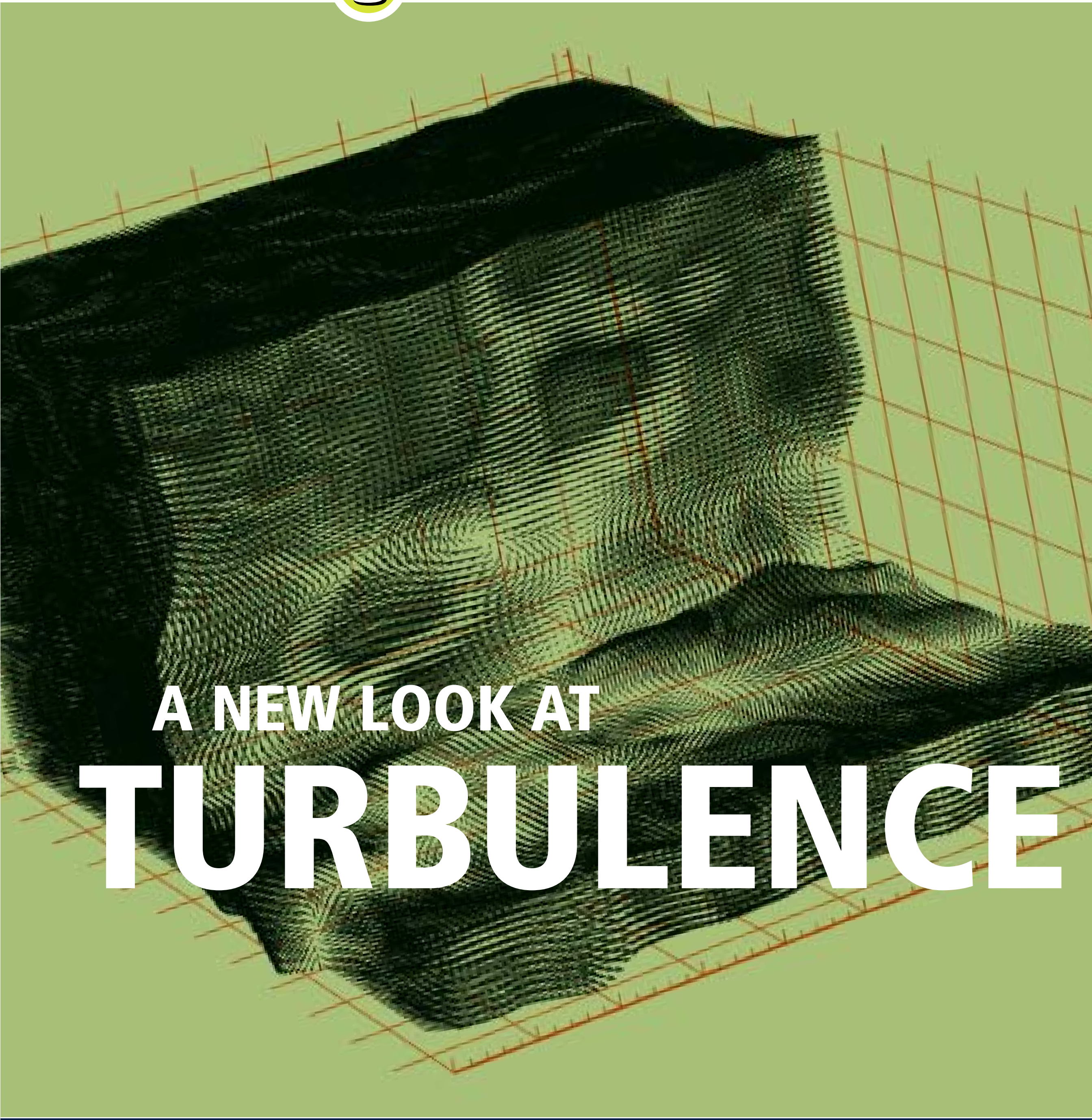

A NEW LOOK AT TURBULENCE

School of Engineering and Applied Sciences

University at Buffalo *The State University of New York*

www.eng.buffalo.edu

FROM THE DEAN

Mark H. Karwan
Professor and Dean

Overview and past issues available at: www.eng.buffalo.edu/IgnitingIdeas

This publication, *Energy, Flows, and Materials Processing*, is the fifth in a six-issue *Igniting Ideas* series highlighting our school's research focus areas. Each area contributes to our strategic objective of performing high quality research while preparing future professionals for industrial, academic, and government positions.

Included in this issue are processes and devices that use combustion, turbulence, and fluid dynamics to achieve advancements in fire suppression, industrial mixing processes, and water and air quality. We've included findings on heat management and aging that contribute to more robust power distribution, computers, and electronics.

Also in this issue are important recent awards recognizing our faculty and students. In particular, I am pleased to announce:

- **Tsu-Teh Soong, Samuel P. Capen Professor of Engineering Science, was named SUNY Distinguished Professor, the highest academic rank in our system**
- **Three of our junior faculty—Paul DesJardin and Venkat Krovi, mechanical and aerospace engineering, and Hung Quang Ngo, computer science and engineering—are 2004 NSF CAREER Award recipients**

Please enjoy!

ENGINEERING AT THE EDGE

Turbulator Suits Give Swimmers an Edge

A team led by two UB scientists has developed the turbulator, a swimsuit element that reduces drag and improves times for swimmers. In a sport where every millisecond counts, the turbulator could improve a swimmer's time by three percent. Led by professors Joseph Mollendorf and David Pendergast, interdisciplinary scientists specializing in physiology, biophysics, and mechanical and aerospace engineering, the team developed the turbulator by building on their expertise in fluid dynamics and their successes in decomposing drag into its component forces.

The turbulator is a strategically placed, fabric-encased, flexible tube that appears as a raised ridge on the suit. The team found that when water hits the shoulders of a swimmer, it separates from the body, creating drag. By adding a turbulator, water follows the contour of the body rather than separating from it. The device increases friction drag, the force of water molecules as they pass over the body, but reduces pressure drag, which occurs as a swimmer pushes water out of the way.

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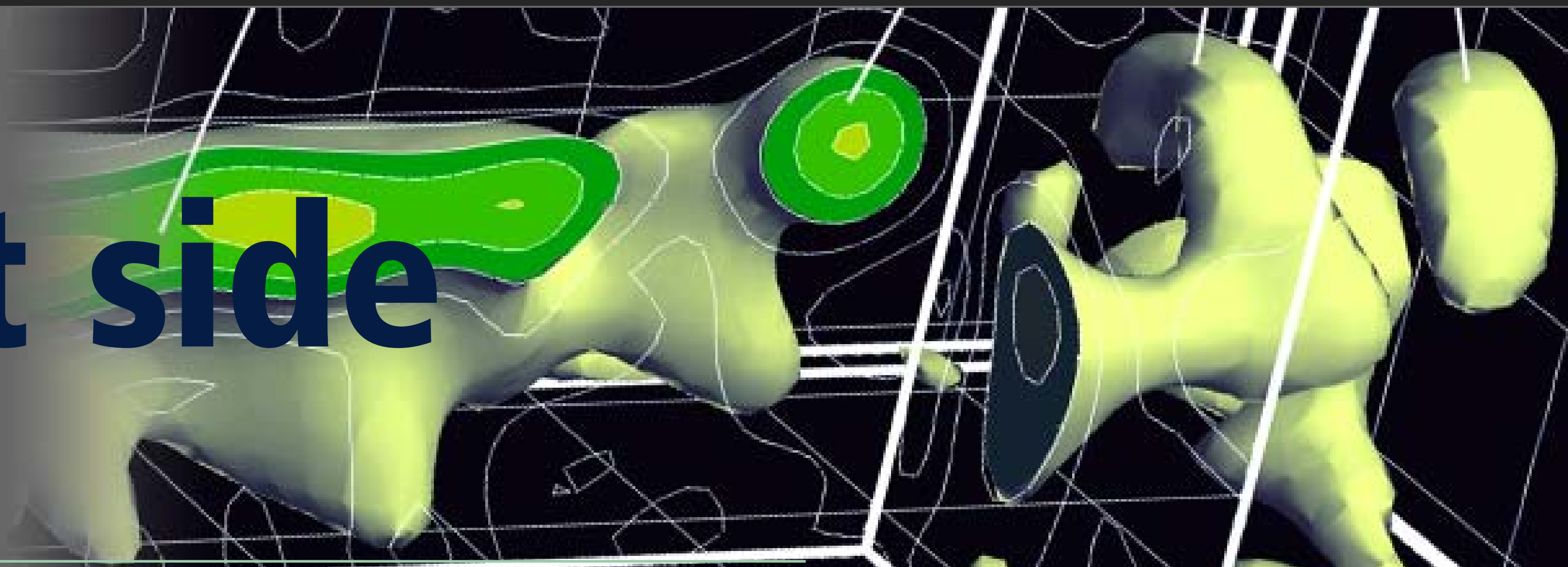
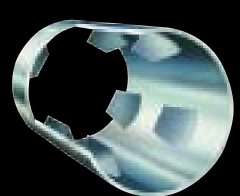


THE turbulent side OF SCIENCE

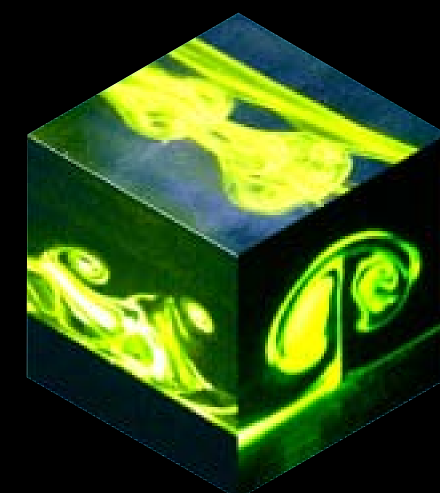
UB engineers and applied scientists are reshaping our understanding of turbulence—and holograms and lasers are their tools of choice

Using holography and powerful pulsed lasers, Hui Meng, professor of mechanical and aerospace engineering, and colleagues working in the Laser Flow Diagnostics (LFD) Lab are taking a new, dynamic look at turbulence, one of the great unsolved physics problems. Turbulent flow is ubiquitous not only in the human body, the environment, and meteorology, but also in airplanes, automobiles, power generation, the chemical process industry, and materials processing.



To better understand, model, and control turbulent flows, the multidisciplinary group has developed Holographic Particle Image Velocimetry (HPIV), delivering detailed full-field measurement. Using the technology, researchers are able to process fluid dynamics in three dimensions over time, with spatial resolutions comparable to those of direct numerical simulations (DNS). The system—which is based on groundbreaking off-axis holography, distributed computing, and 3-D data processing—has been reinforced by advancements in digital imaging technology to directly record holograms, eliminating the need for wet chemical film processing and enabling cinematic HPIV to record time-resolved measurements. The LFD Lab is already applying this robust tool to aerospace, industrial, and biological problems.

Understanding the sorting of particles within turbulent flows is critical for increasing the efficiency of moving, using, and separating particles, whether for chemicals, foods, or pharmaceuticals. Collaborating with Dow Chemical, LFD researchers improved industrial mixing processes by imaging vortex dynamics in flow past surface-mounted tabs in high-efficiency vortex mixers.

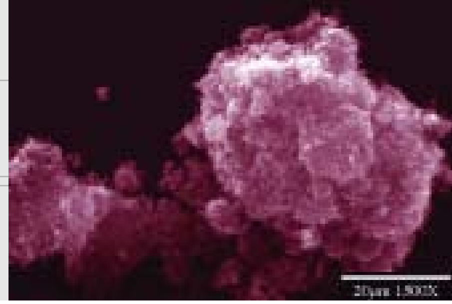


Currently, LFD researchers are working with NASA to study turbulence particle interaction in a microgravity setting. This fundamental research has far-reaching implications in areas like environmental quality. Efficient particle segregation is crucial in sealed cabin environments of spacecraft, where resources are limited and fresh air is scarce, and would be a requisite capability for any human mission to Mars or further.

Increasingly, Meng's research is shifting into biological applications where the dynamics of blood flow and cell movement take on life or death consequences. Advanced particle imaging techniques like digital holography and HPIV are being used to investigate the hemodynamics and cellular response in the treatment of cerebral aneurysms.

Scott Woodward, technical director, has been a key member of the LFD Lab research team. Meng's work on cerebral aneurysms is supported by the National Science Foundation; the National Institutes of Health has invested in her transition to a quantitative research career focused primarily on questions of health and disease.

Material Convergence



Deborah Chung, Niagara Mohawk Chair Professor of Materials Research in the Department of Mechanical and Aerospace Engineering, has taken the challenges of interdisciplinary engineering and made them the creative core of her successful research. In addition to pursuing groundbreaking discoveries with carbon, Chung's research creates convergent qualities in divergent structural materials such as concrete and polymers.

Chung and her team have developed specialized self-sensing materials useful in both airplanes and buildings. Chung has also developed polymers and concrete that shield electronic devices. Among her other advancements are self-heating structural materials that may prove useful for de-icing aircraft and runways.

Recently, Chung has developed a thermal paste that promises to help solve the problem of overheating in high-performance personal computers and electronics. The paste, developed from inexpensive carbon black, is extraordinarily conformable and conductive, making it superior to other thermal pastes, including those involving exotic materials such as carbon nanotubes and diamond. Remarkably, Chung's thermal paste significantly surpasses solder, one of the best materials currently available for improving the thermal contact between two surfaces, and promises to help break down current limits on the performance, speed, and further miniaturization of microelectronics.

Chung's advancements with thermal paste build on her more than thirty-year background in carbon research, including ten years of work made possible by a Defense Advanced Research Projects Agency grant. Her extensive contributions to the field led in 2004 to an American Carbon Society Charles E. Pettinos Award, an international award given once every three years recognizing recent outstanding research accomplishments in the science and/or technology of carbon materials. With over 400 international journal articles and several books to her credit, Chung has covered diverse aspects of carbon science and technology, including research on carbons for structural, thermal, electromagnetic, electronic, environmental, energy, and sensor applications.

Produced by the University at Buffalo Office of Creative Services, University Communications. October 2004. 04-EAS-000.

Purification Devices Harness Flow Principles

A team led by Abani Patra, associate professor of mechanical and aerospace engineering, has integrated a screw pump with photonics to eradicate—within minutes—dangerous bacteria, viruses and other contaminants, such as *E. coli*, salmonella, and anthrax. The device continuously pumps fluid to uniformly expose microorganisms to a high-energy lamp. The action—based on the classical Archimedean-screw principle—pumps even dense liquids and obviates the need for an external pump. The device can fit onto a home faucet. Larger models can be outfitted where a liquid enters a house, office, hospital, or school.

Another group has developed a device that in minutes safely and inexpensively destroys a wide range of airborne biological agents. The BioBlower destroys pathogens by rapidly and continuously heating contaminated air by using mechanical compression. The device can be used as an emergency portable air-purification unit or installed permanently in buildings.

Co-inventors include John Lordi, research professor, James D. Felske, professor, and Joseph C. Mollendorf, professor, all in mechanical and aerospace engineering, and James F. Garvey, professor of chemistry.

Reengineering Rural Power

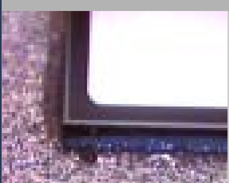
Electric power is foremost on the mind of Mohammed Safiuddin, advanced technology applications professor of electrical engineering and UB Energy Systems Institute fellow. Realizing the archaic state of rural power delivery, which was designed some 70 years ago, Safiuddin used his expertise to develop a new system that would meet the increasingly energy-intensive demands of modern agriculture.

Safiuddin and graduate student Mohammed Y. Soliman teamed with Niagara Mohawk's Technology Transfer and Consumer Relation departments to find an economical, environmentally friendly way to operate the extensive irrigation system of upstate New York's My-T Acres Farm, which spans 8,000 acres in three counties.

Safiuddin and other researchers developed a system that converts three-phase AC power, available far from the farm, to DC power using variable frequency drives that satisfy the power requirements of farm irrigation pumps. As a result, the existing diesel-powered pumps were converted to more efficient, quieter, non-polluting electric pumps. This advancement promises to help farmers and other rural industries—from sawmills to stone quarries to ski areas that require three-phase power not readily available.

350°C Circuits

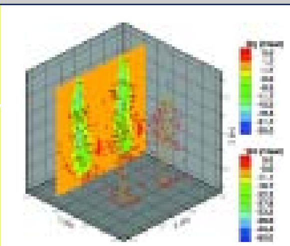
Researchers at the UB Electronic Packaging Laboratory (EPL) and the UB Energy Systems Institute (ESI) have teamed up to develop a new class of embedded circuits able to function in hostile, high-temperature environments. Where normal circuits are limited to 150°C, advanced silicon carbide (SiC) power semiconductors now operate at 350°C, making them useful for severe commercial and military applications.



Sophisticated materials characterization and model development by EPL (featured in *Igniting Ideas #3*) provide predictive reliability modeling of several circuit configurations developed by Douglas Hopkins, ESI fellow and assistant director of EPL. Hopkins' electro-physical topology provides a dense, high temperature, and air-cooled circuit.

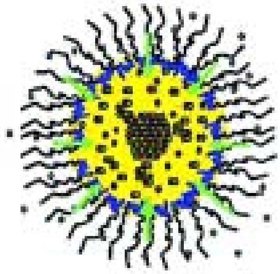
By successfully mating a SiC device to a metalized composite, Hopkins and other researchers are developing a circuit able to endure repeated temperature shifts between -55°C and +225°C. The project is conducted with Cemal Basaran, director of EPL and associate professor of civil, structural and environmental engineering, and is funded by the Naval Research Laboratory.

Taming Infernos with Information



In an effort to aid those who battle large-scale wildfires and urban blazes, Paul DesJardin, assistant professor of mechanical and aerospace engineering, is developing an advanced modeling and simulation framework for predicting the suppression of large fires. The goal of DesJardin's research is to predict the dynamics of flame suppression in highly turbulent, strongly radiating, multiphase flows, ultimately allowing fire protection engineers to enhance the fire suppression systems that protect our critical infrastructures.

This research teams UB with the Sandia National Laboratory, the Naval Research Laboratory, the National Institute of Standards and Technology, and the leaders in fire science from the Departments of Energy, Defense and Commerce. For his research on fire suppression, DesJardin has been recognized with a prestigious NSF CAREER Award (see "DesJardin, Krovi, and Ngo Receive NSF CAREER Awards" in this issue).



A Novel Approach to Synthesizing Quantum Dots

A research team led by T.J. Mountziaris, professor of chemical and biological engineering, has invented a new way to synthesize quantum dots—luminescent nanocrystals made from semiconductor material. Sometimes called artificial atoms, quantum dots potentially can build exciting new devices for biological and environmental sensing, quantum computing, lasers and telecommunications.

The new technique enables precise control of particle size by using a microemulsion template formed by "self assembly." The process involves the direct mixing of a nonpolar substance (heptane), a polar substance (formamide), and an amphiphilic substance or surfactant (a block copolymer) to form a uniform dispersion of heptane droplets in formamide, stabilized by the surfactant. A patent is pending on the technique, recently described in *Langmuir*.

The researchers demonstrated the controlled synthesis of zinc selenide (ZnSe) quantum dots that exhibit size-dependent luminescence. When excited by ultraviolet light, quantum dots emit a particular fluorescent color and brightness, depending on the dot's size. These ZnSe quantum dots have maintained their luminescent properties for over a year.

The technique precisely controls the size (and luminescence wavelength) of the ZnSe dots in one step. "The challenge of quantum dot technology has been how to make dots of a precise size, how to functionalize the surface and also scale up the process for commercial applications," Mountziaris says. "Our technique can be scaled up very easily because it is based on self assembly and does not depend on mixing efficiency or process time to control the size of the dots. We have demonstrated 'dial-a-size' capability."

The team is also developing water-soluble caps that would enable the dots' use as biological tags. A sequence of joined multicolor dots possessing different luminescent properties could be used to create "optical bar codes." "This would be very useful in multiplexed experiments by assigning a different function to different groups of dots and tracking them as they attach to different biomolecules," Mountziaris explains.

Mountziaris's co-researchers are Paschalis Alexandridis, professor of chemical and biological engineering; Athos Petrou, professor of physics; and graduate students Georgios Karanikolos and Grigorios Itskos.

DesJardin, Krovi, and Ngo Receive NSF CAREER Awards


DesJardin


Krovi


Ngo

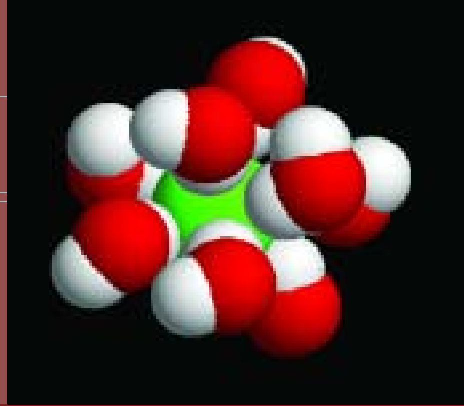
Three junior faculty members from the School of Engineering and Applied Sciences (SEAS) have received prestigious NSF CAREER awards. With their awards, Paul DesJardin and Venkat Krovi, assistant professors of mechanical and aerospace engineering, and Hung Q. Ngo, assistant professor of computer science and engineering, follow in a rich tradition at SEAS, where fifteen such awards have been granted to young faculty members since the award program began in 1997.

DesJardin, featured elsewhere in this issue, is creating advanced predictive simulation software to model and combat large-scale urban blazes and wildfires.

Krovi's research develops robots able to cooperate as they move payloads, accomplishing more by distributing their work than by operating individually. Using complex communication and coordination, these modular robots adapt well to changing conditions or tasks.

Ngo is developing a theory for design and analysis of ultra-fast optical switches—devices at the core of the Internet. He also develops mathematical models of optical switches that allow for a unified view of all kinds of optical switches. Ultimately, these models will provide a foundation for designs that are more economical and efficient.

Packaging Proteins



Jeffrey Errington, assistant professor of chemical and biological engineering, investigates complex fluids and biological systems from a microscopic perspective. By finding ways to preserve proteins and other biomaterials, Errington, who received a 2003 NSF CAREER Award and a 2004 Watson Investigator Award, aims to improve the design of pharmaceutical, personal care, and cosmetic formulations.

Though proteins are becoming increasingly important pharmaceutical ingredients, many are inherently unstable, making them difficult and expensive to store and ship. Fluctuations in temperature during transport may cause the protein to unfold or degrade.

Errington's group is finding ways to temporarily trap proteins in a solid state so that they survive a range of atmospheric conditions. The process works by encapsulating proteins in novel mixtures of polymers and sugars that form a glassy matrix that is largely devoid of water. "We are trying to surround the protein, on a molecular level, with a rigid matrix that prevents it from being able to unfold," says Errington. "The idea is to keep the protein in its native state the entire time." Once product arrives at its destination, it can be reconstituted using a simple solution.

Errington's research is supported by NSF, the American Chemical Society Petroleum Research Fund, and the UB Center for Computational Research.

Fast Prototypes, Smart Materials

Bahattin Koc, assistant professor of industrial engineering, is developing methods to produce complex three-dimensional parts from computer models. An expert in computer-aided design and solid free-form fabrication, Koc's research has applications both in bioengineering and in the fabrication of multi-layered smart materials.

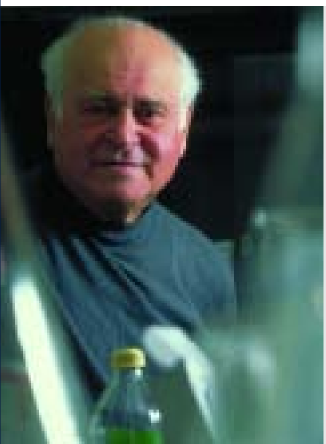
Koc is teaming with Rakesh Nagi, associate professor of industrial engineering, to fabricate heterogeneous smart parts. Together they have developed a new fabrication method based on a reconfigurable tool made out of discrete pins. This approach has yielded a large class of complex and heterogeneous objects that were once impossible to manufacture.

Due to near-instant changeovers, the process is suitable for mass customization in arbitrary lot sizes, and it eliminates completely the need for time-consuming and expensive mold/die fabrication. The rapidly reconfigurable molding process does not require any material removal process to shape molding tools, thereby eliminating material waste, toxic lubricants, and excess energy usage in tooling fabrication.

In related research, models of tissue scaffolds developed by Stelios Andreadis, associate professor of chemical and biological engineering, promise methods to construct new blood vessels for use in heart-bypass surgery. Developed from computer images such as CT scans, MRI scans, and CAD models, the porous structures, which are made partly from biodegradable material, support cells as they form complex tissues.

Eli Ruckenstein: Three Decades of Engineering Excellence at UB

The research interests of Eli Ruckenstein, SUNY Distinguished Professor and member of the UB Department of Chemical and Biological Engineering, cover nearly every aspect of chemical engineering, exhibiting a breadth rarely seen in the work of a single scientist.



Ruckenstein, who has been a UB faculty member since 1973, attributes the remarkable diversity of his scientific work to his own interest in new and exciting things. "What counts in science is novelty," he said. "I am interested mainly in new ideas, which I try to develop and, if possible, find useful applications. However, I don't squeeze them forever. This is what keeps my work exciting."

Ruckenstein conducts both theoretical and experimental research that has, over the years, changed our understanding of fundamental chemical processes and led to enhanced research methods and new materials. He has made groundbreaking contributions in areas including transport phenomena, catalysis, surface phenomena, nucleation, colloids, emulsions, and biocompatible surfaces and materials.

Ruckenstein pioneered thermodynamic theories of microemulsions and liquid crystals and was one of the first to propose models for the aggregation of surfactant molecules in solution, an approach he later extended to other complex fluids. His work developing theories regarding the interaction forces between colloidal particles in colloidal dispersions led him to develop new materials with interesting thermal and rheological properties.

In addition, Ruckenstein has developed new protein separation methods and new technologies to prepare membranes for separation processes that have important biomedical and pharmaceutical applications. His investigations of colloids and emulsions led to the modern theory of microemulsions. Ruckenstein has also developed separation processes that have high selectivity for aromatics, very useful industrial solvents.

Ruckenstein is a member of the National Academy of Engineering and a recipient of the National Medal of Science.

Soong Named SUNY Distinguished Professor

Tsu-Teh Soong, Samuel P. Capen Professor of Engineering Science, was appointed to the elite rank of SUNY Distinguished Professor, the SUNY system's highest faculty designation.

Soong, who joined the UB faculty in 1963, focuses his research on the structural reliability, control, and design of earthquake-resistant structures using active and passive approaches. He was a co-principal investigator on the National Science Foundation grants that established UB's National Center for Earthquake Engineering Research in 1986 and the Multidisciplinary Center for Earthquake Engineering Research in 1997.

Working with Andrei Reinhorn, Clifford C. Furnas Professor of Structural Engineering, Soong co-developed a smart bracing system to control vibrations in skyscrapers. Tested in an experimental building constructed in seismically active Tokyo, the system performed well during several moderate earthquakes. In 1997, the pair won the Association of General Contractors' "Build San Diego" Award for directing a project that protects a San Diego Naval Station building from earthquake damage.

Soong's other awards include the 1999 Norman Medal and the 2002 Nathan M. Newmark Medal, from the American Society of Civil Engineers, and the Humboldt Foundation Senior U.S. Scientist Award in 1988 and 1992.

Sarjeant Leads the Innovation at ESI

Since coming to UB from Los Alamos National Laboratory, W. J. "Jim" Sarjeant, James Clerk Maxwell General Dynamics Chair in Energy Systems, has focused on high-voltage engineering, pulsed-power conditioning, insulation coordination, and, more recently, energy systems ranging from milli-watts to multi-megawatts. His research team at the UB Energy Systems Institute (ESI), an organization Sarjeant founded and now directs, conducts research for industry, government agencies, and military groups while educating the next generation of power and energy systems engineers. Specifically, ESI studies the effect of aging on electronic components and subsystems.

Current research, funded by such groups as General Atomics Electronic Systems, Sandia National Laboratories, TPL, and the U.S. Army, includes:

- Development of efficient power- and energy-dense, hot-swappable mobility platforms
- Development of an ultra-low electrical energy plasma initiation source for pulsed-power applications
- Analysis of thin-film materials via partial discharge
- Validation of partial discharge testing as an accurate, non-destructive predictor of the operational life of insulating materials
- Partial discharge evaluation of thin film polymer insulation for high-energy-density capacitors
- Understanding flashover generation and inhibition for complex insulation structures

ESI's experimental results enhance the performance and lifespans of armaments, communication systems, navigational systems, and satellites. The work has led to innovative insulating materials now used by the automotive and wireless communication industries.

Sarjeant is joined at ESI by colleagues Mohammed Safiuddin, advanced technology applications professor, and Douglas Hopkins, research associate professor.

Sarjeant received the 2004 William G. Dunbar Award at the IEEE International Power Modulator Conference, recognizing his "continuing contributions to high voltage research, development and education and for dedication to transferring that technology to the high voltage community."

UB Wins RoboCup Championship

The UB Robotics team won first place at the 2004 RoboCup American Open, beating competitors from Cornell, Canadian universities Laval and Manitoba, and Instituto Technologico Autonomo de Mexico.

In the competition, teams of up to five robots play autonomously, coordinated only by one or more central computers. Connected to the computers is a camera that, from its position above the playing field, captures images of the game. Image processing software scans each image for the positions and angles of each robot and artificial intelligence algorithms decide the next action for the robots to execute.

With three well-designed and well-coordinated robots, the UB team won all their games, even surpassing teams with more robots. The group included Michael Licitra (Department of Computer Science and Engineering), Stefan Zickler (Departments of Social Science and Psychology), John Casey (Department of Mechanical Engineering), and Sue Potera (Department of Computer Science and Engineering). The group's advisor is Mohammed Safiuddin, advanced technology applications professor.

Next Issue: Visualization, Simulation, and Modeling