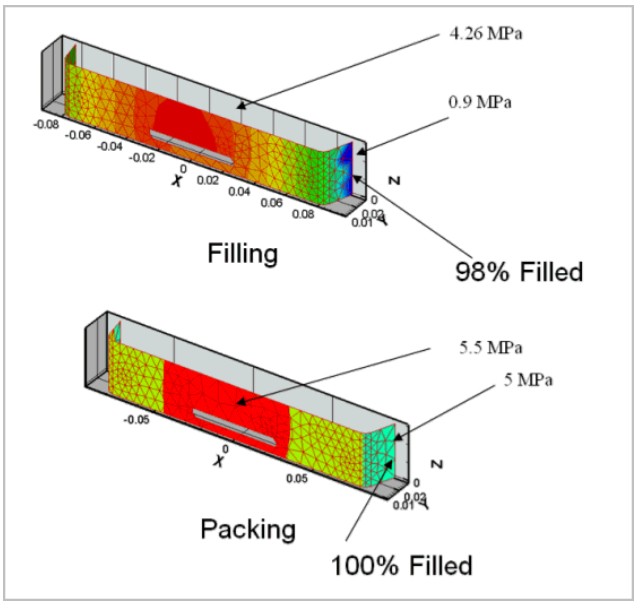
Software for Enhancing In-Mold Coating Processes of Plastic and Composite Products

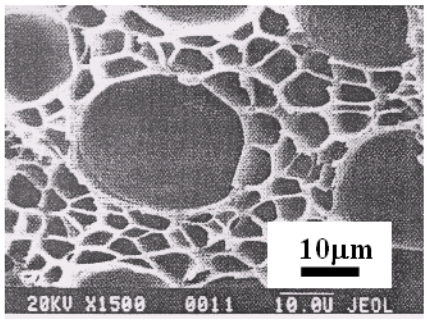


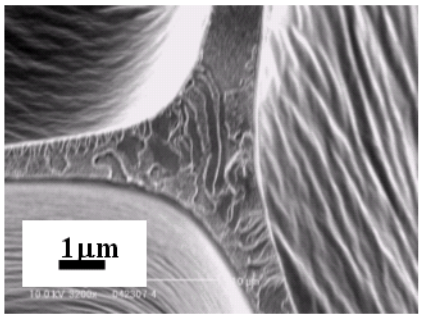
CAPCE research led by Jose Castro has produced new software to enhance in-mold coating processes. The technique of in-mold coating has the potential to revolutionize the coating and paint processing industries because it allows the coatings to be injected under high pressure right inside the mold used, 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, Phone: 614-688-8233; e-mail: 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, e-mail: Lee.31@osu.edu or Roland Loh, Owens Corning Foam System, e-mail: 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 Studies in Novel Surfactants (CASNS)

Columbia University
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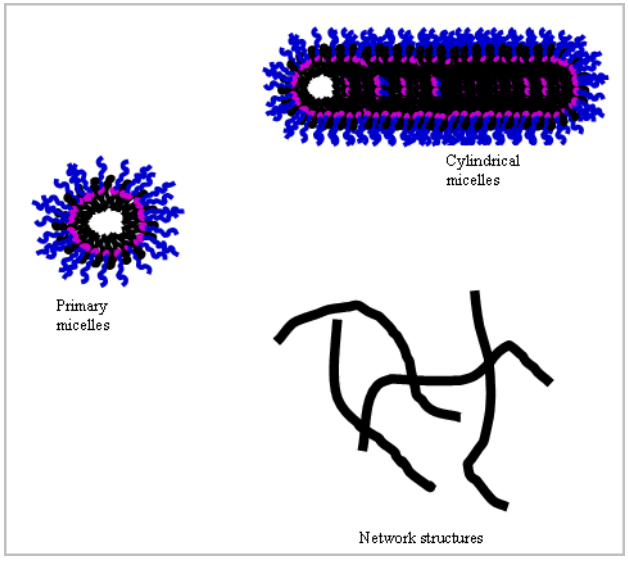
Coexistence of Nanostructures in Mixed Surfactant Solutions

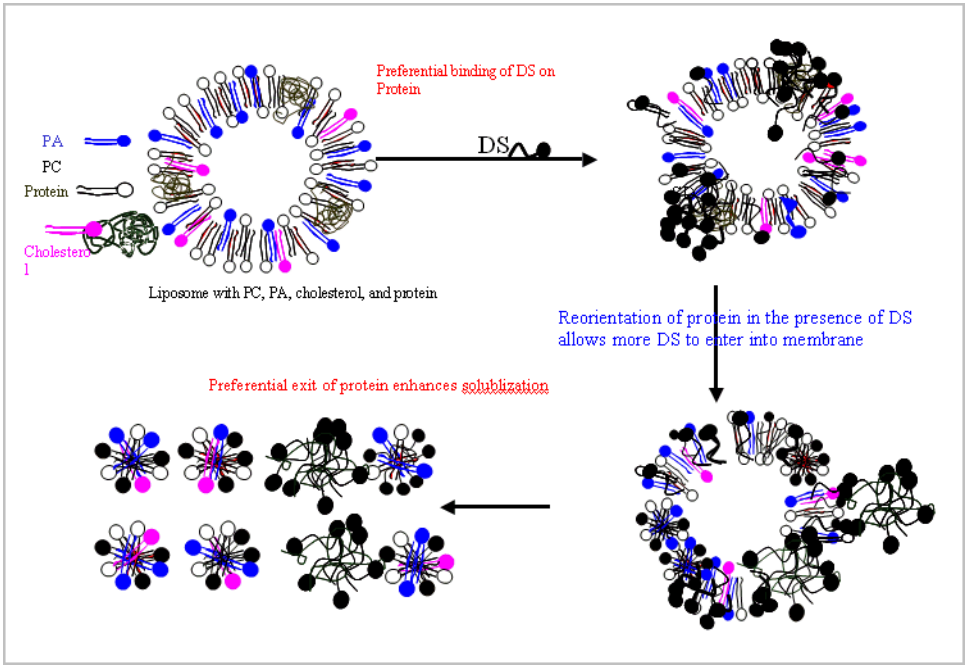


Analytical ultracentrifugation technique, is used for the first time to quantitatively determine speciation in surfactant mixtures and surfactant/protein mixtures in solutions. This technique is nondestructive and is particularly powerful for distinguishing the size and shape of various species in mixtures. Recent results have revealed coexistence of two types of micelles in polyethylene oxide solutions and its mixtures with sugar-based surfactant while only one micellar species is present in sugar-based surfactant solutions. Also, unlike ionic surfactants, the micellar growth of the nonionic sugar-based and polyethylene oxide surfactants are found to occur at a concentration immediately above the cmc. 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; e-mail: ps24@columbia.edu.
Above: Nanostructures of micelles in the same aqueous surfactant solutions.

Mechanisms of Interactions of Surfactants with Lipid Vesicles and Biomembranes

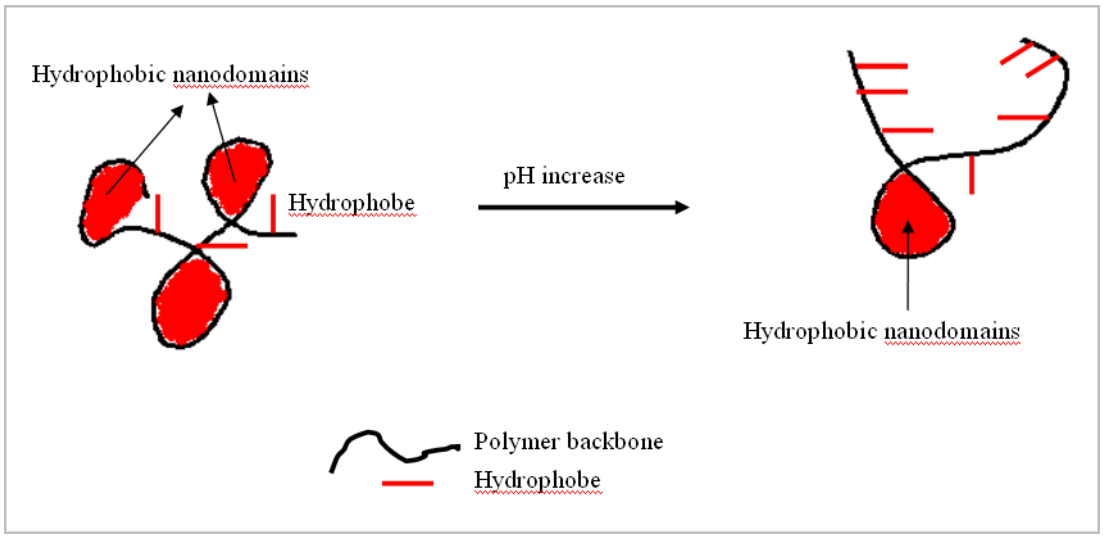
Our recent results on membrane-surfactant interactions with simpler biomembranes such as phosphatidic acid (PA) and phosphatidyl choline (PC) liposomes using electron spin resonance and fluorescence demonstrated for the first time in the history of liposome research that one of the liposome component, (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. This has sig-

nificant implications in the formulation and use of consumer and drug products. 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. The results on the mechanisms of surfactant interaction with biomembranes helps industry to develop formulation of efficient but mild personal care products.
Below: Conformational change of protein by dodecyl sulfate (DS) enhances the liposome solublization.



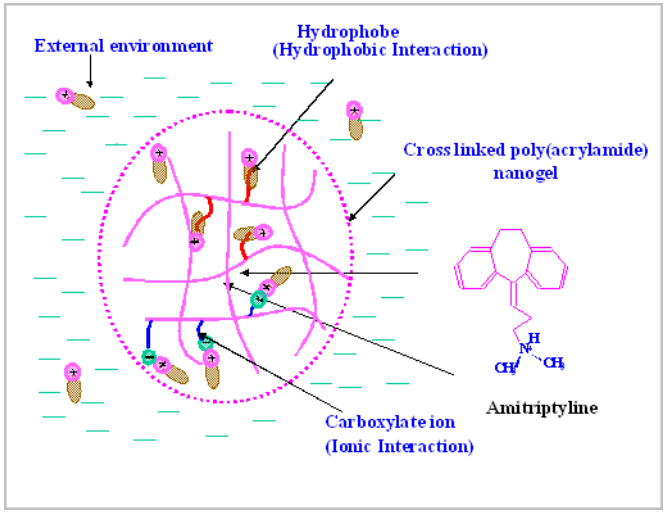
Conformational Behavior of Hydrophobically Modified Polymers

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, dirts etc. by change in pH, salinity 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; e-mail: ps24@columbia.edu.

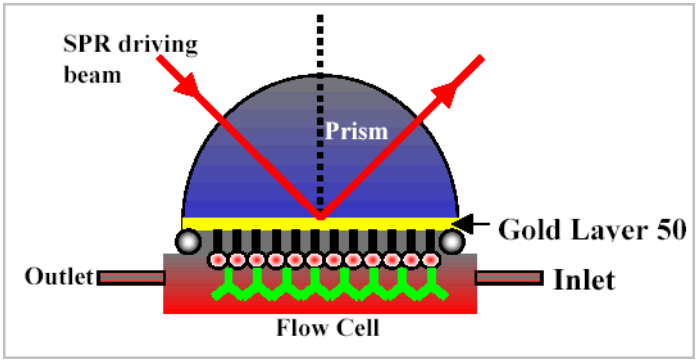


Novel Poly(acrylamide) Nanoparticles for Extraction and Release of Drug and Fragrance

Novel polyacrylamide nanogels (10-100nm) modified with functional hydrophobic and ionic groups, capable of almost complete removal of some overdose drugs have been produced by inverse microemulsion polymerization. Nanoparticles, in view of their a) submicron size, b) tendency to swell in different environments and c) ability to be functionalized show unique potential as drug and cosmetic carriers. Excessive use of amitriptyline is one of the major reasons for suicide in the United States. The hydrophobically modified and the ionic nanoparticles exhibited dramatic enhancement for amitriptyline and bupivacaine binding (80%) when compared to unmodified nanogels (18%). These hydrophobic and ionic interactions between the tested drug molecules and functional groups are represented in the following figure. The efficacy of these nanoparticles was excellent also for the extraction and release of vanillin, a flavoring ingredient for food materials and perfumes.

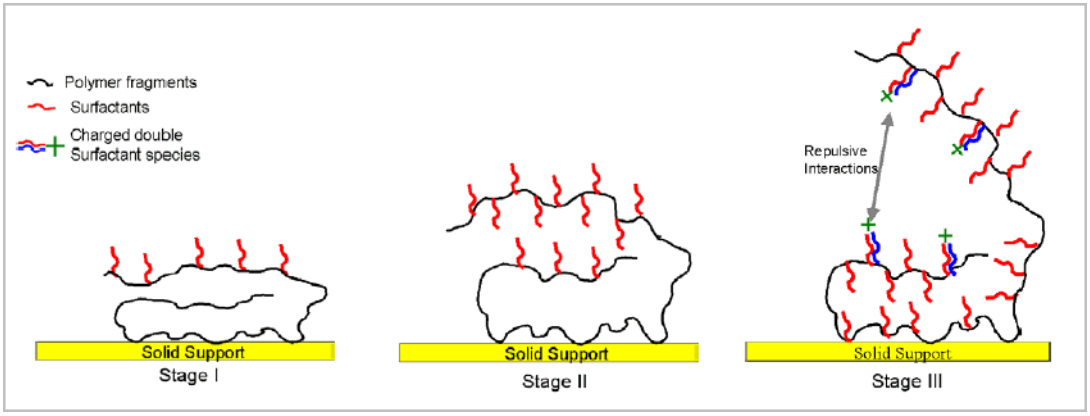


Interfacial Dynamics of Macromolecules using Surface Plasmon Resonance Spectroscopy



Understanding the short-term dynamics of interfacial processes is imperative in developing smart materials of the future. However none of the instruments allowed studying short term interactions in real time in situ. We developed a surface plasmon resonance spectroscope (adjacent figure) and applied it for the first time in studying the conformational dynamics of polymers and polymer surfactant interactions in millisecond time scales.

Surface plasmons (SP) are trapped surface modes existing at the interface between a metal and a dielectric with electromagnetic fields decaying exponentially in both media. The wavevectors of SPs are dependant on the refractive indices of the materials in the interfacial region an optical monitor of changes in the local environment. One of the most notable results, show the opening up of polymer (polyacrylic acid) matrix, during the binding of an oppositely charged surfactant (Dodecyltrimethylammonium Chloride). This result was contrary to normal expectations as charge neutralization is expected to increase the hydrophobicity of the layer causing the layer to collapse.



Center for Advanced Vehicle Electronics (CAVE)

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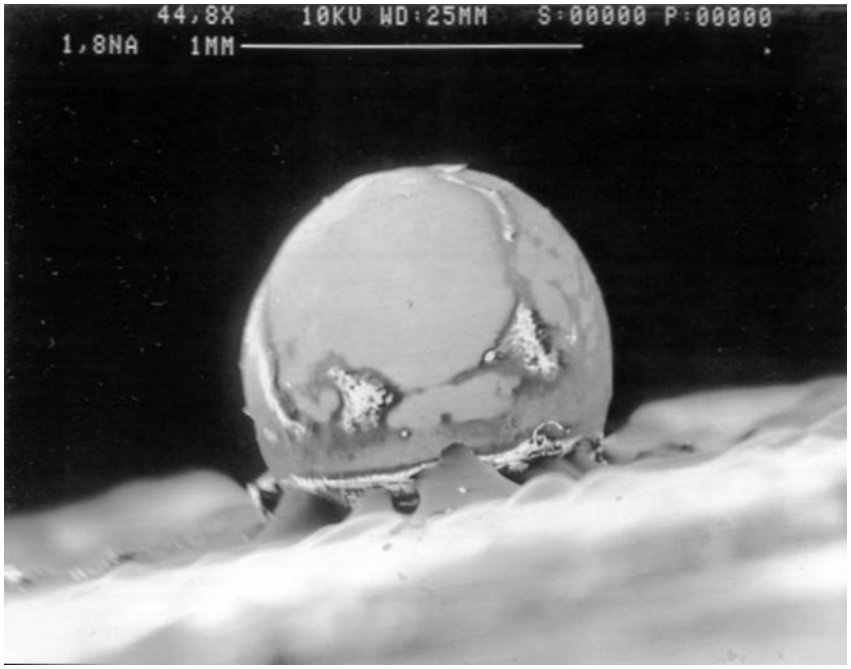
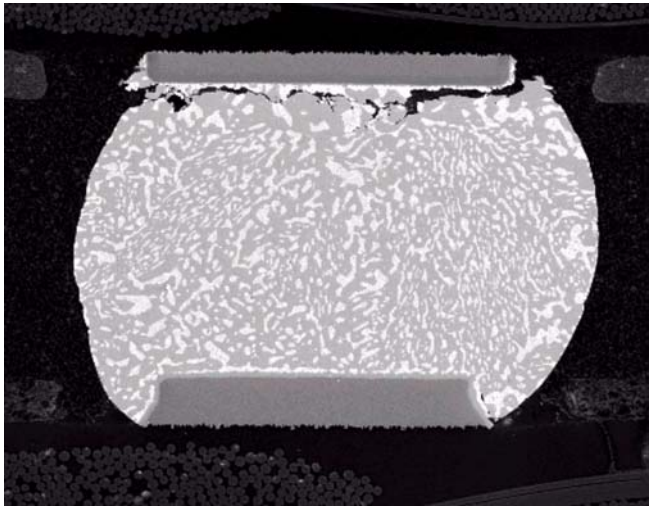
Improved Electronic Circuitry for Terrestrial and Space Vehicles



The Center for Advanced Vehicle Electronics (CAVE) has a number of industrial partners who design, develop, and manufacture state-of-the-art electronic circuitry for terrestrial and space vehicles. The electronics must operate reliably for long periods of time in hostile environments including high temperatures, low temperatures and high radiation fields. The center's work in materials physics and process breakthroughs based on long-term reliability studies of solder joints have identified a number of key factors which have impaired progress in circuit longevity. Studies to identify and measure the growth kinetics of brittle inter-metallic compounds that form in solder joints led to significant process improvements in flip-chip and ball grid array circuitry for Daimler-Chrysler Corporation. The processes have proven capable of stopping crack propagation in solder joints by controlling several critical process variables during soldering operations. Theoretical and experimental studies of the heat distribution on a circuit board using miniature thermocouples have led to identification of heat-susceptible locations on the board that impact circuit reliability. This has been especially useful for NASA, which has an abundance of circuitry located near hot rocket engines. For more information, contact Jeff Suhling, Auburn University, 334-844-3332; e-mail: jsuhling@eng.auburn.edu. *Above*: A molten solder ball.

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. 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.The novel techniques have especially benefited Cookson Electronics and Loctite, two CAVE industrial sponsors who specialize in solder materials and technology. No comparable instrumentation exists elsewhere. This is the first scanning electron microscope that allows for real-time, in-situ melting, wetting, and spreading of Pb-free solder alloys and pastes. The system allows for microscopic observation of the advancing wetting and simultaneous analysis of alloy-substrate chemical reactions during wetting. CAVE's is the first laboratory to develop a scanning electron microscope to measure strains in materials during repetitive temperature cycling processes such as are common in vehicular-related under hood applications. 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; e-mail: jsuhling@eng.auburn.edu. *Above*: Failed solder ball.

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

The Center for Advanced Vehicle Electronics has developed a number of applied and fundamental methodologies that directly impact the financial bottom line of several member companies. CAVE has become one of the first laboratories to study the materials science of leading candidate Pb-free solder alloys, particularly during formation of the metallurgical bond. Work on state-of-the-art electronics assembly operations and Pb-free solder alloys has helped industrial partners stay ahead of the pack in their respective technological areas. For example, Cookson Electronics and Loctite Inc., are leading manufacturers of electronic solder. This research has world-wide significance due to the expected ban on the element lead (Pb) by the year 2005. This ban will eventually impact every circuit board on planet Earth and has enormous financial implications. 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 Cookson 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; e-mail: jsuhling@eng.auburn.edu.

Center for the Built Environment (CBE)

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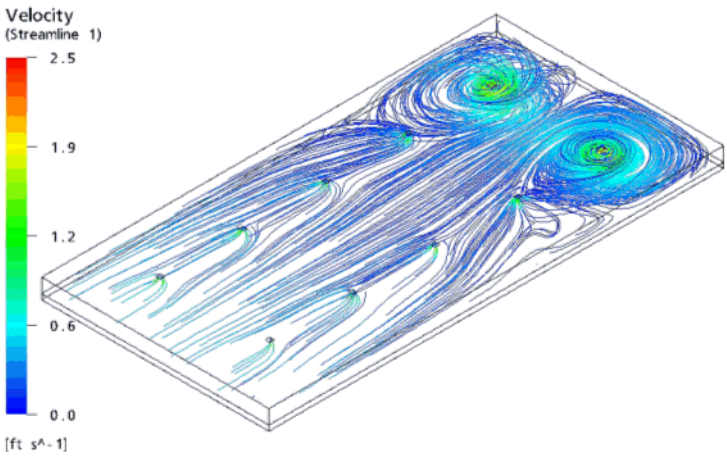
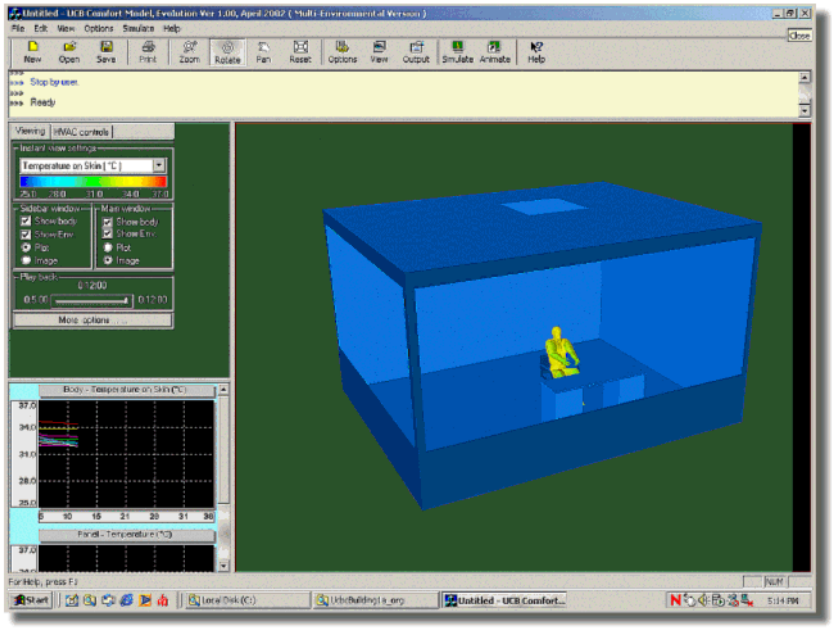
Engineering and Design Guidelines for Underfloor Air Distribution (UFAD) Technology



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, 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) in December of 2003.
For more information, e-mail 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. 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, e-mail cbe@uclink.berkeley.edu.

Center for Building Performance and Diagnostics (CBPD)

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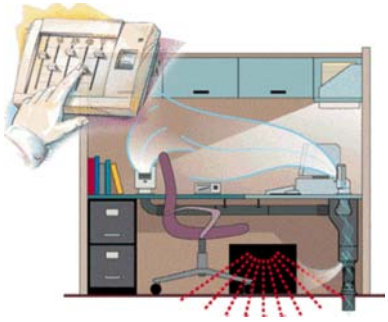
Building operations (heating, cooling, lighting, and ventilation) consume almost 40% of the U.S. primary energy, and 67% of electricity. The Center for Building Performance and Diagnostics (CBP&D) is dedicated to research, develop, design, engineer, demonstrate, and test, as well as apply systems, components, and materials and their integration to create built environments which simultaneously increase: occupant comfort and productivity, organizational flexibility and effectiveness technological adaptability, as well as energy and environmental effectiveness; thereby creating 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.

The Robert L. Preger Intelligent Workplace (IW)



Since December 1997, the IW, designed and engineered by the Center, 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 resulted in unprecedented levels of user accessibility, organizational flexibility, and technological adaptability, 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 Dr. Ing. Volker Hartkopf; e-mail: hartkopf@cmu.edu.

Personal Environmental Module

The work of the Center 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. Ing. Volker Hartkopf; e-mail: 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. Ing. Volker Hartkopf; e-mail: hartkopf@cmu.edu.

Center for Coatings Research (CCR)

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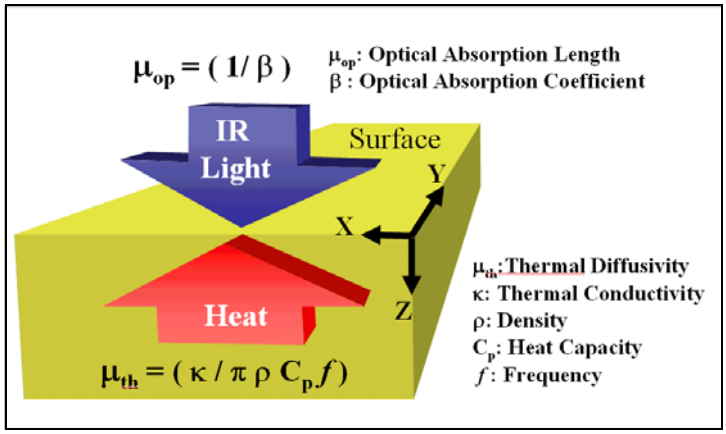
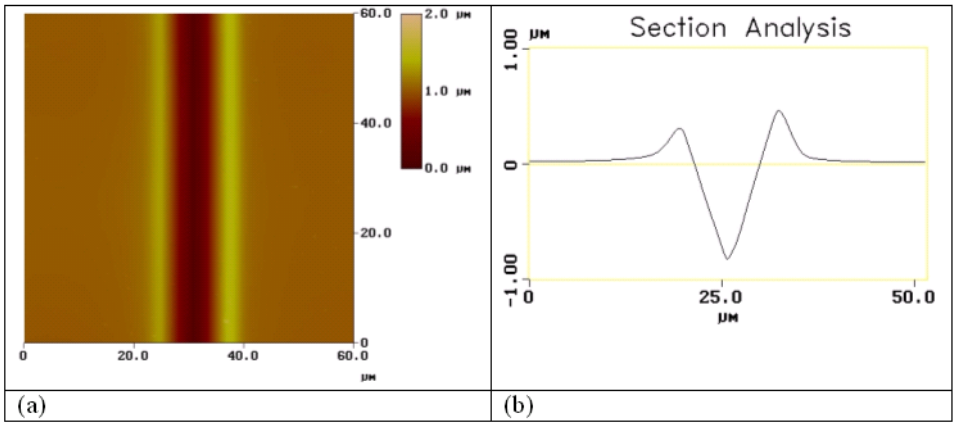
Coating Analysis with Step-Scan Photo-Acoustic FTIR Spectroscopy



Marek Urban at the University of Southern Mississippi has 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; e-mail: marek.urban@usm.edu.

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

Dr. Weidian Shen and Dr. Frank Jones 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 directed by Dr. Shen. 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; e-mail: wade.shen@emich.edu, or Frank Jones, 734-487-2203; e-mail: 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 jamil.baghdachi@emich.edu.

Center for Communications Circuits and Systems (CCCS) – Connection One

Arizona State University, University of Arizona, University of Hawaii

Dr. Sayfe Kiaei, Director (ASU)
Phone: 480-727-8044
E-mail: sayfe.Kiaei@asu.edu.

Dr. Jeffrey Rodriguez, Director (UA)

Dr. Magdy Iskander, Director (UH)

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; e-mail: sayfe.Kiaei@asu.edu.

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

Washington State University, Oregon State University,
State University of New York (SUNY) at Stoney Brook,
University of Washington

Professor John Ringo, Director
Washington State University
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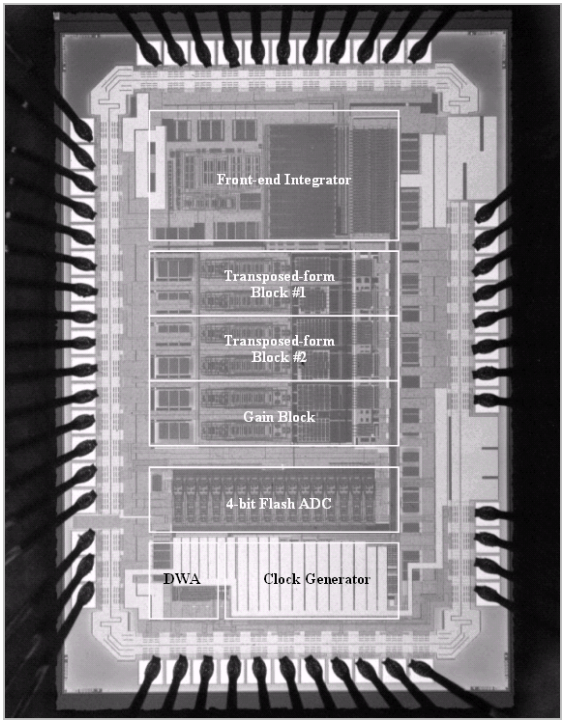
New Integrated Circuit Technique: Output Prediction Logic

At CDADIC, University of Washington electrical engineering professor Carl Sechen is currently designing and implementing the world's fastest digital logic technique. This ultimately will allow for significant increases in chip speed. Sechen's Output Prediction Logic (OPL), a new integrated circuit technique that was recently patented, will double the speed of existing methods of computing digital logic functions on a chip. Eventually, this technology will make it possible to double computer speed as well as greatly enhance video and speech processing technologies. Sechen has already made considerable progress in the area of computing circuit design for speech recognition, an area that requires much faster computer chip capability than currently exists. The high-speed logic design methods and libraries that Professor Sechen has been working on will, for example, allow Boeing for the first time to implement the STAP (Space-Time Adaptive Processing) algorithm on a single silicon integrated circuit. Boeing will be able to process imaging data using that algorithm at previously unachievable speeds in a small space and at acceptable power levels. The STAP algorithm, running at those speeds, will enable data filtering and clutter reduction at unprecedented levels. If successfully implemented, this algorithm has been targeted for adoption by several high-visibility defense applications and will become truly breakthrough/enabling technology to the associated programs. For more information, contact Carl Sechen, 206-685-8756; e-mail: sechen@ee.washington.edu.



Circuit Protection Modeling Systems

University of Washington electrical engineering professor Bruce Darling is developing compact circuit simulation models that predict the effects of electrostatic discharge (ESD), a problem of major concern in modern microelectronics. As integrated circuits become more dense and miniaturized, they become more fragile and susceptible to damage by static electricity. Previously, the design of ESD circuit protection has largely been a trial-and-error process and, consequently, the introduction of new product design has been slow and difficult. Darling's novel research takes the guesswork out of this process. He and his Ph.D. student, Yeshwant Subramanian, are developing software tools that identify the pathways that an ESD current pulse can take within the layout of an integrated circuit, and predict the effects of this pulse on the semiconductor devices that it passes through. By simulating many possible ESD events before they happen, industry will be able to understand the robustness of a given design prior to fabrication, and be able to produce more reliable, secure integrated circuits. This will allow new products to move on to the market more quickly and more economically. For more information, contact Bruce Darling, 206-543-4703; e-mail: bdarling@ee.washington.edu.

Low-Cost Phased Array Antenna Using Silicon Germanium Technology

CDADIC researcher Dave Allstot is developing a low-cost phased array transmit/receive system on a monolithic microwave integrated circuit (MMIC) chip based on silicon germanium technology. Such systems traditionally have been implemented using gallium arsenide technology, which is more expensive and won't support putting the transmitter, receiver, and control chip on the same integrated circuit. Phased array antennas, used in aerospace and satellite communications, for example, use MMICs for each element of the array. The cost of the MMICs is a large factor in the cost of the antenna, which limits how widely the technology gets used. This research should help dramatically increase the use of phased-array antennas in applications that are critical, for example, to the military for DOD's next-generation battlespace communications. For more information, contact Dave Allstot, 206-221-5764; e-mail: allstot@ee.washington.edu.

Delta-Sigma Toolbox Enhances the Design of Data Converters

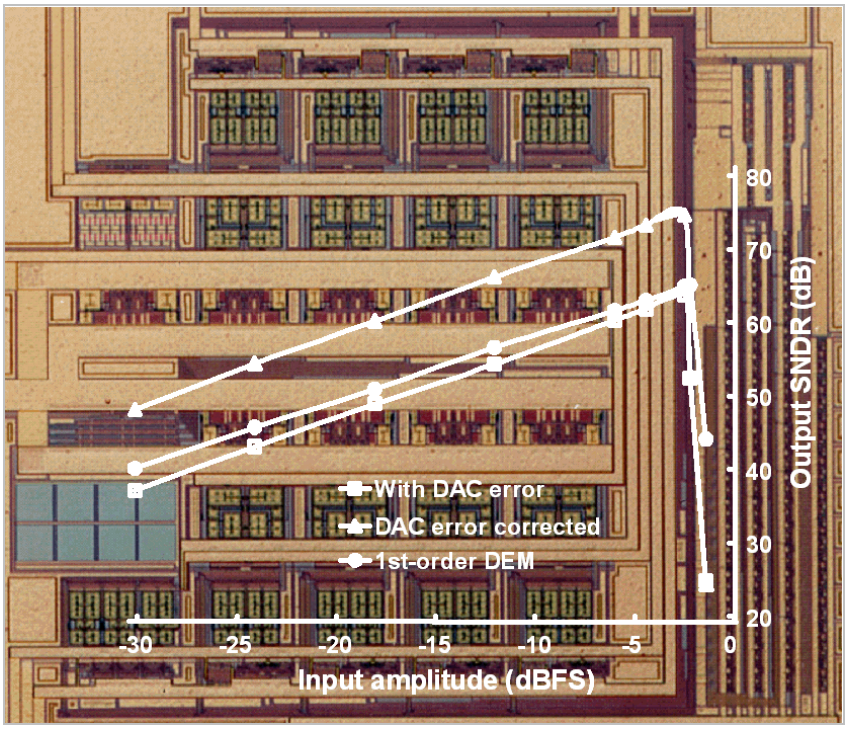
The Delta-Sigma Toolbox is a tool developed at CDADIC and made available to the general public that allows engineers to explore "What if" scenarios in designing Delta-sigma over-sampled data converters, one of the most important of all general architectures in the conversion of real world signals (analog) to data manipulation signals (digital). With this tool, engineers can quickly explore the effects of arranging converters in different configurations. Analog Devices, a CDADIC industry partner, is one company that has made extensive use of this tool over the years and has saved a tremendous amount of time trying to figure out the best way to make these converters. The tool is used by thousands of engineers in the United States. For more information, contact Richard Schreier at richard.schreier@analog.com.

Changes in Analog/Digital Converters

CDADIC researchers have developed current-mode logic circuits for low-noise performance. The technology provides a way to reduce digital substrate noise in mixed-mode integrated circuits, which has been a major limitation of the accuracy achievable in such circuits. Digital switching noise is a potential problem in the design of analog/RF/digital system-on-chip (SoC) solutions. At high frequencies, the sensitive analog/RF circuits are unable to reject substrate-coupled switching noise. Current-mode logic circuits were invented to overcome this problem; they generate

switching noise that is more than two orders of magnitude less than that of conventional static logic circuits. The proposed digital design methodology in SoC solutions is to use conventional logic for low-frequency functions and low-noise current mode logic for high-frequency functions. Although it dissipates DC power, current-mode logic is actually more power efficient at high frequencies. To date, the current mode logic has been used in the frequency divider blocks of phase-locked loops wherein it provides superior jitter performance. Several semiconductor companies have used the logic techniques in these applications. For more information, contact Sayfe Kiaei, 480-727-7761; e-mail: sayfe.Kiaei@asu.edu, or David Allstot, 206-221-5764; e-mail: allstot@ee.washington.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; 541-737-3118, e-mail: moon@ece.orst.edu, Terri Fiez, 541-737-3118; e-mail: terri@ece.orst.edu, Gabor Temes, 541-737-2979; e-mail: temes@ece.orst.edu.

Center for Dielectric Studies (CDS)

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Dr. Clive Randall, Director
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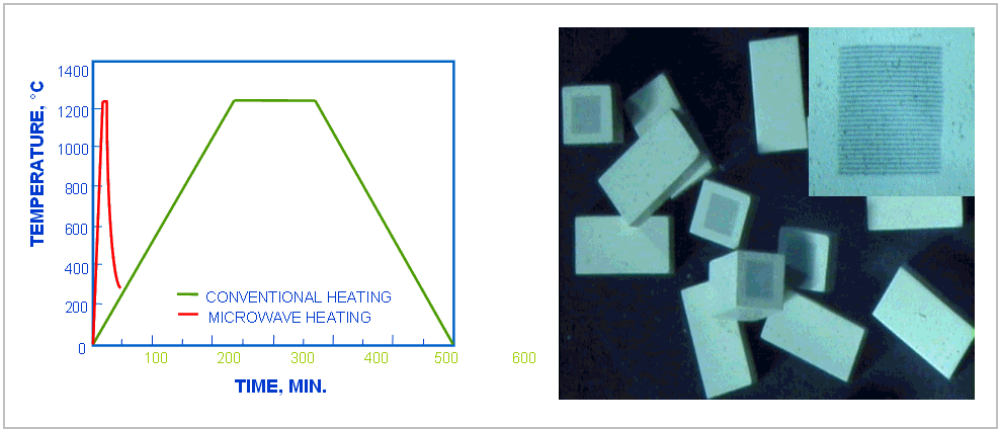
Microwave Sintering

Although the general technique of microwave sintering of electronic devices has been known for some 25 years, it has not been applicable in industrial practice to date. CDS has developed microwave sintering of electronic devices to levels that have not been observed before. The center has demonstrated parts made via this technique that are comparable to standard production parts. The potential of microwave sintering in the electronics industry is large because it will reduce sintering costs and increase efficiency and throughput. For more information, contact Dinesh Agrawal 814-863-8043, e-mail: dxa4@psu.edu or Rustum Roy, 814-865-3421; e-mail: rroy@psu.edu.



Left: Vastly improved production of base metal multilayer ceramic capacitors using microwave sintering techniques. *Right*: Examples of microwave sintered multilayer ceramic capacitors with nickel electrodes.

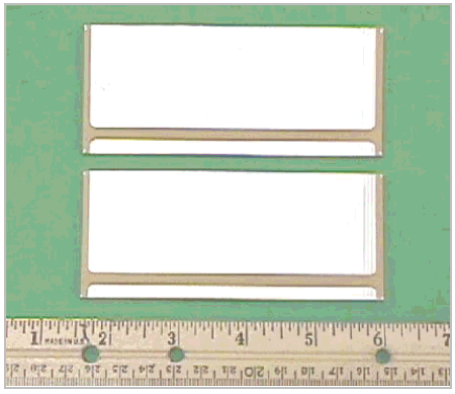
Low-Temperature Co-Fired Ceramics

Center research illustrated curvature changes in low temperature co-fired ceramic (LTCC) substrates under various heating rates and firing times and temperatures with various LTCC materials. LTCC materials are used for packaging applications. The work was fundamentally helpful to Dupont, Ferro and Heraeus in their development of LTCC materials systems. For more information, contact Gary Messing 814-865-2262; e-mail: messing@matse.psu.edu.

Chemical Modeling of Base Metal Electrode Multilayer Ceramic Capacitor Systems

The Center for Dielectric Studies (CDS) research has generated a fundamental understanding of base metal electrode multilayer ceramic capacitor systems. The results have led to improved reliability of these capacitors, which are widely used in computers, telecommunications, aerospace applications--wherever electronics are used. CDS developed a model elucidating the chemistry of rare earth lanthanides in these devices: they are amphoteric, residing on the A or the B site of the barium titanate perovskite lattice. This model has been thoroughly tested and is now widely accepted in the electronic components community. For more information, contact Clive A. Randall, 814-863-1328; e-mail: car4@psu.edu.

Pulse Power Capacitors



CDS researchers at the University of Missouri-Rolla are fabricating large-scale capacitors for pulse power applications. These systems are being tested by center members Lawrence Livermore National Laboratories, Honeywell FM&T, and Sandia National Laboratories for rapid discharge of high-energy capacitors. Previous technology used low dielectric constant materials, which are not useful for mobile applications. Center research on increasing the dielectric constant and the breakdown strength is making it possible to reduce the weight and volume of such capacitors. Applications include military communications equipment and future combat systems, aerospace and avionics, power conditioning systems, cardiac defibrillators, X-ray equipment, pulse forming networks for radar, radio and TV, lasers, accelerators, ignition systems, and electric vehicles. For more information, contact Dr. Harlan Anderson, University of Missouri-Rolla, 573-341-4886; e-mail: harlanua@umr.edu.

Above: Large high voltage capacitors for pulse power fabricated at CDS-Rolla.

Center for Engineering Logistics and Distribution (CELDi)

University of Arkansas, University of Louisville,
Oklahoma State University, University of Oklahoma

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Fleet Optimization

The Center for Engineering Logistics and Distribution (CELDi) has been conducting research on power forecasting and fleet location optimization with a member company called American Commercial Barge Lines (ACBL). Researchers on the project have optimized fleet scheduling in the Ohio River valley and the utilization of fleet locations in the Gulf of Mexico. The power-scheduling model currently being implemented at ACBL is expected to replace the manual methods currently used. Preliminary testing indicates that power requirements on the Ohio River may be drastically reduced. Specifically, it is anticipated that as much as one full boat can be removed from service on the river. The exact savings associated with a one-boat reduction are proprietary, but they easily exceed 10 times the investment for a CELDi membership. For more information, contact Don Taylor, University of Louisville Professor G. Don Taylor, Center Director at University of Louisville, 502-852-2741; Fax: 502-852-5633, e-mail: don.taylor@louisville.edu.

Airspace System Security

CELDi researchers are working with the FAA Logistics Center in Oklahoma City to model logistics systems under heightened National Airspace System (NAS) security requirements. This project resulted in the development and application of security procedures and technologies. In addition, an integral part of this project was to identify part numbers that are vulnerable to potential threats to the NAS. The algorithms developed provided benefits that yielded a pay back of less than two years. For more information, contact Tom Landers at landers@ou.edu or Babur Pulat at pulat@ou.edu at the University of Oklahoma.

Improved Production Line Performance

The Industry/University Cooperative Research Center for Engineering Logistics and Distribution (CELDi), involving the University of Arkansas, the University of Oklahoma, the University of Louisville, and Oklahoma State University, has made research advances that improve production line performance in processing industries. These results are applicable to many processing industries and in most cases produce significant cost savings. For example, using these advances, a food processing company (ConAgra) realized a productivity improvement of greater than 2 percent, resulting in an increase of 75,000 cases per year on two production lines and generating a savings of over $l million per year. In addition, through operational analysis studies, CELDi identified a significant improvement in sanitation procedures in this company, helping them reduce their environmental impact. For more information, contact Erhan Kutanoglu at erhank@mail.utexas.edu at the University of Texas or Earnest W. Fant at erhank@mail.utexas.edu at the University of Arkansas (ewf@engr.uark.edu).

Center for Glass Research (CGR)

Alfred University, University of Missouri-Rolla, Pennsylvania State University

Dr. Tom Seward, Director
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E-mail: seward@.alfred.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; e-mail: 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; e-mail: 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; e-mail: 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; e-mail: seward@alfred.edu.

Center for Infrastructure Engineering Studies (CIES)

University of Missouri at Rolla and North Carolina State University
Dr. Antonio Nanni, Director
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E-mail: nanni@umr.edu

Method of Building Reinforcement

CIES research has produced a cost-effective, simple-to-implement method of upgrading thousands of buildings that have a great probability of failing and taking human life when subjected to seismic loading, high winds, or blast loading. The concept has been proven to work and is ready for implementation as a direct result of the work sponsored and encouraged by the NSF. This research on near surface mounted reinforcement systems for strengthening unreinforced masonry walls has been conducted by center director Tony Nanni and Gustavo Tumialan. The work has been extended by the U.S. Army Corp of Engineers and resulted in Federal Guidelines for strengthening government-owned buildings. Army Corp research based on full-scale and half-scale masonry buildings has validated the concepts and is leading towards commercial adoption of the UMR techniques. The key researchers are extending their work toward adobe masonry and masonry construction typical of third-world countries, realizing that most of the worlds population lives in less than ideal masonry structures. The advantages of this technology rest in the rapid and clean method of application. This translates into cost savings and less inconvenience for the building occupants. The use of composites also allows for the strengthening technique to be applied on exterior surfaces without corrosion concerns and maintaining the original aesthetics of the wall. For more information, contact Dr. Antonio Nanni, 573-341-4497; e-mail: nanni@umr.edu.

Bridge Rehabilitation

The Repair of Buildings and Bridges with Composites (RB2C) is an I/UCRC based at the University of Missouri-Rolla and NC State University. The RB2C center has been contracted by the Missouri Department of Transportation to rehabilitate five aging concrete bridges throughout the state. The bridges will be strengthened using fiber-reinforced polymer (FRP) materials. They will then be instrumented and monitored biennially over five years. The data, information, and understanding gained from this project will be used to draft specifications for future FRP-related bridge-strengthening projects. Alongside these specifications, guidelines will also be written, documenting how bridges should be selected for various FRP-strengthening procedures, providing associated cost estimates of competing schemes, and predicting the life expectancy of strengthened bridges. For more information, contact Dr. Antonio Nanni, 573-341-4497; e-mail: nanni@umr.edu.

Center for Integrated Pest Management (CIPM)

North Carolina State University
Dr. Ronald Stinner, Director
Phone: 919-515-1648
E-mail: cipm@ncsu.edu

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 Membrane and Applied Science and Technology (MAST)

University of Colorado, University of Cincinnati

Dr. Alan Greenberg, Director
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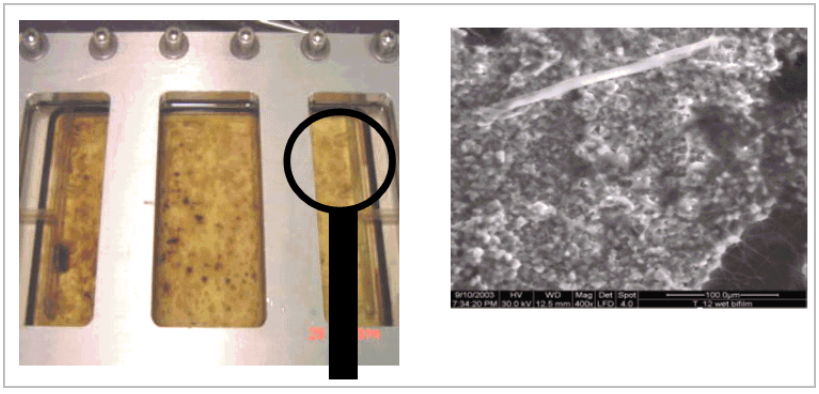
Acoustical Method of Characterizing Membrane Fouling and Cleaning

Center researchers have developed an acoustical method of characterizing the operational fouling and cleaning of membranes used in a wide variety of industrial processes. Membranes are used in separations processes to separate materials from liquid feedstreams. Such processes include water desalination operations, food and beverage processing, waste treatment processing, and pharmaceutical operations. Membranes used for these purposes may become fouled, causing a decrease in membrane permeability and a corresponding decline in process efficiency. Previous methods of detecting fouling have been done primarily by means of membrane permeability measurements, which provide an average over the entire membrane surface area--they are not site specific. The acoustical sensor developed at the Membrane and Applied Science & Technology Center uses low-energy, high frequency sound waves to detect levels of fouling and cleaning in a site-specific manner. The sensor provides a non-destructive, non-contact testing method that can be done on line, in real time. A U.S. patent has been issued, and significant industrial interest in the technology has been shown. Licensing negotiations with a major company are currently in progress. This technology was developed in response to a project that was submitted by a center sponsor (TACOM-TARDEC, U.S. Army) in 1993. For more information, contact Alan Greenberg 303-492-6613; e-mail: alan.greenberg@colorado.edu or Gary Amy, 303-492-6274; e-mail: gary.amy@colorado.edu.



Above: Photograph showing the membrane surface after the onset of biofouling on the left; environmental electron scanning micrograph that shows the growth of the biofouling layer on the membrane surface on the right.

Solid supported membranes (SSM) for reconstitution of ion channels

The Center Researchers have developed devices that contain ion channels on synthetic membranes. Ion channels are biological proteins that span cell membranes and generate electrical currents when ions pass through a highly selective pore within the channel. Many ion channels have evolved to generate currents in response to binding of biological and environmental toxins and pharmaceutical agents. Sensors for environmental and biological toxins and screening procedures for pharmaceutical agents would benefit from technologies that use the electrical signals generated by ion channels. The potential advantages of these devices over other methods are low cost and high specificity. A U.S. patent has been prepared. This technology was developed in response to a project that was submitted by a center sponsor (Procter and Gamble) in 2000.

Center for Microcontamination Control (CMC)

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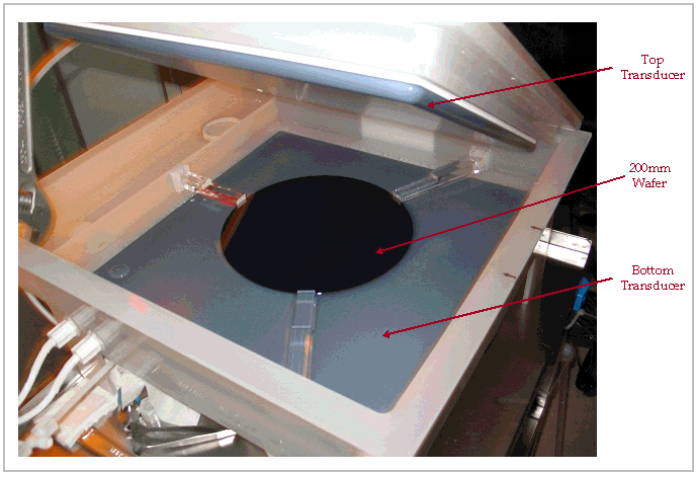
Physical Removal of Nanoscale Particles from surfaces and trenches



Center researchers 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 shown that it is 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. This 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; e-mail: 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; e-mail: 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.

Hardware for 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 Machine Tool Systems Research (CMTSR)

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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 reconfigurable 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; e-mail: 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.

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, web site: 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).

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.

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.

Self-Healing Polymers to Improve Microelectronic Components

The Machine Tool Systems Research Center's current 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 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.

Center for Management of Information (CMI)

University of Arizona

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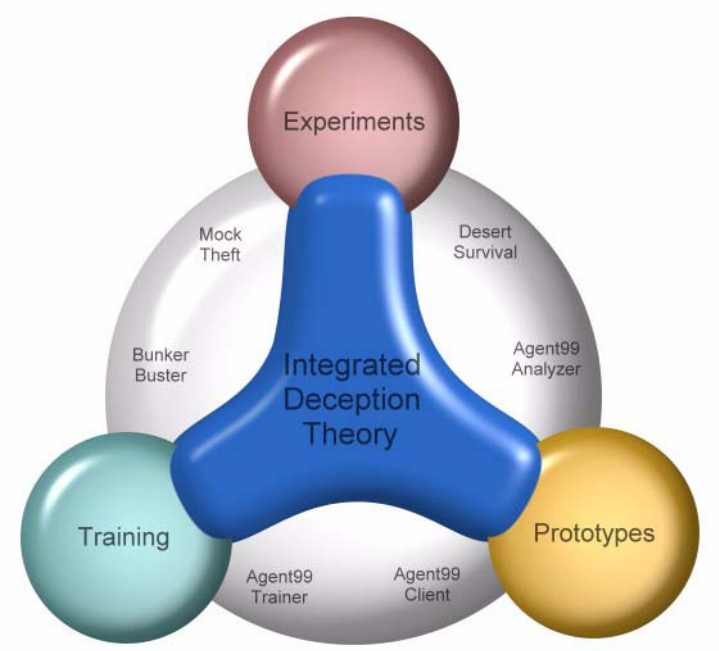
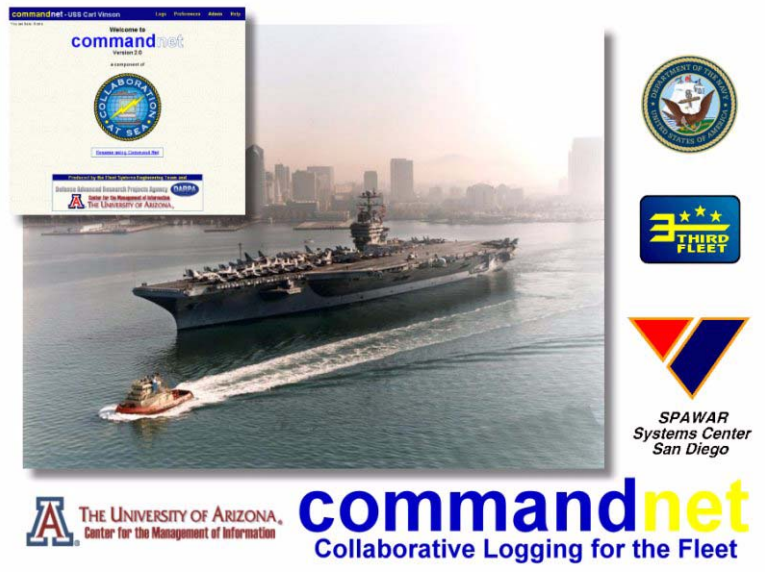
Detecting Deceptive Communications

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, 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 NetworkCentric 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 Dr. John Kruse, kruse@cmi.arizona.edu.

Center for Next Generation Video (CNGV)

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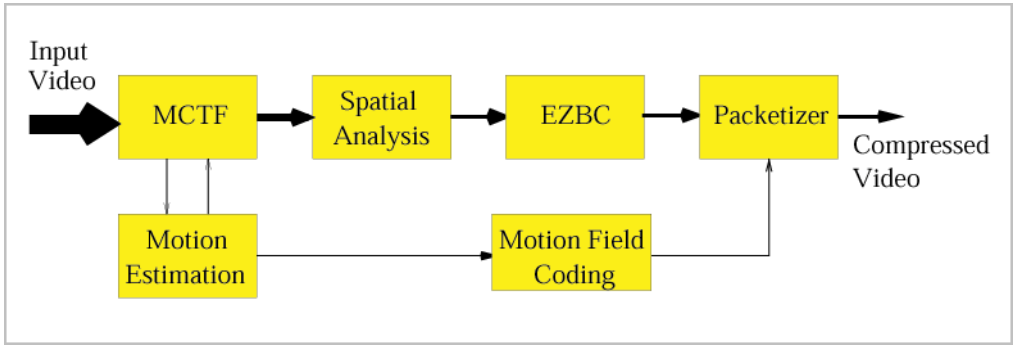
Scaleable Video Coding

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.



Center for Nondestructive Evaluation (CNDE)

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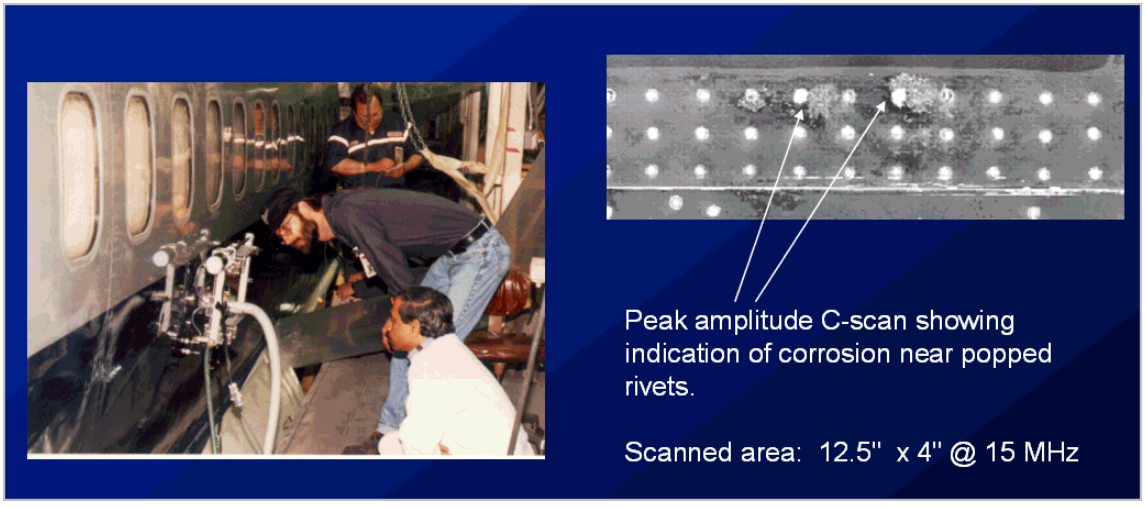
Dripless Bubbler: Portable Scanner for Aircraft Inspection

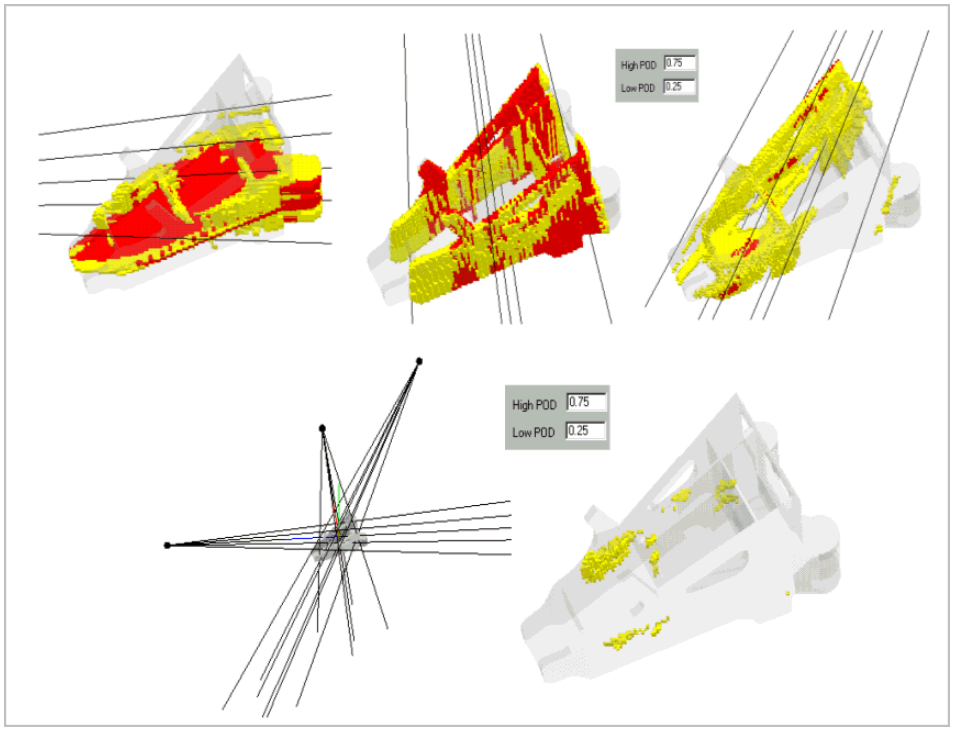
The Center for Nondestructive Evaluation (CNDE) has developed a fieldable ultrasonic scanning system for aircraft inspection. It was developed by the Composite Group of CNDE, led by Prof. David K. Hsu. The "Dripless Bubbler" is the first portable ultrasonic scanner with a closed-cycle water couplant 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 allows the use of 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.



Above: Dripless Bubbler Field Demo at NWA- Corrosion Detection on Boeing 747

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&D100 award. The Dripless Bubbler was licensed to and commercialized by Sierra Matrix, Inc. of Fremont, California. The technology was used in addressing the corrosion problem of KC135 wing skins around fasteners. For more information, contact professor David K.Hsu, 515-294-2501; e-mail: dhsu@cnde.iastate.edu.

Simulation Tools for Nondestructive Evaluation

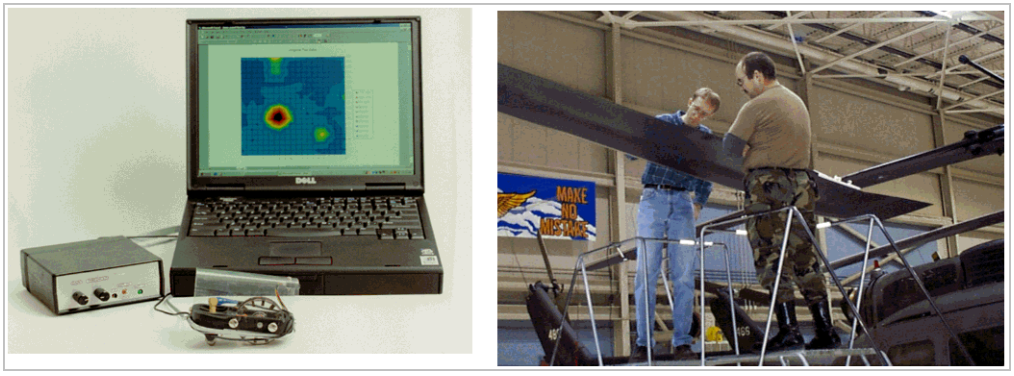


Simulation tools have been developed that make it possible to predict the results of nondestructive evaluation (NDE) measurements to detect and characterize flaws in structural materials. These incorporate rigorous, physics-based models, and procedures to determine the necessary input parameters to describe 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 OEMs 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; e-mail: 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, dhsu@cnde.iastate.edu.



Left: The CATT system. *Right*: Inspecting a Black Hawk rotor blade with CATT.

Center for Precision Metrology (CPM)

University of North Carolina-Charlotte
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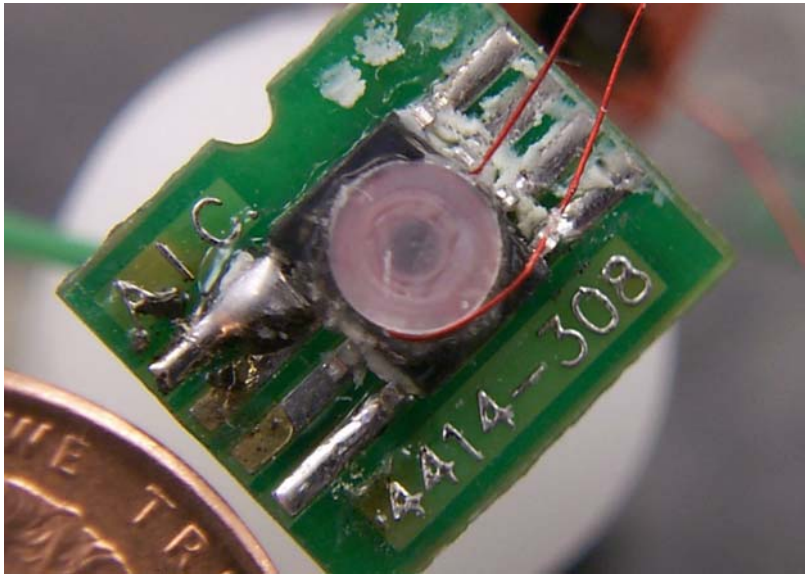
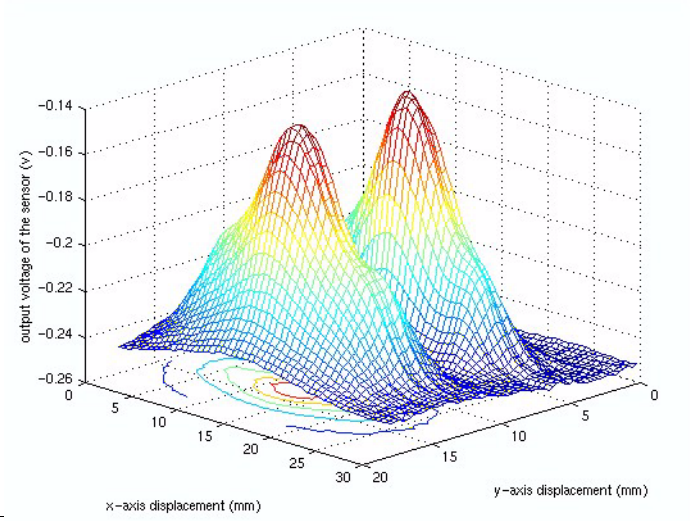
Giant Magneto-Resistive Eddy Current Sensor

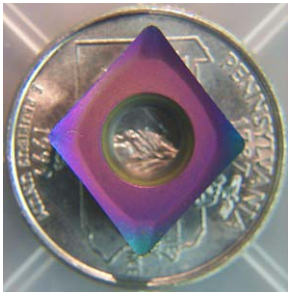


These miniature sensors utilize the Giant Magneto-Resistive (GMR) property that has been demonstrated in some materials. The GMR property is present when an external magnetic field significantly alters the resistance of a conductor. The device produces a magnetic field and then measures it using a GMR 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, 704-547-4863; e-mail: hocken@uncc.edu.



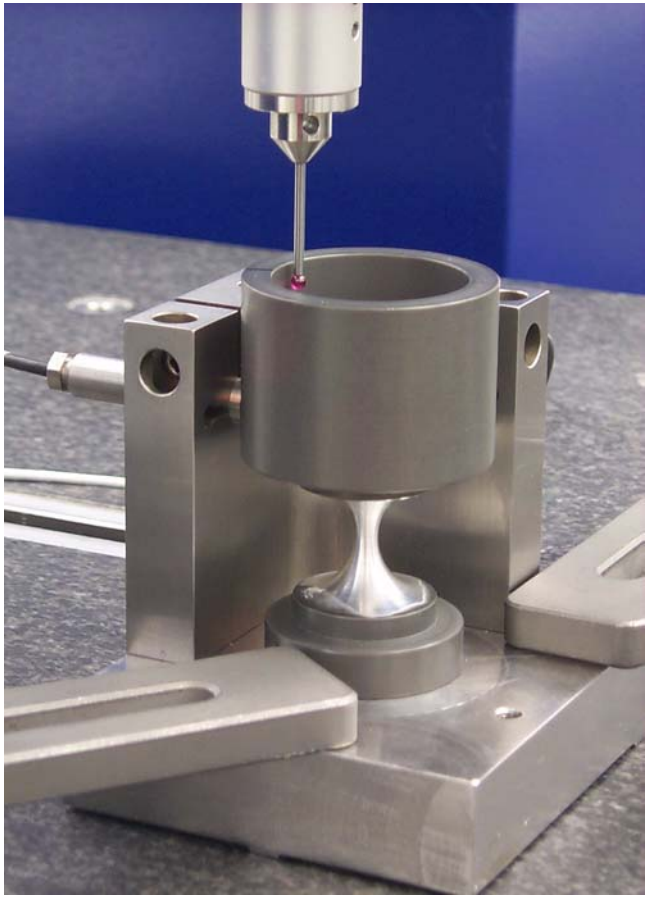
Diamond Thin Films



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 useful properties. It is hard and it is a excellent thermal conductor. The results of coating tools with diamond are greater wear resistance and the removal of heat from the tool/workpiece interface. The latter may increase the material removal rate for materials such as titanium which have traditionally been machined at very slow rates to prevent flash combustion and material softening due to near melting temperatures. Additionally less coolant may be required resulting in a more environmentally friendly process. The processing techniques provided the basis for the development of technologies for a pending patent. For more information, contact Robert Hocken, 704-547-4863; e-mail: hocken@uncc.edu.

Standards for Tight-Tolerance Manufacturing Machines

Several projects were 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, 704-547-4863; e-mail: hocken@uncc.edu.



Center for Process Analytical Chemistry (CPAC)

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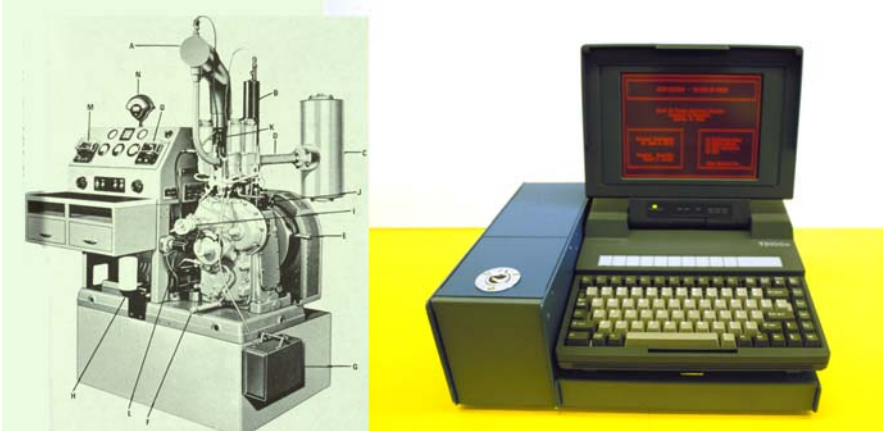
Non-Destructive Spectroscopic Measurement: Inline Octane Sensor

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, 206-543-1208; e-mail: callis@u.washington.edu.



Above: Before and after images of the equipment.

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. And, 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, e-mail: bskowalski@mydurango.net or Mel Koch, 206-616-4869; e-mail: mel@cpac.washington.edu.

Center for Sensors and Actuators Center (BSAC or CSAC)

University of California, Berkeley and Davis Campuses
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Dr. Norman Tien, Director (UCD)
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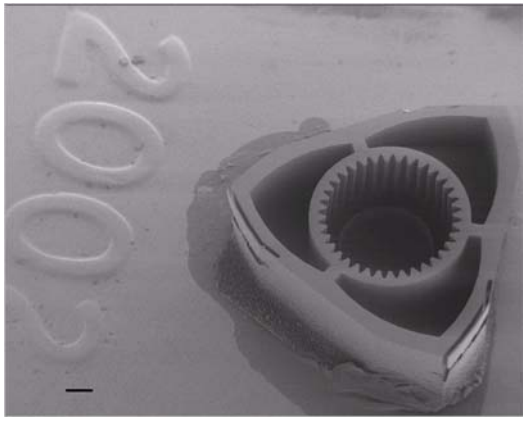
Rotary Internal Combustion Engine on a Chip



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 900µm. 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, walther@eecs.berkeley.edu.

Radio-Equipped Wireless Sensors called “Smart Dust”

The Sensors and Actuators Center (BSAC) at the University of California, Berkeley has developed hardware and software for sensor networks. These radio-equipped wireless sensors called "Smart Dust" are larger than dust particles; about a cubic centimeter in size. Deployed in large numbers across a battlefield, they can track troop movements. Embedded in a road, they can report traffic density. Several BSAC member companies are funding additional R&D, and a startup called Dust, Inc. has been launched. Intel has established a new research lab in Berkeley to pursue research in this area. For more information, contact Kris Pister at kpister@dust-inc.com.

Center for Surface Engineering and Tribology (CSET)

Northwestern University and Georgia Institute of Technology

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Dr. Steven, Director at Georgia Institute of Tech.
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Design of Energy-Saving Lubricants

Research at 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 the 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; e-mail: l-keer@northwestern.edu or Michael Hoeprich, e-mail: 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; e-mail: 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; e-mail: l-keer@northwestern.edu.

Center for the Study of Wireless Electromagnetic Compatibility

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Web site: 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; e-mail: 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; e-mail: 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; e-mail: 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; e-mail: 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 the pacemaker companies to better understand how to design their 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; e-mail: 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 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 (EMC), 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 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; e-mail: emc@ou.edu.

Center for Tree Genetics (CTG)

Oregon State University
Dr. Steven H. Strauss, Director
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E-mail: Steve.Strauss@orst.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. CTG 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 CTG 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, CTG 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, 541-737-6578; e-mail: Steve.Strauss@orst.edu.

Precocious Flowering in Populus

Federal regulators have made it clear that a transgene confinement system must be developed before genetically engineered trees can be deployed commercially. Center researchers are attempting to genetically engineer reproductive sterility 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 impart sterility, researchers must wait for flowering to occur. 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. CTG 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. CTG experimented with a variety of inductive treatments and discovered one that restored the early-flowering phenotype. Center researchers now have an effective model system for testing sterility constructs, without having to conduct lengthy, expensive field trials. For more information, contact Rick Meilan, 765-496-2287; e-mail: rmeilan@fnr.purdue.edu.

Center for Virtual Proving Ground Simulation (CVPGS)

University of Iowa, University of Texas-Austin

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National Advanced Driver Simulation Facility

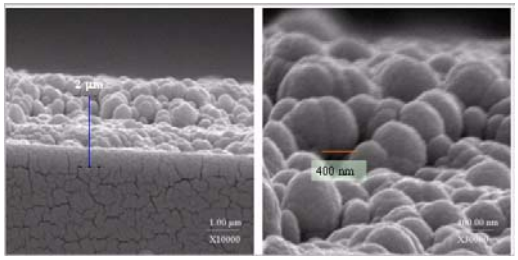
The I/UCRC for Virtual Proving Ground Simulation at the University of Iowa and the University of Texas at Austin has developed a world-class facility that pushes the envelope in high-speed mechanical system simulation, providing a revolutionary new capability to test vehicle designs using a super-realistic driver interface. The center's National Advanced Driver Simulation (NADS) facility, completed in 2002 at a cost of around $80M, is being used by companies like John Deere for "operator-in-the-loop virtual proving" of new vehicle systems before they are built, as well as by agencies like the National Highway Traffic Safety Administration to conduct highway safety studies under precisely controlled and safe experimental conditions. NADS is the only driving simulator in the world in which such activities can be carried out in a full 360^{o} wrap-around virtual environment.

For more information, contact L. D. Chen, 319-335-4851; e-mail: ldchen@nads-sc.uiowa.edu.

Ceramic and Composite Materials Center (CCMC)

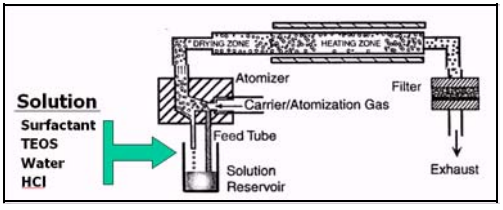
University of New Mexico, Rutgers University
Professor William Koenke, Co-Director
Phone: 505-277-6824
E-mail: yonder@unm.edu.

Ambient Pressure Technology



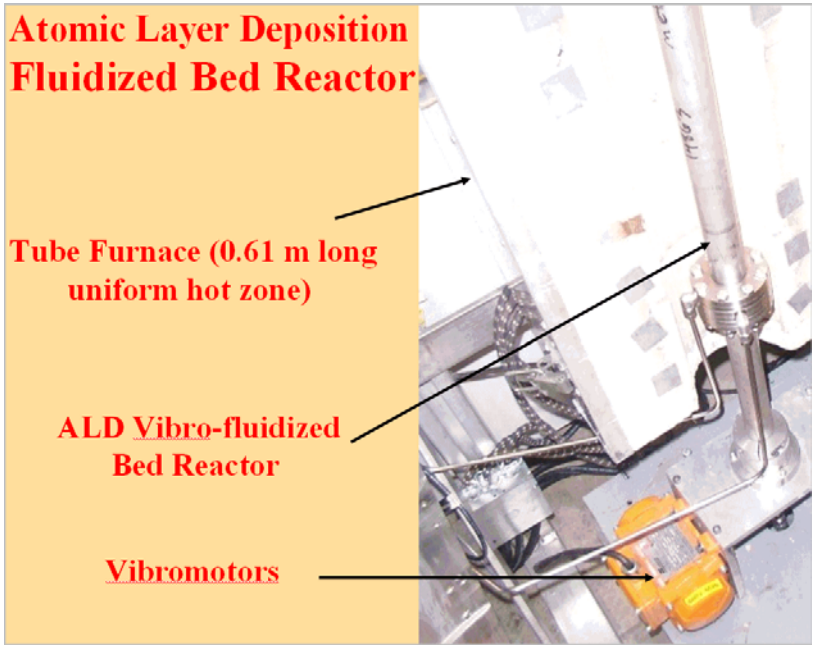
The Ceramic and Composite Materials Center (CCMC) has developed an ambient pressure process for making aerogels and xerogels. Previously these materials had to be made under critical conditions, a commercially unattractive process. This breakthrough technology spawned a spin-of company, NanoPore, which has developed into a multi-million 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; e-mail: 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; e-mail: yonder@unm.edu.

Atomic Layer Deposition Method to Coat Small Particles

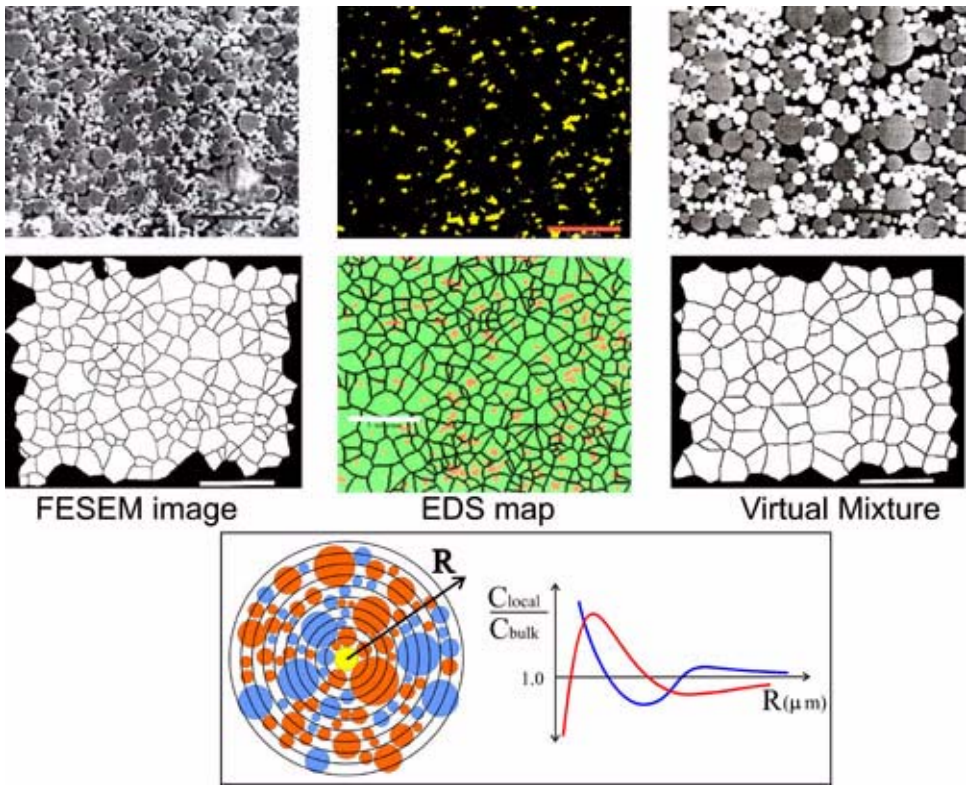


The optimum chemistry for using Atomic Layer Deposition, ALD, to conformally coat fine particles of oxides, nonoxides, and metals with metal oxides has been established under vacuum conditions. The advantage of the ALD technique over other vapor coating processes is that it permits precise deposition 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; e-mail: 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; e-mail: gpopov2@rci.rutgers.edu.

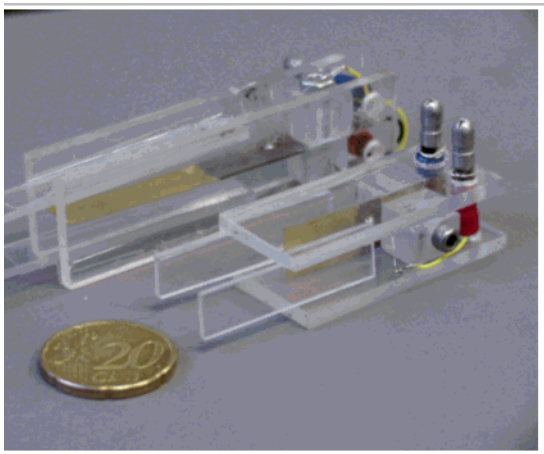


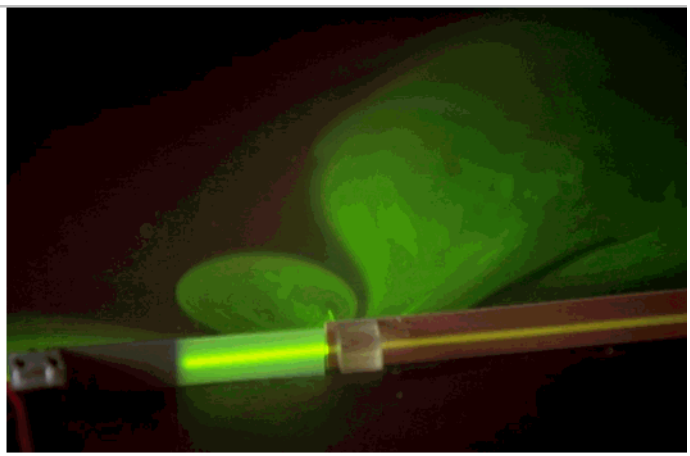
Cooling Technologies Research Center (CTRC)

Purdue University
Dr. Suresh V. Garimella, Director
Phone: 765-494-5621
E-mail: sureshg@ecn.purdue.edu.

Miniature Piezoelectric Fans

Innovative, miniature piezoelectric fans have been developed in this CTRC project (by Arvind Raman and Suresh Garimella) 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 very 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. For more information, contact Suresh Garimella, 765-494-5621; sureshg@ecn.purdue.edu.





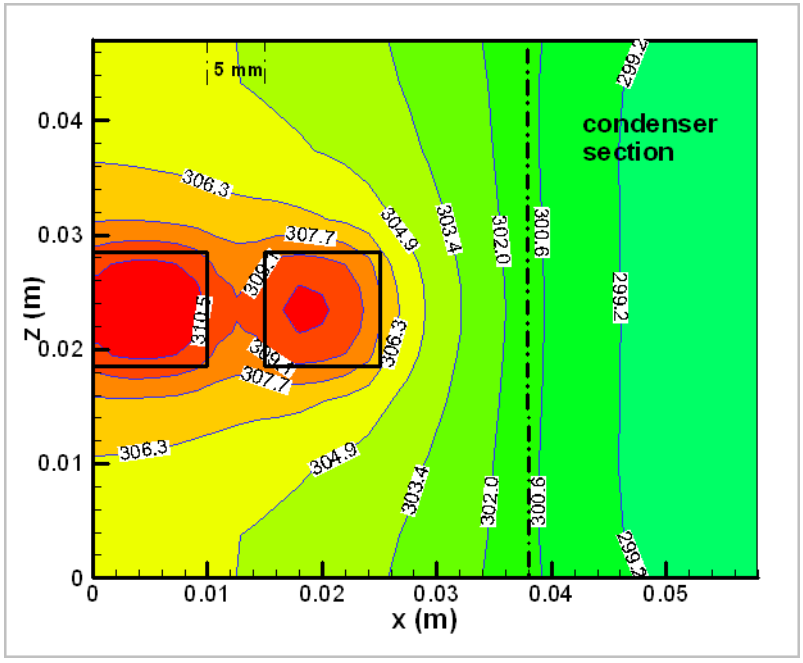
Above: The fans and the visualized flow around it.

Microchannel Heat Sinks

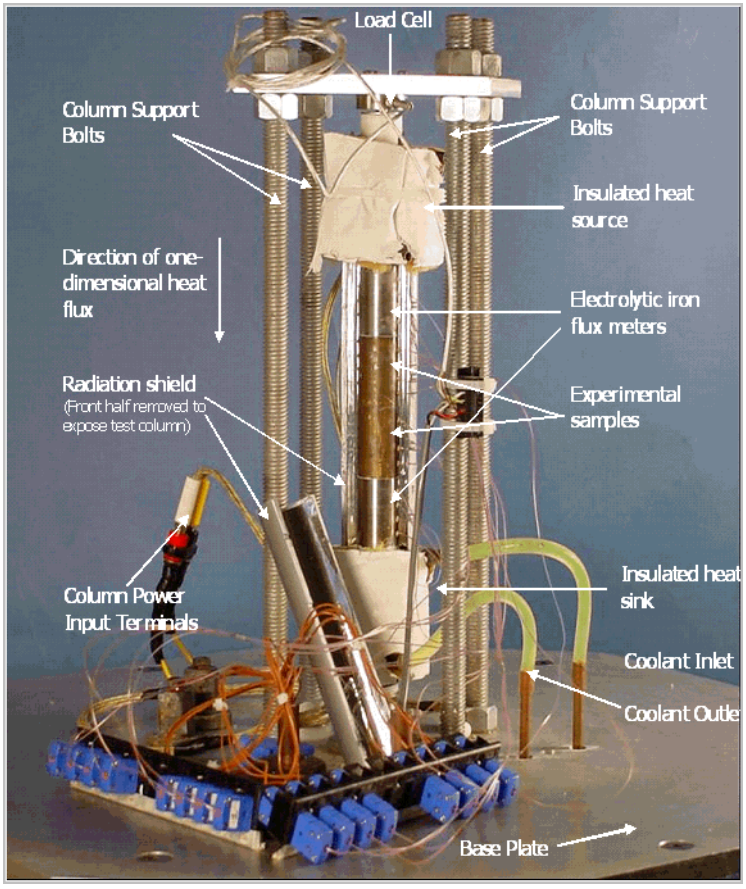
Major strides are being made in this CTRC project in better understanding transport in microchannels, and hence in rendering microchannel heat sinks implementable in electronics cooling applications. Several novel experimental and modeling tools have been developed. Infrared Particle Image Velocimetry (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; this work is a collaboration between Suresh Garimella and Steve Wereley. Accurate velocity measurements are currently possible (from images like the IR photograph which shows tracers flowing through a microchannel) with this technique, and it is being extended to measuring temperatures inside such flows. Boiling in microchannel heat sinks is currently under investigation using this technique. 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. For more information, contact Suresh Garimella, 765-494-5621; sureshg@ecn.purdue.edu.

Miniature Flat Heat Pipes

A first-of-its-kind sophisticated model has been developed through this CTRC project for three-dimensional, transient analysis of non-conventional heat pipe designs for low-form-factor applications in electronics packaging. The software package allows for the design and optimization of heat pipes for operation with multiple, discrete heat sources mounted on the heat pipe; sample temperature contours under two chips mounted on a flat heat pipe are shown in the figure on the rights. The model predictions have been validated against experimental measurements. The model is being used to investigate issues in the miniaturization of heat pipes, including improved wick structures and heat pipe layouts. This project is a collaboration between Suresh Garimella and Jayathi Murthy. For more information, contact Suresh Garimella, 765-494-5621; sureshg@ecn.purdue.edu.



Prediction and Mitigation of Thermal Contact Resistance

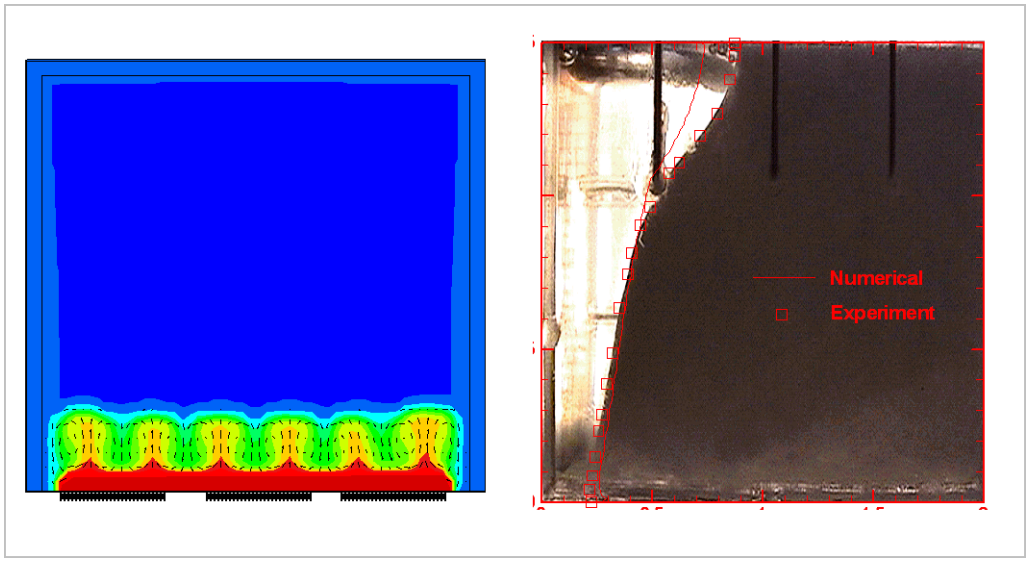


A comprehensive, combined theoretical and experimental investigation has led to the development of a validated model and associated software for the prediction of thermal contact conductance at interfaces in electronics cooling applications at low loads. Contact resistance at different interfaces is a ubiquitous problem in such applications, and can often present the primary resistance to heat flow in an electronics package. The software model allows for better prediction of contact resistance, and compares well with experimental data (obtained from the custom-built facility shown). It can easily be applied to any interface if the material properties are known and profile scans of the surfaces are available. The program combines three sub-models for constriction resistance, surface deformation, and surface characterization into the first contact conductance model of its kind, generally applicable to any flat metallic surface regardless of mode of deformation, gas gap conductivity, or resolution of the scanning instrument used.

For more information, contact Suresh Garimella, 765-494-5621; sureshg@ecn.purdue.edu.

Phase Change Energy Storage For Transient Power Dissipation

Thermal transients occur in power semiconductors and electronics due to the current in-rush while starting a motor, in inductive devices such as heaters and transformers, in capacitive charging, and in power grid management. The suppression of temperature overshoots during the dissipation of transient power spikes is an important challenge in electronics package design. As an alternative to using solid metal heat sinks to absorb the thermal transients from these power spikes, this CTRC project has investigated energy storage into a phase change material (PCM) as an alternative. A versatile software package, easy-to-use analytical formulae, and experimental demonstrations of the use of a PCM storage unit have led to designs that results in lower junction temperatures while at the same time yielding weight and volume savings. Temperature and velocity fields in a PCM storage unit under the action of pulsed heating of three discrete components mounted on the bottom are shown. The photograph is of a simulated unit with a transparent PCM melting from the left, with the calculated interface shape superimposed. Other novel designs of heat sinks exploiting fins and foams impregnated with PCMs are currently being explored. For more information, contact Suresh Garimella, 765-494-5621; sureshg@ecn.purdue.edu.



Industry/University Center for Biosurfaces (IUCB)

State University of New York at Buffalo, University of Memphis

Robert E. Baier, Ph.D., P.E., Director
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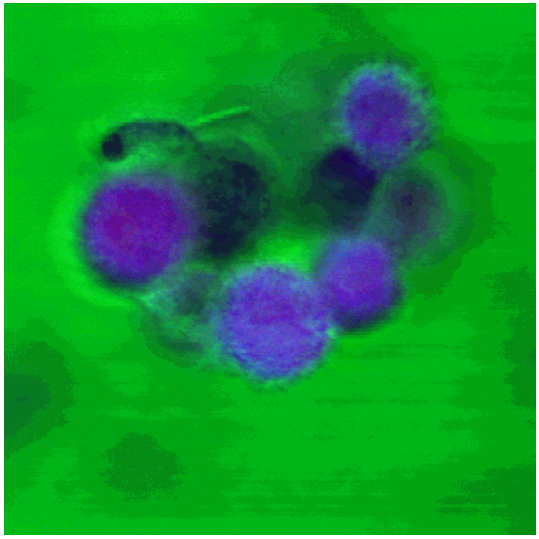
Inadvertent Implants? Visualizing Lung Cell pH



Inhaled particles and pollution can stress lungs, causing asthma and other diseases. Most difficult to remove are long, thin asbestos-like fibers. IUCB has 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. Indigestible fibers, too long to be engulfed, cause lung disease.

Measurement & Control Engineering Center (MCEC)

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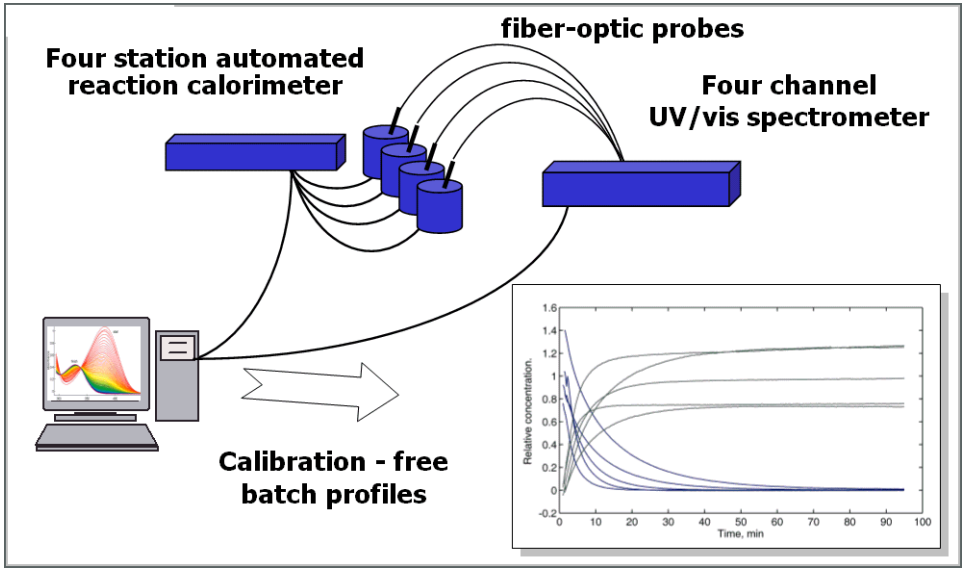
Automated Reactor with Fiber-Optic Spectroscopic Monitoring

Industry scientists have gained a new tool to enhance the development of chemical manufacturing processes thanks to MCEC's chemical reactor coupled with in-situ optical monitoring and data analysis software. An MCEC project led by chemistry professor Paul J. Gemperline, East Carolina University, and small business partner, H&A Scientific, Inc., Greenville, N.C., resulted in a four-station, automated chemical reactor with fiber-optic spectroscopic monitoring. By comparing multiple lab-scale batch reactions, the new instrument allows development scientists in the pharmaceutical and chemical industries to quickly determine process conditions with better yields, faster reaction times, and lower material and energy costs. The technology is able to estimate composition profiles of starting materials, intermediates, and products using novel mathematical resolution techniques developed by Dr. Gemperline. The mathematical resolution technique uses non-negative alternating least squares, a type of self-modeling curve resolution (SMCR). Multi-batch SMCR analysis of consecutive batches permits standardless comparisons of consecutive batches to determine which produced more or less product and which batch proceeded faster or slower. The product was introduced at the 2001 Pittsburgh Conference, the country's largest chemical instrumentation exhibit. Software for the product has broader application and has been licensed to IntelliFORM. For more information, contact Paul Gemperline, 252-328-6767; e-mail: gemperlinep@mail.ecu.edu.



Technology to Monitor and Enhance Fluidized Bed Operations

MCEC research led to the development of new measurement and data analysis techniques to monitor fluidized bed operations. The project was initiated in MCEC and supported by a sponsor; in addition, the sponsor funded a separate proprietary development project outside of MCEC to protect its intellectual property. The technique that has been developed applies nonlinear time series analysis tools based on chaos theory to analyze data from high-speed delta pressure measurements. Based on these results, the status of fluid bed operation can be inferred. This new technology may be used to monitor and improve the performance of fluidized bed operation, thus improving unit efficiency. For more information, contact Duane Bruns, 865-974-5317; e-mail: dbruns@utk.edu.

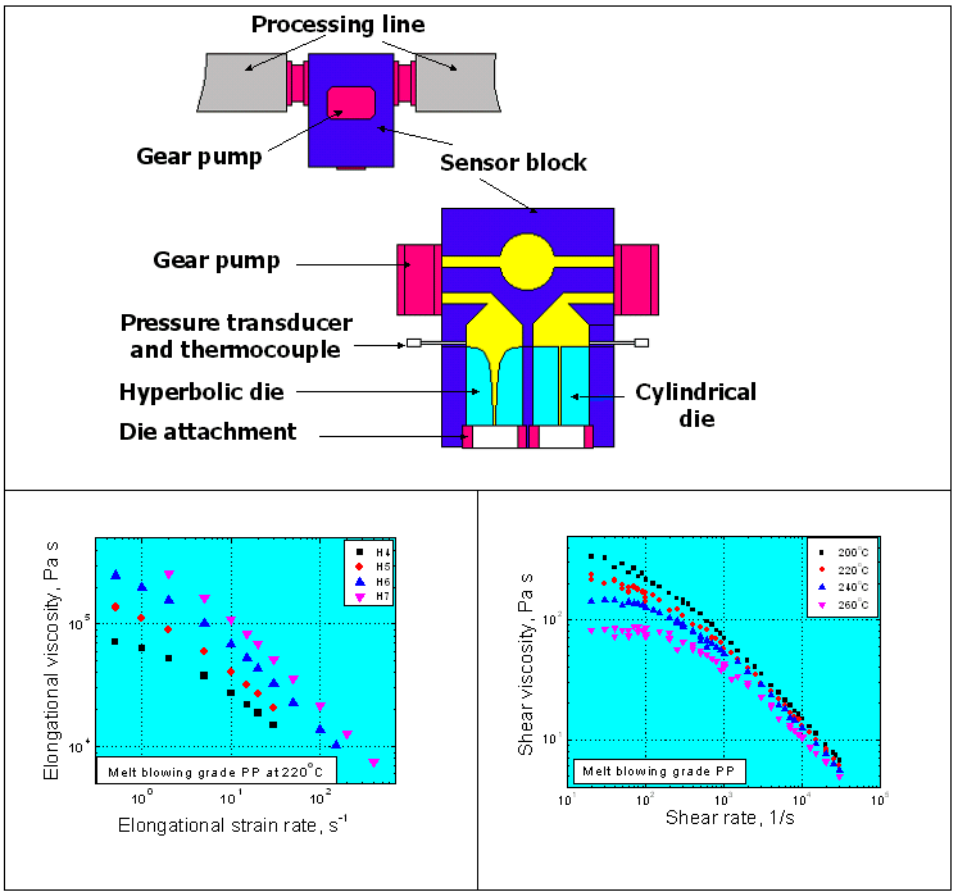
Raman Spectroscopy for On-line Measurement of Chemical Composition in Manufacturing Processes

Initial MCEC research led to a major research grant from the Department of Energy Office of Industrial Technology to develop Raman spectroscopy for on-line chemical measurements. In collaboration with Eastman Chemical, MCEC demonstrated the practical application of Raman spectroscopy to measure the composition of a chemical mixture in a distillation column. Research at MCEC is widely recognized in the early proof of concept. Numerous vendors now manufacture devices that are applied to on-line Raman composition measurement in many manufacturing situations. For more information, contact Charlie Moore, 865-974-5339; e-mail: cfmoore@utk.edu.

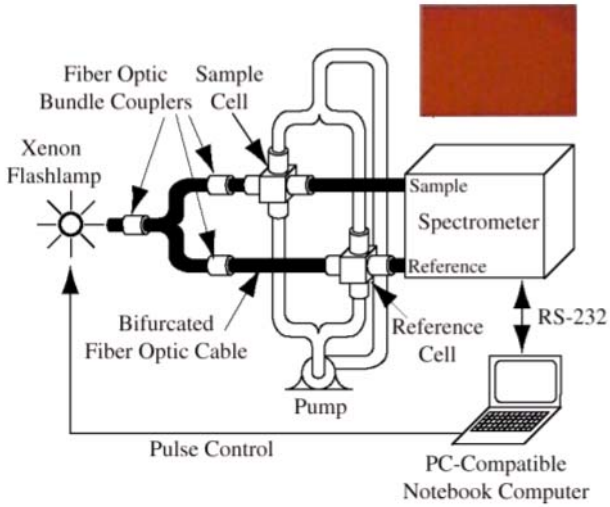
Right: The UT's department of chemical engineering unit operations lab. This device is similar to the industrial unit but much, much smaller. The industrial column is the size of a Saturn rocket but we could not provide pictures of the experimental setup because of proprietary concerns.

Rheology Measurement Technology

John Collier, an MCEC PI at the University of Tennessee, has invented a hyperbolic die and developed the hyperbolically converging flow technique for the measurement of elongational viscosity of polymer melts and solutions over much higher (of industrial interest) ranges of Hencky strains and elongational strain rates, as compared with other techniques. Rheometric Scientific has marketed this die as an accessory for the ACER capillary rheometer. Also, based on the same new technique, an on-line rheological sensor is being developed for the simultaneous measurement of both elongational and shear viscosity. For more information, contact John Collier, 865-974-2421; e-mail: collier@utk.edu.



On-line Optical Sensors for High Acidity and Basicity



Novel optical sensors for high acidity and basicity measurements have been developed by MCEC researchers at the University of Tennessee. These sensors are based on thin sol-gel films encapsulated with selected acid-base indicators, and are designed for the highly acidic and alkaline systems (such as 1-11 M HCl or 1-10 M NaOH) encountered in many industrial processes. Methods have been developed for correction of interferences from metal ions (acid probe) and organic co-solvents (base probe). The sensors have response times less than 5 sec, and are durable for repeated measurements. The probes provide reliable alternatives to the manual sampling and titration approaches often used for acid and base determination in corrosive environments, enabling online acidity and basicity monitoring and control. The PI is working with vendor companies to study commercialization of the technology. For more information, contact Ben Xue, 865-974-3443; e-mail: xue@utk.edu.

Material Handling Research Center (MHRC)

Georgia Tech University

Professor Nemhauser, Director
E-mail: gnemhaus@isye.gatech.edu

Selected Accomplishments

MHRC-developed technologies have resulted in a pattern of substantial cost savings for the Center's industrial sponsors. Selected accomplishments by the MHRC include:

1) Assisting a major electronics manufacturing firm in redesigning its material acquisition operation, which resulted in a reduction of Work-in-Process (WIP) inventory by $100 million while reducing staffing requirements by $3 million annually;

2) Developing quantitative design software used by a major military avionics firm to save $400,000. The firm used the software to review an AS/RS system acquisition designed by traditional methods. The software revealed that the equipment was significantly over-designed, and;

3) Developing algorithms to allocate and slot electronic chips on automatic insertion equipment, which resulted in productivity increases of more than $1 million monthly for a major electronics manufacturer.

For more information, contact Dr. Nemhauser at gnemhaus@isye.gatech.edu.

Photopolymerizations Center

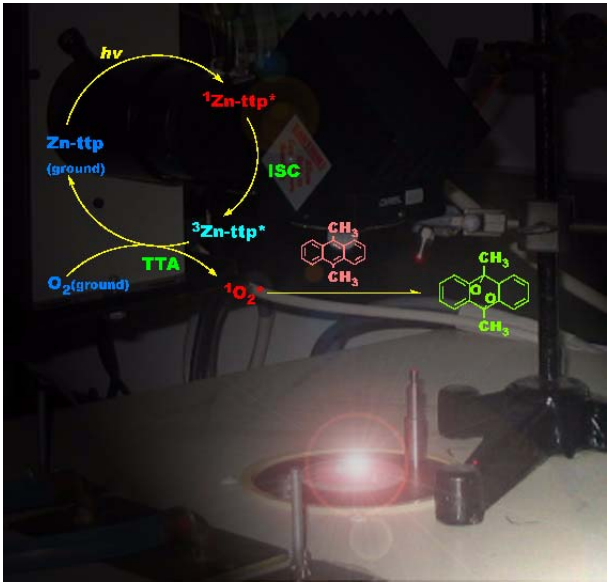
University of Iowa, University of Colorado

Dr. Alec Scranton, Director (UI)

Dr. Christopher N. Bowman (UC)

Phone: 319-335-1414
E-mail: alec-scranton@uiowa.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 by A. Scranton and group. 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. Henkel Loctite Corporation expects this technology to be of significant commercial value.

For more information, contact Alec Scranton, 319-335-1414; e-mail: alec-scranton@uiowa.edu.

Energy-Efficient Adhesives and Coatings

Center research by C. Bowman and group at the University of Colorado has completed the most comprehensive study of thiol-ene photopolymerization kinetics yet undertaken. The findings provide a framework for the development of low-energy consuming adhesive and coating products and they represent a major advance in this field. For more information, contact Christopher Bowman, christopher.bowman@colorado.edu.

Ultra-Rapid Photopolymerization Method

Novel (meth)acrylate monomers for ultra-rapid photopolymerization have been developed by C. Bowman, University of Colorado. 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, christopher.bowman@colorado.edu.

Dental Restorative Materials

Professor Bowman's research in the field of dental restorative materials has recently received a great deal of attention and numerous accolades. His 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 Bowman's group utilizing 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. Bowman's most recent efforts with Professor Stansbury has resulted in the collaborative development of an instrument to simultaneously measure degree of conversion and polymerization shrinkage stresses of polymerizable materials. 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, christopher.bowman@colorado.edu.

Power Systems Engineering Research Center (PSERC)

Cornell University, Arizona State University,
University of California - Berkeley, Carnegie Mellon University,
Colorado School of Mines, Georgia Institute of Technology,
Howard University, University of Illinois at Urbana-Champaign,
Iowa State University, Texas A&M University,
Washington State University, University of Wisconsin-Madison,
Wichita State University

Dr. Robert J. Thomas, Director
Phone: 607-255-5083
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Dr. Dennis Ray, Executive Director
Phone: 608-265-3808
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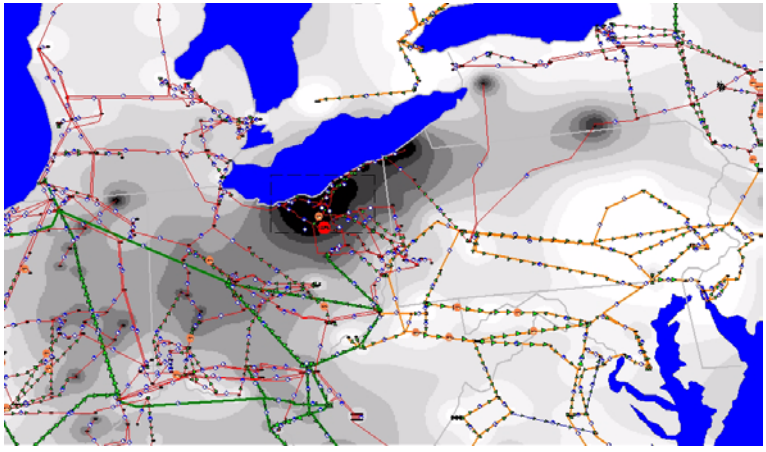
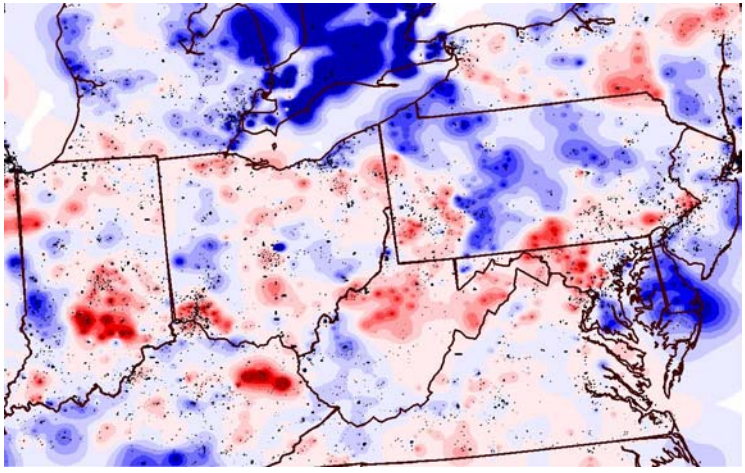
Responding to the Blackout of 2003



PSERC has made significant contributions to understanding and developing solutions to electric power system reliability issues. Researchers from the thirteen-university Power Systems Engineering Research Center (PSERC) are supporting analysis of the Blackout of 2003. PSERC's Director at Cornell University was on leave to the U.S. Department of Energy's new Office of Electric Transmission and Distribution, where he provided technical briefings and materials to investigators and helped to establish priorities for the office, including research priorities. 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. Interviews with PSERC researchers have appeared in news media around the world. The center is providing resources to help people understand the blackout. For example, 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; e-mail: rjt1@cornell.edu.

Image on previous page: 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.

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. And 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, could be applied to complex electricity market design has contributed to new methods for market design policy development that is 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, e-mail: rjt1@cornell.edu.

Improvements in Power System Reliability

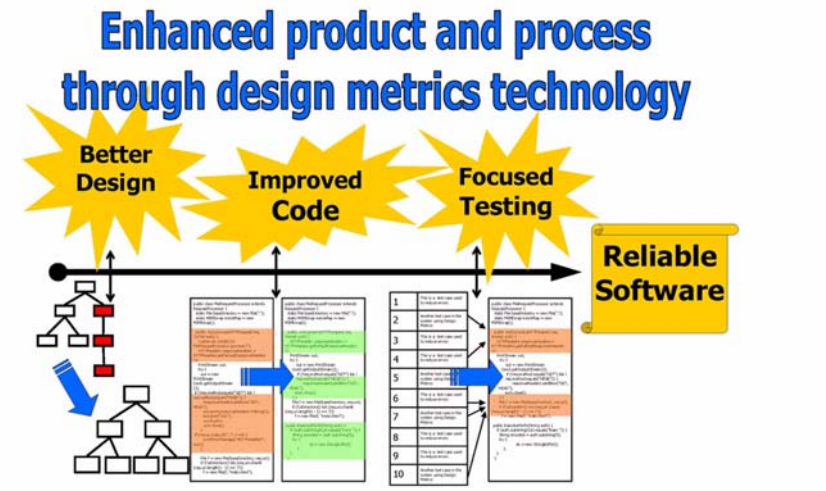
Power system reliability is increasingly a concern to the power industry and society at-large. PSERC researchers have played leading roles in studying reliability problems and suggesting solutions. PSERC researchers contributed to an important study that was published in May, 2002 for the U.S. Department 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; e-mail: rjt1@cornell.edu.

Software Engineering Research Center (SERC)

Ball State University, Purdue University, and West Virginia University
Dr. Wayne M. Zage, Director
Phone: 765-285-8664
E-mail: wmzage@bsu.edu

Design Metrics Technology

Improvements in the software development process depend on our ability to collect and analyze data drawn from the various phases of the development life cycle. The Software Engineering Research Center (SERC) Design Metrics Team has developed a metrics-guided methodology for software reliability that begins with architectural design. This technology provides a framework that is unbiased, efficient, and cost-effective to determine design improvements, code-modification, and testing and management strategies. Applying this methodology to software designs highlights the stress points and determines overall design quality. Stress points are defined as critical components in software where errors in coding and programming logic are likely to occur. Identifying such components in advance and applying mitigating approaches results in effective resource allocation. In the coding phase, the technology can identify those stressful components and provide change impact analysis. In testing, the metrics can assist in determining where testing effort should be focused and the types of test strategies to employ. In the thirteen years of metrics validation, on a wide variety of projects ranging from missile defense, satellite, accounting, and telecommunications systems to interactive games, the design metrics have identified at least 75 percent of the error-prone components 100 percent of the time with very few false positives. Applying the design metrics technology can assist developers in engineering quality into the software product. For more information, contact Dr. Wayne M. Zage, 765-285-8664; e-mail: wmzage@bsu.edu.



Spotlighting the Code

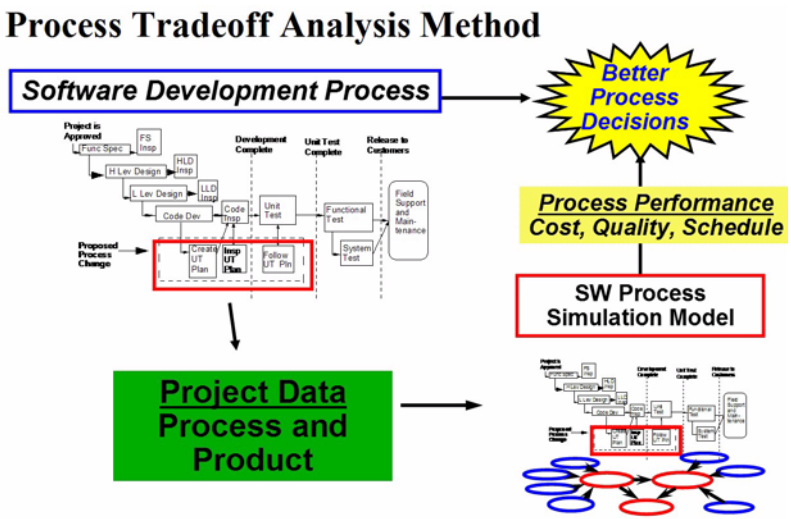
Professor Norman Wilde has developed a technology called the Reconnaissance Tool to find specific sections of computer code that carry out specific functions. A recent example is quickly identifying sections of computer code with date information that were susceptible to Y2K problems. The software is widely available. For more information, contact N. Wilde, University of West Florida, 850-474-2548; e-mail: nwilde@uwf.edu.

Smart Manuals

Large organizations such as the U.S. government and industrial operations often have many thousands of pages of manuals. These present considerable challenges not only in terms of locating information, navigating large document systems, eliminating overlaps/redundancies, and upgrading information, but also in providing guidance for users in carrying out work based on the manual information. Professor Hany Ammar of West Virginia University has worked with a government contractor called ManTech Inc. to develop a prototype design of a smart interactive electronic technical manual that provides many advantages over previous approaches. The prototype not only enhances the interactions of users with these large manuals, but can also receive input from users to help in diagnosing problems and can guide them through the repair process. The method uses Bayesian nets to determine the most likely problems and best courses of action. The method is more flexible, more interactive, accepts more user inputs, and provides more guidance than previous technologies. For more information, contact Many Ammar, West Virginia University, 304-293-0405 ext. 2514.

Improvements in Software Development Processes

Professor Raffo, Portland State University (PSU), has worked to achieve rapid deployment of process models to improve software development. The method provides a more rapid and effective way for organizations to analyze and improve the way they develop software. The rapid process modeling Raffo has developed working with Lockheed could reduce the barriers to use of modeling and simulation to improve software development processes.



Safety in SmartHomes

With the increasing availability of low cost wireless devices such as cellular phones, medical devices, and home networking devices, it is now possible to remotely and programmatically control various devices and events at home, and outside. However, while offering increased flexibility and convenience to humans, these devices have also raised the possibility of serious malfunction due to proximity. For example, aircraft navigation systems and medical implants are affected adversely by cellular devices and other devices that emit large amounts of radiation such as an NMR. Despite stringent emission standards, proximity of two or more devices, often of different kinds, can raise serious threats to human life. The SmartHome project has investigated, among others, issues of safety. A key contribution of this work is universal software/hardware architecture for devices that radiate. Such an architecture, obtained with the help of Digital Device Manuals, allows controllers embedded in various life threatening environments such as hospitals and aircraft, to ensure safe operation of mobile and other radiating devices. For more information, contact Aditya Mathur, 317-494-7822; email: apm@cs.purdue.edu.

Silicon Wafer Engineering and Defect Science Center (SiWEDS)

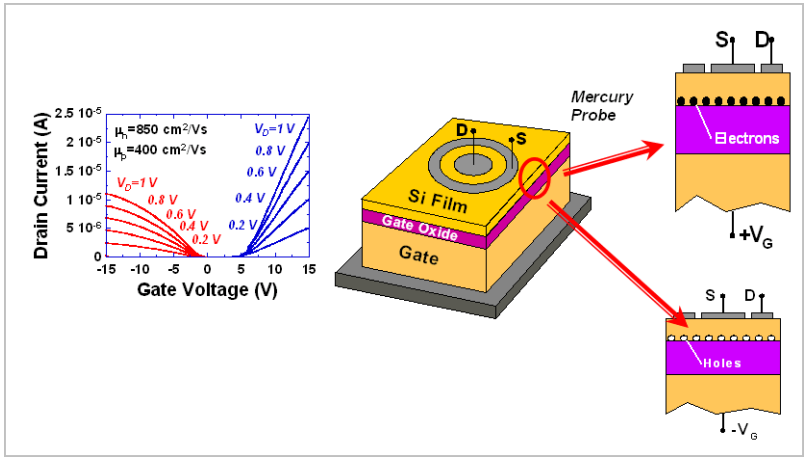
Arizona State University, Hanyang University (Korea), UC Berkeley
MIT, North Carolina State University, Stanford University,
Waseda University (Japan), University of Washington

North Carolina State University
Prof. G.A. Rozgonyi, Director
Phone: 919-515-2934
E-mail: rozgonyi@ncsu.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; e-mail: 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 and which resulted in classical textbook data on Cu in Si to be revised. 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 the SiWEDS member companies, which used it for improving of 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; e-mail: istratov@socrates.berkeley.edu or Eicke Weber, 510-642-0205; e-mail: 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 1E15cm^{-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; e-mail: nas_karoui@ncsu.edu.

Water Quality Center (WQC)

University of Arizona
Dr. Ian Pepper, Director
Phone: 520-626-3328
E-mail: ipepper@ag.arizona.edu

Land Application of Bio-Solids

There has been considerable national debate over the safety of land application of bio-solids. Such applications have been under a moratorium in many areas of the country as a result of public concern about potential adverse health effects from pathogens in the bio-solids becoming airborne contaminants. Research at the Water Quality Center showed that the risk of such airborne contamination is low. The center's research was instrumental in reversing or preventing moratoriums on land applications of bio-solids in Solana County, Calif., and Loudoun County, VA. For more information, contact Dr. Ian Pepper, Director, 520-626-3328; e-mail: ipepper@ag.arizona.edu.

Above: The Water Quality Center evaluates water quality issues related to land application of liquid biosolids.

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 Dr. Ian Pepper, Director, 520-626-3328; e-mail: 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 Dr. Ian Pepper, Director, 520-626-3328; e-mail: 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.

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.