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MULTISCALE ENGINEERING

This issue of InFocus is dedicated to the efforts of pioneering faculty and students at the Charles V. Schaefer, Jr. School of Engineering who are making enormous contributions and are creating new knowledge in the frontiers of multiscale engineering.

Dear Friends and Colleagues,

I have often wondered how our world of science and technology would have been shaped if the early Egyptians and Greeks were able to make direct observations at the atomic level. In reality, it wasn’t until the late 15th century that the father-son team of Hans and Zacharias Janssen constructed and put into production the first compound microscope. The magnification power of those microscopes ranged from 3x to 9x but that was enough to open our eyes into a new world. The first scientific treatise of the study of ‘minute bodies’ was written by Robert Hook in 1665, in his book, Micrographia. An explosion in discoveries and scientific advances has taken place since. Yet it was not until 1959 when the genius of Nobel Prize winner Richard P. Feynman captured our imagination with the historic lecture “Plenty of Room at the Bottom.” Feynman opened the door that takes us from observation to the realm of intervention, design and engineering at the atomic level. The term nanotechnology has been coined to capture that leap. Still in its infancy, nanotechnology provides an immensely fertile ground for engineering innovation. As a better understanding of properties, interactions and behavior of materials at the nanoscale emerges, the need for design, manufacturing and mass production of engineered systems across multiple length-scales becomes prevalent. The emergence of complex biological functions, from the cell level to macroscale physiological behavior, has created another frontier of multiscale engineering.

This issue of InFocus is dedicated to the efforts of pioneering faculty and students at the Charles V. Schaefer, Jr. School of Engineering who are making enormous contributions and are creating new knowledge in the frontiers of multiscale engineering. Research in carbon nanotubes, piezoelectric fibers, nanomaterials, enabled photonic sensors, nanopowders for environmental applications, microchemical reactors and nanobiomedical applications are a sample of the exciting work carried out in our laboratories. There is no doubt that engineering in the future will be dominated by diminishing length and time-scales and that we will be increasingly challenged by systems integration and complexity. We will be there to provide the solutions and launch the technologies that meet and overcome those challenges.

As always please do not hesitate to contact me.

My Best Regards,
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"Nanotechnology stands out as a likely launch pad to a new technological era, because it focuses on perhaps the final engineering scales people have yet to master."

Those words appeared in a 1999 report, Nanotechnology: Shaping the World Atom by Atom, by the National Science and Technology Council. Indeed, technologies designed to build complex structures, molecule by molecule, have allowed scientists to create new structural materials 50 times stronger than steel of the same weight, making possible the construction of a Cadillac weighing 100 pounds, according to Ralph Merkle of the Xerox Palo Alto Research Center. It could also, Merkle said in an article in MIT’s Technology Review, “give us surgical instruments of such precision and deftness that they could operate on the cells and even molecules from which we are made.”

A bold new world of science and engineering has opened up, and it has only just begun to hint at the benefits it will yield to humankind.

Well prior to the US Nanotechnology Initiative of 2001, engineers and scientists at Stevens Institute of Technology were performing distinguished and highly recognized funded research in the fields of nanotechnology and microtechnology; and since 2001, with growing federal support in funding and new faculty added to strengthen work in interdisciplinary focus areas, greater strides are being made each year.
INTERDISCIPLINARY RESEARCH IN NANOSENSORS

Dr. Henry Du and his research team have pioneered work on the integration of photonic crystal fibers (PCFs) with nanoscale technologies that will potentially lead to robust chemical and biological sensing devices. The National Science Foundation recently granted Du's team $1.3 million to pursue their multidisciplinary project. Using molecular and nanoscale surface modification, state-of-the-art laser techniques, and computer simulation, their research seeks to enhance the prospects of PCF sensors, sensor arrays, and sensor networks for diverse applications such as remote and dynamic environmental monitoring, manufacturing process safety, medical diagnosis, early warning of biological and chemical warfare, and homeland defense.

"Through basic and applied research," said Du, "the optically robust PCFs with surface-functionalized, axially-aligned air holes are expected to achieve a quantum leap in chemical and biological detection capability over conventional fiber-optic sensor technology."

PCF sensors enabled by nanotechnology also have the potential to be a powerful research platform for in-situ fundamental studies of surface chemistry and chemical/biological interactions in microchemical and microbiological systems. Specifically, PCFs are fabricated via a modified sol-gel method for optical fibers with the aid of a simulation-based design for optimum light-analyte interactions. Nanoscale surface functionalization is conducted following two strategies:

1. Surface attachment of Ag nanoparticles mediated by 3 mercaptopropyltrimethoxysilane self-assembled monolayer (SAM) for chemical sensing of NOx, CO, and SO2, where surface-enhanced Raman scattering (SERS) can be exploited for high sensitivity and molecular specificity; and
2. Surface binding of biospecific recognition entities for biological sensing using the following recognition pairs: biotin/avidin, cholera toxin/anti-cholera toxin and organophosphorous hydrolase (OPH)/paraoxon, where SERS may also be exploited.

Then, the surface-functionalized air holes are filled with analytes in order to evaluate the sensing capabilities of PCFs. Surface functionalization studies employ various surface-sensitive analytical techniques with a range of state-of-the-art laser techniques used for taking measurements. Furthermore, experimental studies augmented by computer simulation take into account the effects of surface functionalization, analyte medium, and biospecific interactions on the optical characteristics of PCFs.

In view of the challenges faced by the nation, the interdisciplinary team of academic and industrial researchers also involves postdoctoral fellows, graduate students, and several undergraduate/high-school summer research scholars, thus affording them training in chemical and biological sensing and monitoring - a priority area of federal R&D.

AN ENGINEERING EVOLUTION: MEMS AND NANOTECHNOLOGY

In the evolution of micro-electro-mechanical systems (MEMS) design and modeling and the fabrication of nanomaterials, Dr. Yong Shi develops radio frequency (RF) MEMS switches and nanopiezoelectric fibers for nanoscale sensors, actuators, and devices.

Breakthrough Technology: RF MEMS Switches

RF switches are devices that provide a short circuit or open circuit in the RF transmission line. RF switches (millimeter wave frequencies 0.1 to 100 GHz) are used in satellites, radar and wireless communications. While MEMS technology has been extremely successful in developing acceleration sensors for automobile airbags, inkjet printers, blood pressure monitors, and digital video projection systems, the incorporation of MEMS into the micro/millimeter RF wave system has started a new technological revolution. Different types of MEMS switches have evolved since the first one was developed by Petersen in 1979. The contact configuration can be either vertical or lateral; direct metal-metal contact or of a capacitive type. The actuators used for these switches are typically electrostatic, thermal-electric, electro-magnetic and piezoelectric. However, they will not be viable in the market unless their life cycle and power handing capacity are dramatically increased and costs are reduced. Dr. Shi’s goal is to increase the life cycle (to over 100 billion cycles) and power capacity (to more than 100mW) of an RF switch used for radar and other instrumentation systems. He developed a novel RF MEMS switch shown in Figure 1 and has already demonstrated that by using the modulated contact surfaces shown in Figure 2, the life cycle of the MEMS switch can be significantly increased while maintaining low contact resistance. RF MEMS switches provide extreme performance advantages such as lower insertion loss and higher isolation over solid-state switches like p-i-n diodes. Further investigations are being conducted in system design and optimization; modeling of the friction and wear of the continued on next page
undulated contact surface; thin film piezoelectric actuator optimization; device integration; and packaging.

The Building Blocks: Nano-Piezoelectric Fibers

One-dimensional nanostructures such as nanotubes, nanowires and nanofibers have great potential as either building blocks for micro/nano devices or as functional materials for microscale electronics, photonics, and sensing and actuation applications. Lead Zirconate Titanate (PZT), an important piezoelectric material, is used for both actuators and sensors at the macroscale. PZT nanofibers provide the capability to make active fiber composites (AFC) and nanoscale devices.

Dr. Shi’s research develops nanofibers with diameters from 6 micrometers to 50 nanometers using electrospinning. Fibers with a diameter of about 200 nm have already been developed as shown in Figure 3, where the nanofibers are distributed arbitrarily. SEM, TEM and X-ray diffraction are used to characterize the nanofibers and their crystal structures. Different approaches are being explored to fabricate well-aligned or uniformly distributed PZT nanofibers. Some aligned nanofibers are shown in Figure 4. Dr. Shi uses MEMS-based microfabrication technologies to assist the development of

Figure 3. Arbitrarily distributed nano-piezoelectric fibers

Figure 4. Aligned nano-piezoelectric fibers

The microreactor-based production approach, if successfully demonstrated, will replace the existing energy inefficient, cost ineffective, environmentally detrimental, and inherently dangerous slurry semi-batch reactor-based catalytic hydrogenation manufacturing practice. The primary challenge is the development of paradigm-changing design and hardware integration methodologies for auxiliary equipment and plant infrastructure that will enable many aspects of the microchannel reactor technology. The next phase of the project will involve a real-world pharmaceutical molecule patented by BMS.

Articles were written about the two projects in Chemical Engineering Progress, EurekAlert, Jersey Journal, Small Times News, and the Chemical and Engineering News. Stevens faculty team members are the PI, Dr. Adeniyi Lawal, assisted by two Co-PIs, Drs. Woo Lee and Ronald Besser, and Dr. Suphan Koven. Drs. Emmanuel Dada and Dalbir Sethi of FMC, and Don Kientzler and Dr. San Kiang of BMS provide technical guidance from industrial perspectives.

REVOLUTIONIZING CHEMICAL SYNTHESIS

by Dr. Adeniyi Lawal

At the New Jersey Center for Micro-Chemical Systems (NJ CMCS), we are currently demonstrating two novel microreactor-based process intensification concepts for on-demand, on-site, energy-efficient, and cost-effective chemical production. Both projects are funded by the DOE-OIT to develop and deliver advanced technologies that increase energy efficiency, improve environmental performance, and boost productivity.

Microchannel Reactors Revolutionize the Production of Hydrogen Peroxide (H₂O₂)

In September 2002, we partnered with FMC (one of the largest producers of H₂O₂ with more than 12% of the world market) to develop a microchannel reactor system for on-site production of hydrogen peroxide.

Today, we have successfully designed and evaluated a laboratory microreactor system for the controlled, direct combination of H₂ and O₂ in various compositions, including explosive regimes. The reaction is extremely fast with a residence time that is almost two orders of magnitude less than that of macroreactors. The direct combination concept is possible with microchannel reactors because they possess extremely high surface to volume ratios by virtue of their small transverse dimensions, and consequently exhibit enhanced heat and mass transfer rates. The enhanced heat transfer enables rapid wall quenching of free radicals which in conventional-size reactors lead to runaway thermal conditions and explosion.

Another achievement is the production of H₂O₂ in concentrations of significant commercial interest with acid (~1.5 wt%, exceeding the 1 wt% requirement of the project) and without acid (~1500ppm) at moderate pressure and temperature conditions using our in-house formulated catalyst. The 1.5 wt% concentration finds direct commercial application in environmental remediation, while the 1500ppm concentration can be used as a biocide.

Catalytic Hydrogenation of Nitroanisole to Anisidine

In September 2003, we partnered with Bristol-Myers Squibb (BMS), one of the world’s largest pharmaceutical companies to design and evaluate a microchannel reactor system for the multiphase catalytic hydrogenation of a model pharmaceutical compound, nitroanisole to anisidine. Hydrogenation reactions are ubiquitous, accounting for 10-20% of all reactions in the pharmaceutical industry.

We have screened over eight different catalysts and have identified the right catalyst/support for the model hydrogenation reaction. Also, an extensive investigation of the effects of various processing conditions on the activity of the selected catalyst in terms of conversion, yield, and selectivity has been carried out in the microreactor system. Similar experiments are currently being undertaken in a semi-batch reactor system at the New Brunswick facility of BMS. Preliminary results indicate that the mass transfer efficiency of the microreactor system is two orders of magnitude higher than that of the semi-batch reactor system.

The significant reduction of heat and mass transfer resistances in microchannel reactor systems enables the realization of fast intrinsic kinetics (millisecond reactions) which suppresses side reactions, leading to high yield and a reduced need for energy intensive separation/purification steps.
Microchemical Systems Enable Real-World Solutions

By Dr. Ronald Besser’s Research Team

Nanotechnology offers great potential in advancing scientific discovery and technological development. The federal government is spending more than $1 billion on nanotechnology, making it the largest public-funded science initiative since the space race. Various nanomaterials such as nanoparticles, nanotubes, and nanowires have been developed to create sensitive analytical sensors, miniature medical devices, electrical components, and machinery. In addition, nanomaterials with at least one dimension in the nanometer range (10⁻⁹m) may possess superior physicochemical properties such as high conductivity and hardness; fascinating optical phenomena; excellent catalytic activity for chemical reactions; and enormous adsorption capacity for chemicals and pollutants.

In 2002, researchers at the Center for Environmental Systems developed a nanocrystalline titanium dioxide with a high adsorption capacity for arsenic, lead, and other heavy metals (Figure 1). Titanium dioxides are widely used as pigment in paints, paper, plastics, sun block lotion, and tooth paste. However, the commercial pigment is not effective for the removal of heavy metals. Nanocrystalline titanium dioxide is produced by the hydrolysis of titanium in solutions under controlled pH, temperature, and time. The crystalline size and specific surface area of the material is about 6 nm and 330 m²/g, respectively. This high surface density of functional groups strongly binds arsenic and heavy metals. The material is also an active photocatalyst. In the presence of dissolved oxygen and with UV-light irradiation, the following are generated at the titanium dioxide surface: hydroxyl radicals, superoxide ions, and hydrogen peroxide. These highly reactive chemical species destroy organic pollutants and kill bacteria.

Currently, a patent pending nanocrystalline titanium dioxide is marketed by Hydroglobe, Inc., a company founded by Stevens in 2000 and acquired by Graver Technologies in 2004. Because nanocrystalline titanium dioxide enables the effective removal of lead and other heavy metals, it was used to develop a faucet mount filter (Figure 2) available at Target, Wal-Mart, and other stores. DOW Chemical has also licensed the patent and developed a new adsorbent with the material.

In the near future, more water treatment products will be made of nanocrystalline titanium dioxide as the drive to fulfill the promise of nanotechnology continues.
Dr. Frank Fisher's primary research area is the mechanical modeling of polymer nanocomposites with a focus on carbon nanotube-reinforced polymers (NRPs). Since their discovery in the early 1990s, carbon nanotubes (CNTs) have excited scientists and engineers with their wide range of unusual physical properties. These properties are a direct result of the near-perfect microstructure of the CNTs, which at the atomic scale can be thought of as an hexagonal sheet of carbon atoms rolled into a seamless, quasi-one-dimensional cylindrical shape. Besides their extremely small size (single-walled carbon nanotubes can have diameters on the order of 1 nm, or $1 \times 10^{-9}$ m, 100,000 times smaller than the diameter of a human hair), carbon nanotubes are half as dense as aluminum, have tensile strengths 20 times that of high strength steel alloys, have current carrying capacities 1,000 times that of copper, and transmit heat twice as well as pure diamond. Given these unparalleled physical properties, CNTs offer the potential to create a new type of composite material with extraordinary properties. However, the nanoscale interaction mechanisms between the CNTs and the surrounding polymer must be understood and coupled to the micro/macroscale mechanical response of the material.

One aspect of this work is the development of enhanced modeling methods and corresponding experimental techniques to describe the effective mechanical behavior of these systems. For example, due to the extremely small size of the embedded nanotubes, a polymer interphase region forms in these systems with mechanical properties that are different from the properties of the bulk polymer matrix (see Figure 1, left). Due to the extremely large surface area of the embedded nanotubes, this interphase region can comprise a significant portion of the volume fraction of the composite and significantly influence the overall mechanical properties of the composite. However, because of the extremely small size of this interphase region, experimental characterization is exceedingly difficult. Thus, to quantify the change in properties of this non-bulk interphase region, we have developed a coupled experimental-modeling technique to characterize the changes in the relaxation processes of the nanocomposite response due to the properties of the non-bulk polymer interphase (Figure 1, center). The existence of this interphase region has recently been verified via high resolution scanning electron microscopy (SEM) images of the fracture surface of a CNT-polycarbonate fracture surface (Figure 1, right). Working in conjunction with colleagues in chemistry and materials science, one important application of these modeling techniques is to quantify how different processing methods influence the size and properties of this interphase region. For example, tethering short polymer chains covalently to the surface of the nanotube prior to composite fabrication has been shown to alter the size and properties of this interphase region.

Another project investigates alternative methods of enhancing the load-transfer mechanisms in these nanocomposite material systems. With collaborators at the University of North Carolina-Charlotte, the team is looking to exploit a novel template-based method to fabricate bone-shaped carbon nanotubes as shown in Figure 2. The highly uniform geometry of these nanostructures (length, inner and outer diameters, wall thickness) can be controlled via appropriate manipulation of the template fabrication and carbon deposition processes. Enhanced load-transfer for these bone-shaped inclusions is anticipated through mechanical interlocking with the polymer matrix at the widened ends.

![Figure 1](image1.png)  
*Figure 1.* (left) Three-phase model of NRP accounting for the presence of a non-bulk polymer interphase region. (center) Relaxation spectra for MWNT-PC samples showing additional, long-timescale relaxation processes that are due to the mechanical behavior of the non-bulk polymer interphase. (right) High-resolution SEM imaging of a CNT-polycarbonate fracture surface.

![Figure 2](image2.png)  
*Figure 2.* High magnification TEM images of a bone-shaped templated carbon nanotube. The outer stem and end diameters are ~40 and ~70 nm, respectively. The wall thickness is ~30 nm. The length of the T-CNT is ~5 µm.
"HUNDREDS OF TINY HANDS:" THE MAKING OF NANO-MANIPULATION TOOLS

Dr. Zhenqi Zhu’s Research Team

True realization of nanotechnology requires nanoscale components/structures to be inexpensively assembled into functional systems; nanoscale manipulation is one of the key enabling technologies in this vision.

The power and capacity of manipulation tools in changing our world were highlighted in 230 B.C. by Archimedes, a Greek mathematician, engineer, and physicist: "Give me a lever long enough and a place to stand, and I will move the world." Tool searching and development continues today as scientists and engineers demand manipulation tools small enough to extend their arms into the nanoscale world. Such small-enough manipulation tools are what Feynman first challenged in 1959 with his "hundreds of tiny hands" vision of nanotechnology.

Nanotechnology will enable one to understand, measure, manipulate, and manufacture at the atomic and molecular levels creating materials, devices, and systems with fundamentally new functions and properties. A great breakthrough in nanotechnology came with the inventions of the scanning tunneling microscope in 1982 and the atomic force microscope in 1986. These revolutionary inventions opened the nanoworld to scientists and engineers. However, the relatively large-size mechanical nanopositioning systems employed in scanning probe microscopes and optical microscopes are too massive to be used in parallel operation in the nanoworld. Bio-inspired by the motion mechanisms found in cilia and flagella, the goal of research by Associate Professor Zhenqi Zhu, of Mechanical Engineering, and his colleagues from several departments, is to develop and demonstrate a disruptive design methodology based on a monolithic jointless Stewart platform to yield nanometer positioning resolution with a unique combination of fully-flexible 6 DOFs and truly scalable device size. The focus of the design will be on manufacturability of the device(s) utilizing existing MEMs-based fabrication techniques. (2) Fabrication and performance evaluation of 6-DOFs microscale nanomanipulator devices, including theoretical, computational, and experimental study of the nanomanipulators with integrated actuators and sensors. (3) Demonstration of device use in (a) “full device” 6-DOF manipulation under SPM probe; (b) “real device” 6-DOF in-situ scanning with nanomanipulated optical fiber based sensors; (c) massively-parallel, coordinated flexible nanoautomation.

This research effort is complemented with an educational and outreach program with a strong support from CIESE to introduce K-12 and undergraduate students to topics in nanotechnology.
Libera's research centers on the development, implementation, and application of advanced electron-optical techniques for the measurement and control of microstructure and morphology in engineering materials at high resolution. A main theme of his research concentrates on the study of polymers and polymeric biomaterials such as hydrogels using such techniques as electron holography and electron energy-loss spectroscopy. One of his group's recent innovations has been the development of new methods to map the spatial distribution of water in synthetic materials for health and personal care applications using advanced methods of cryo-electron microscopy. It is important to understand such problems, for example, as how biodegradable polymer tissue-engineering scaffolds degrade in the human body.

Over the past few years, Libera’s group has been using electron microscopes not only as materials-characterization tools but also as materials-processing tools. High energy electrons can modify the structure and properties of polymers, and because electrons can be focused by a microscope into fine probes with nanoscale dimensions, electron microscopes can be used to pattern polymers into nanostructures. These properties have been exploited in the practice of electron beam lithography, which has been essential to the semiconductor device community for several decades. Libera and his students have pushed this technology in an entirely new direction by applying it to polymers of interest because of the way in which they interact with physiological systems involving proteins, cells, and tissues.

The central idea is to create biospecific surfaces - surfaces which interact with physiological systems in very controlled ways. “People have been working in this area in different ways for several decades,” Libera explains, “but new tools and new ways of thinking based on nanotechnology are opening radically different pathways to achieve success. We certainly see this in our work.” Polymeric materials have been increasingly utilized at surfaces and interfaces for a variety of biomedical applications including tissue-engineering matrices, implants with biocompatible surfaces, drug delivery, and biosensors. Due to the chemical diversity of polymeric materials, both biological and synthetic, researchers can fine tune the desired physical properties of surfaces and design bioactive interfaces from a molecular perspective. Understanding the complex interactions between biomaterial surfaces and their environment is critical to improving healthcare technologies related to implants, devices, and future innovations in these areas.

Significantly, Libera’s team is aggressively investigating the properties of hydrogels, the kinds of polymeric materials that form the basis for everyday soft contact lenses and other common biomedical applications.

“We have used focused electron-beam cross-linking to create nanosized hydrogels,” says Libera, “and this provides us with a new method with which to bring the attractive biocompatibility associated with macroscopic hydrogels into the nano length-scale regime.”

Using thin films of polyethylene glycol (PEG) films on silicon and glass substrates, Libera, working with Ph.D. candidate Peter Krsko, generated nanohydrogels with lateral dimensions of order 200 nanometers – about 500 times smaller than the diameter of a human hair - which can swell by a factor of five or more, depending on the radiative dose of electrons.

“These things are like little sponges,” explains Krsko, “and we can control how spongy they are by controlling how we irradiate them in the SEM. One of the really cool things we found is that we can control whether or not various types of proteins bind to these little nanosponges.”

With the focused electron beam, high-density arrays of such nanohydrogels can be flexibly patterned onto silicon surfaces. Significantly, the amine groups remain functional after e-beam exposure, and the research shows that they can be used covalently to bind proteins and other molecules.

“We use bovine serum albumin to...
amplify the number of amine groups,” says Krsko, “and we further demonstrate that different proteins can be covalently bound to different hydrogel pads on the same substrate to create multifunctional surfaces useful in emerging bio/proteomic and sensor technologies.”

“There is a lot of student interest in this stuff,” says Libera. “When I talk about it in my undergraduate materials class, I always find students – very good students – appearing at my office door later trying to find out more about it.” Indeed, one such interaction has led to a senior design project of patterning hydrogels for possible application to nerve regeneration in spinal cord injury. “Our NIH collaborator on this is so excited he has invited one of my undergrad research students – Jen Sipics – to work in his lab in Bethesda this summer.”

Another student – Ali Saaem – joined the group after taking Libera’s Materials Processing course. “This guy is an EE major. He came in and reconstructed the computer interface to our SEM and elevated the entire level of e-beam patterning capabilities. Now, I think we’ve got him really interested in the biological problems the group is pursuing,” comments Libera.

Libera’s work on nanohydrogels holds implications for the eventual production of the next generation of protein microarrays, which can be used to establish the function of various genes that become active during cancer, disease, and aging processes.

Libera’s work on nanohydrogels holds implications for the eventual production of the next generation of protein microarrays, which can be used to establish the function of various genes that become active during cancer, disease, and aging processes.

Figure 3. The adhesion of Staphylococcus Epidermidis bacteria to synthetic surfaces can be controlled using functional hydrogels on surfaces, a cell-repulsive hydrogel pad (left) and a cell-adhesive hydrogel pad (right).
INTERDISCIPLINARY RESEARCH

In the Realm of the Very Small

In the popular mind, and sometimes in popular science writing, nano- and microtechnology are often used interchangeably to describe very different phenomena. Professor Frank Fisher explains the distinction.

"The most straightforward difference is the feature size," says Fisher. "Microtechnology typically refers to feature sizes on the order of one micron, whereas nanotechnology refers to feature sizes on the order of a nanometer. To put that into perspective: The width of a human hair is about 100 microns. In nanotechnology, on the other hand, we're interested in exploiting novel phenomena that happen on the nanoscale. So it's a distinction between miniaturization versus taking advantage of novel properties that are available below the microscale."

"The first direction that we went, as we started looking at microdevices, really evolved from microchip technology," says Associate Dean of Engineering Keith Sheppard. "The techniques that were developed to create different layers on the surface of silicon, particularly for chips, which typically involve adding layers or etching layers or changing the properties of surfaces - those same technologies have then been directed to making devices."

Various of those microdevices have been tailored to accomplish work on the nanoscale, where engineered arrangements of individual atoms are now becoming a reality.

Some methods necessary to build structures consisting of large numbers of precisely arranged atoms include molecular self-assembly, in which molecular building blocks assemble themselves in pre-designed ways. Using this technique, researchers have created carbon nanotubes with diameters of about one ten-thousandth of a human hair that can be used as miniature structural materials, electronic components and drug delivery systems.

Scientists also depend on such tools as Scanning Tunneling Microscopes and Scanning Probe Microscopes to build images on surfaces, manipulate atoms into microstructure, or analyze the identities of atoms and molecules one atom at a time.

"When you come from basic physics, what you like to do is understand things on the smallest possible scale, which for all these applications is the atomic or the molecular level," says Dr. Kurt Becker, who works in the field of microplasmas. "That level is typically in the realm of about a nanometer. So from the science perspective, you take it apart, step-by-step, until you reach the nanoscale; and then, of course, once you understand it, you put everything back layer by layer, and go back into the micro- and macroscale."

WHY NANO-MICRO-BIO?

Recent Reflections and Revelations by Dr. Woo Y. Lee

When Dean Korfiatis decided to highlight "nano-micro-bio" activities in this issue of SSOE InFocus, I thought that it would be a timely forum for me to share my latest view of this very broad interdisciplinary research area. My interest in making "very small things" started when I was given a chance to study chemical vapor deposition (CVD) for my Ph.D. degree in chemical engineering under the interdisciplinary supervision of Prof. Jack Lackey, a ceramicist, and Prof. Pradeep Agrawal, a chemical engineer, at Georgia Tech.

CVD is a coating technique widely used for making semiconductor, solid state laser, and photonic devices as well as aerospace structures, synthetic diamond films and carbon nanotubes. In this method, we mix gaseous chemicals in a reactor and let them react preferentially on the substrate surface. Subsequently, small clusters of atoms produced from the decomposed gaseous species nucleate and grow on the surface, and are assembled into a solid thin-film structure. For example, as part of my Ph.D. work, I produced my first nanostructured material, a self-lubricating nanocomposite coating that contained hard AlN whiskers (2 nm wide and 1 µm long) in a soft BN matrix phase from a gaseous mixture of AlCl₃, BCl₃, and NH₃.

What Is Nanoscale Science and Engineering?

To a large extent, my Ph.D. research exemplifies the National Science Foundation's broad definition of Nanoscale Science and Engineering: "the fundamental understanding and result-
another example, a graduate student, Dr. Yi-Feng Su, observed that α-Al₂O₃ (sapphire) grains present in a thin-film form can grow laterally, abnormally, and incredibly at temperatures about 950ºC below the melting point of α-Al₂O₃, as long as the film is thinner than 100 nm (Figure 2b). We also demonstrated that the abnormally grown α-Al₂O₃ film increases the oxidation life of a single crystal Ni-based superalloy used in advanced gas turbines by five-times. These examples show how nanoscale phenomena can provide enabling building blocks for making useful multiscale structures that are relevant to the human scale.

"Nano-Micro" Integration

About 4 years ago, I initiated a new research effort in microreactors for several reasons. First, after receiving my tenure, I wanted to expand my research horizon beyond CVD. Second, I was intellectually driven by the recognition of complex surface-fluidic interactions that are present in microreactors (just like in CVD) because of their high surface-to-volume ratios and the technological need to control these interactions for rational microreactor design. Third, as I just became Chair of the newly merged Department of Chemical and Materials Engineering, I envisioned that microreactors could provide a common engineering platform for synergistically integrating individual faculty research interests and motivations. Fourth, I foresaw that we were able to compete in some major funding opportunities due to the strong presence of chemical, defense, pharmaceutical and microsystems industries in our region and their growing interests in the emerging microreactor technology.

Through collaborative work with my colleagues, Professors Ronald Besser, Suphan Koven and Adeniyi Lawal, and with strong support from our partner organizations such as ARDEC-Picatinny, Bristol-Myers Squibb, FMC, Lucent-Bell Labs and Sarnoff, this effort has grown from a small internal seed project to the establishment of the New Jersey Center for MicroChemical Systems (www.stevens.edu/njcmcs). My contribution to this team effort is to explore new ways to design, control, and make "very small" surface structures as an integral part of fabricating "small" microreactors. For example, Mr. Honwei Qiu, a Ph.D. candidate, in my research group, is investigating self-assembly infiltration methods to deposit a layer of close-packed microspheres (Figure 2a) as a potential means of integrating catalyst particles into microreactors with help from Professor Svetlana Sukhishvili and her expertise in polyelectrolytes. Mr. Haibao Chen, another Ph.D. candidate, is experimenting with 3-dimensional cellular structures (Figures 2b and 2c) which can be directly infiltrated as net-continued on next page
shape structural elements into microreactors using polymeric and ceramic microspheres as key building blocks. With my collaborators, we are evaluating these new structures for controlling and improving microreactor performance for miniaturized chemical, fuel cell, and pharmaceutical system applications.

**Importance of Bio in "Nano-Micro-Bio"**

I admit that I was somewhat skeptical about the relevance of nanotechnology, based on my initial estimate of the potential return on the federal government's investment in nanotechnology. This view has changed over the past several years, as I read about human physiology, cell biology, and biological transport phenomena in conjunction with the implementation of our new Biomedical Engineering program. From my recent understanding of cells (as super-intelligent nanostructure factories) and proteins (as ultimate nanostructures), I began to see some exciting integration points that may link my past, current, and future research activities. Also, through my participation in various workshops sponsored by the National Academies, the Keck Foundation, the National Science Foundation, and the National Institute of Health, I was profoundly influenced by some remarkable progress being made in the biomedical research community with emerging microsystem and nanotechnology tools.

As my view was drastically evolving, I came across an interesting "nano-micro-bio" research topic last October: microbial infections of implanted medical devices which constitute an ever increasing threat to human health with significant clinical and economic consequences. In most infections, bacteria attach to the surfaces of indwelling medical devices (such as intravascular catheters, cerebrospinal fluid shunts, aortofemoral grafts, intraocular lenses, prosthetic cardiac valves, cardiac pacemakers, and prosthetic joints) by forming adherent and cooperative communities known as biofilms. Bacteria in a biofilm are well protected from host defenses and antibiotics, making most biofilm infections difficult to treat with conventional antibiotics which have been developed assuming the planktonic state of bacteria. I have become interested in the topic because of similar issues at a methodological level between biofilms and the "physical" thin-films of my previous research, while recognizing the greater complexity of biofilms due to the "living" aspects of microorganism communities.

**Prof. Matt Libera**, who has a somewhat different scientific perspective, **Prof. Jeff Kaplan**, a microbiologist at the University of Medicine and Dentistry- NJ, and I are working on a long-term plan to design and build microreactors with 3-dimensional nanoscale surface elements and patterns that will: (1) emulate physiologically relevant micro-environments and (2) increase the predictive capability of "in vitro" investigations of cell-material and cell-cell interactions in reference to "in vivo" and clinical studies. We foresee that this type of new "in vitro" microreactors can be instrumental in the rapid development of rational therapeutic delivery strategies for treating a variety of infectious and other diseases. As I am writing this article, our graduate students are traveling to Newark to learn how to grow Staphylococcus epidermidis bacteria in Prof. Kaplan's laboratory.

I am very excited by this interdisciplinary collaborative effort. As our region is the center of the global health care economy, I look forward to developing extensive research and educational collaborations that leverage the exciting initiatives we are engaged in at Stevens as we push out the "nano-micro-bio" frontier. I can be reached at: wlee@stevens.edu.
Dr. Cardinal Warde, a professor of electrical engineering at MIT, is considered one of the world's leading experts on materials, devices and systems for optical information processing. Warde holds ten key patents on spatial light modulators, displays, and optical information processing systems.

He is a co-inventor of the microchannel spatial light modulator, membrane-mirror light shutters based on micro-electro-mechanical systems (MEMS), an optical bistable device, and charge-transfer plate spatial light modulators.

Warde grew up on the small Caribbean island of Barbados. His parents demanded excellence in school but gave him lots of freedom and support to engage his inquisitive mind outside the classroom. By age 16, he had converted his father’s unused carpenter’s shop into a chemistry and physics laboratory, and with high school friends, he launched homemade rockets (with mice aboard) from the beach near his home. Fortunately, he says, none escaped Earth’s gravity and most of the mice were freed when the rockets crashed.

After high school, Warde boarded a plane for the United States. He received a bachelor’s degree in physics from Stevens in 1969, where he was also a member of the varsity soccer team. His passion for physics continued at Yale University where he earned his Master’s and Ph.D. degrees in 1971 and 1974.

While at Yale, Warde invented a new interferometer that worked at near absolute zero temperature in order to measure the refractive index and thickness of solid oxygen films. This experience stimulated his keen interest in optics and optical engineering. After Yale, he joined MIT’s faculty of Electrical Engineering and Computer Science as an Assistant Professor.

At MIT, Warde’s interest shifted toward engineering the applications of optics. He became involved with other faculty in the development of devices for enhancing the performance of optical atmospheric (wireless) communication systems to improve communication performance in inclement weather, and photorefractive materials for real-time holography and optical computing. To date, he has published over a hundred technical papers on optical materials, devices and systems.

Today, Warde’s research is focused on developing the optical neural-network co-processors that are expected to endow the next generation of PCs with rudimentary brain-like processing; transparent liquid-crystal microdisplays for display eyeglasses and novel cellular phones; membrane-mirror-based spatial light modulators for optical switching and projection displays; and spectro-polarimetric imaging sensors for remote-sensing applications.

Warde is also an entrepreneur. In 1982, he founded Optron Systems, Inc., a company that develops electro-optic and MEMS displays, light shutters and modulators for optical signal processing systems. Later, he co-founded Radiant Images, Inc., which manufactures transparent liquid-crystal microdisplays for digital camera viewfinders, portable telecommunications devices, and display eyeglasses.

Dr. Warde is also dedicated to working with Caribbean governments and organizations to help stimulate economic development. He lectures throughout the Caribbean at scientific and government meetings on the role of technology and education reform. Also, for the last decade, Warde has mentored students in the Network Program of the New England Board of Higher Education, whose mission is to motivate and encourage minority youth to consider majoring in science and engineering and to pursue careers in these fields. He has received a number of awards and honors, including the Renaissance Science and Engineering Award from Stevens in 1996, and currently serves on Stevens’ Board of Trustees.
Stephen T. Boswell ’89 and ’91

An Entrepreneurial Civic Leader

by Roberta McAlmon

Dr. Boswell, a highly successful entrepreneur, is an alumnus and trustee of Stevens. He has pursued an illustrious career in business, assuming leadership roles in entrepreneurial endeavors that bring credit to himself and the Institute. And his generosity to Stevens and the community-at-large has been enormous. He has dedicated his ingenuity and leadership to advancing the education of our students and developing environmental technologies that benefit our society.

Stephen Boswell began his career as President and CEO of Boswell Engineering. Under his direction, the firm designed and engineered the construction of hundreds of miles of roads, highways and bridges throughout the northeastern United States. Dr. Boswell has also authored numerous environmental impact statements and wetlands reports. His doctoral research proposed a novel method for removing volatile organic chemical contaminants and radon from groundwater. Since 1993, he has served as an advisory board member to Stevens’ Center for Environmental Systems.

For many years, Dr. Boswell has also shared his knowledge, time and experience with Stevens’ Civil Engineering Department. His dedication to the students has been extraordinary and his mentoring - invaluable. Boswell Engineering was one of the first industry sponsors of a senior design project. The company has also been very active in the Cooperative Education Program and has employed many of Stevens’ graduates. In appreciation of their support and through gifts made in their honor, the Stephen and Karen Boswell Scholarship Fund was recently established to support the educational aspirations of Stevens’ Civil Engineering majors.

Over the years, his generous and public-spirited endeavors include, the donation of engineering services for the construction of school playgrounds, public parks and the expansion of facilities at Stevens.

In addition, Boswell has received numerous awards including: the American Council of Engineering Companies’ Community Service Award; the American Society of Civil Engineers’ North Jersey Branch Service to the People Award; and the NJ Society of Professional Engineers’ Engineer of the Year Award.

In recognition of his many years of public service in civil and environmental engineering, his entrepreneurial accomplishments, his community-minded efforts to improve the quality of life for his neighbors and the public, and his distinguished service to Stevens, Dr. Boswell recently received the 2004 Charles V. Schaefer, Jr. Entrepreneur Award.

In recognition of his many years of public service in civil and environmental engineering, his entrepreneurial accomplishments, his community-minded efforts to improve the quality of life for his neighbors and the public, and his distinguished service to Stevens, Dr. Boswell recently received the 2004 Charles V. Schaefer, Jr. Entrepreneur Award. This award is presented to individuals like Dr. Boswell who embody Schaefer’s entrepreneurial and leadership spirit.

Dr. Boswell resides in Wyckoff, N.J., with his wife Karen and their daughter, Kristen, who is pursuing an engineering degree at Duke University.

Roberta McAlmon is a writer living in Convent Station, N.J.
Following the appearance in 2004 of the Liam Neeson film "Kinsey," with its portrayal of Stevens Institute of Technology in the early 20th century, some note was taken of Alfred S. Kinsey (father of the famous Alfred C.), who was employed for many years as a "professor of shop practice." It can be said that the elder Kinsey, whose son spent several years at Stevens before moving on to other disciplines, established a tradition of hands-on machining at the Institute that continues to this day.

Kinsey began working at Stevens at the age of 15 in 1886 as a machinist's helper. After graduating from Cooper Union in 1890, he worked in the Department of Tests for 18 years, and obtained his teaching position in shop practice under Professor David S. Jacobus. More remarkably, in 1908 he expanded and modernized the course on shop practice in the then-new Carnegie Mechanical Laboratory. He also wrote a complete textbook in shop practice for engineering students that was used by the young Alexander Calder, a 1919 Stevens graduate, and by several generations of freshmen. Among the machining disciplines covered in the text were pattern-making in metal, founding and casting, lathing, punching and heavy-duty drilling.

After Kinsey retired in 1941, machining became gradually less central to the freshman curriculum, and "the shop" was decentralized into five or six separate shops, each serving a different academic department.

Still, on a recent visit to Stevens, award-winning author Richard Reeves recalled his indoctrination in the late 1950s into numerous machining skills, including, notably, glass-blowing. (Asked if he had preserved any examples of his student work, Reeves was quick to respond: "Of course not!")

By the early 1990s, when Dr. Arthur Shapiro served as Stevens' provost, the various machine shops had become fairly neglected facilities, run mostly by octogenarians using ancient equipment. "For a school this size," said Shapiro, "having five or six shops seemed a little inefficient and they took up a lot of scarce space." In 1992, the decision was made to recentralize all of the shops back into one location as the Institute Machine Shop in the basement of the Burchard Building, directed by George Wohlrab. "The Institute Machine Shop's mission," says Wohlrab, "is to enrich Stevens with a high-precision manufacturing capability focused mainly on academic tasks. It was also designed to provide students with a short, but fundamental, background of what a machine shop can do and how to use its resources."

Since 1993, the success of the Machine Shop's academic programs has brought many customers to its doors. Today, students from many departments are trained by George Wohlrab and Joe Vaspol. Courses in Senior Design and Design III in the School of Engineering, in the New York University exchange program, and in the Physics Department SKIL Program use the excellent facilities found in the Institute Shop. "George and Joe are two of the great problem-solvers," said Shapiro, who is also a sculptor of note in the Calder tradition. "Though my studio is off-campus, I still like to drop by the shop frequently to discuss technical ideas and possibilities."

Damien Marianucci '03 and a graduate student in Physics, said, "Over the summer of 2004, I worked alongside George and Joe to design and construct a vacuum chamber to reevaluate Rutherford's Scattering Experiment, as a project for the Physics Department commissioned by Stevens alumnus and writer, Richard Reeves. I learned skills that were invaluable and that set me apart from others in my field."

Senior Mechanical Engineering student Keith Yzquierdo attests: "Standing back and looking at something you have created, knowing that its dimensions are within 0.001 inches of those specified - the feeling of accomplishment is unparalleled."

First-year Electrical Engineering student Kyle Mulligan sums up the experience of many students: "Mr. Wohlrab said that working in the machine shop would give me vital experience that I could take with me through any career I pursued. What I have learned has been exceptional. Each day I pick up a new skill or learn a better way of doing something...I am going out for Co-op in the fall and my experience in the Machine Shop will give me an edge over others."

A tradition begun early in the last century continues to enrich the educational experience and to serve the broader community at the beginning of the new century.
Through the generous support of the Clare Boothe Luce Program, two undergraduate women at Stevens have achieved an esteemed designation as Clare Boothe Luce Scholars. These merit-based scholarships are awarded through a competitive selection process to outstanding engineering majors interested in academic careers. “These scholarships will help these accomplished young women complete their last two years of undergraduate studies and encourage their participation in research and graduate school,” said Susan Metz, Executive Director of Stevens’ Lore-El Center for Women in Engineering and Science. “Stevens is most interested in new scholarships for engineering students, since engineering continues to be the field with the greatest under-representation of women.”

One of the two Luce Scholars is Tracey Ryan, a resident of Westfield, N.J. In her junior year, she is studying biomedical engineering and maintains a 3.69 average. Tracey will be receiving both a Bachelor of Engineering degree and a Master’s degree in Engineering Management with a Graduate Certificate in Pharmaceutical Manufacturing Practices in four years – a highly notable accomplishment. Tracey plans to pursue a doctorate and get involved in biomedical engineering research. She explains, “My main goal in life is simply to help others. If I can contribute to medically helping just one individual, my life will have been a success.”

On campus, she is involved in a plethora of activities. These include: the Scholars Program; the Biomedical Engineering Society, as the chapter’s first President; the Phi Sigma Sigma International Sorority; the Society of Women Engineers; the International Society of Pharmaceutical Engineers; the Ambassadors Club; Peer Mentoring; and representative to the Association of Independent Colleges and Universities of New Jersey.

Jennifer Kurucz resides in Port Reading, N.J. She has a 3.67 average and is majoring in Computer Engineering. Jennifer participates in the Stevens Co-operative Education Program and is going into her fourth year at Stevens. She has worked for Colgate Palmolive on three consecutive Co-op assignments, demonstrating how much the company values her talents. Recently, she completed an assignment with United Parcel Service and will be returning there in the summer. “By working for UPS, I have grown both technically and professionally and have experienced another side of engineering,” said Jennifer.

At one time, Jennifer was interested in joining a sorority, but when the one she chose turned her down, she decided to devote all of her extra time to the Society of Hispanic Professional Engineers. Although she is not a Latina, she finds the warmth, community, and diversity of this organization enormously satisfying and has been an active student volunteer for their Eastern and National Conferences.

Shotmeyer Scholar: Lisa Ditto

By Dr. Leslie Brunell

In December, Lisa Ditto, a Civil Engineering senior, received the Henry J. Shotmeyer Scholarship. This scholarship is awarded to selected Civil Engineering undergraduate students based on academic merit, financial need, and accomplishments in Civil Engineering.

Lisa’s many awards include: the 2004 Moles’ Scholarship Award, Edwin A. Stevens Society Honorary Membership Award; Henry J. Shotmeyer Scholarship; ACEC Scholarship; Construction Industry Advancement Program Scholarship Award; Terminal Construction Scholarship; Edwin A. Stevens Scholarship; and Women in Engineering Scholarship.

Consistently on the Dean’s List, Lisa is also a Teaching Assistant and has interned at Port Authority of NY/NJ, URS Corporation, and Langan Engineering & Environmental Services. She is also involved in several campus activities including: Delta Phi Epsilon International Sorority, Chi Epsilon (National Civil Engineering Honor Society), Tau Beta Pi (National Engineering Honor Society), Gear & Triangle Society, and the Senior Week Planning Committee.

Currently, Lisa is working on her senior design project with fellow team members James DeMarco, James Myers, and Adam Yoda. They are working on the design of an inlet structure for their sponsor, the Duke Farms Foundation. This structure will control flow into the Dead River from its main water source, the Raritan River. During moderate to heavy storms, the area experiences...
**InnertCHILL: Overclocking made easy**

The InnertCHILL System Cooler is an ambitious student-created and -run research and design project, initially developed to satisfy the Senior Design requirements for students enrolled in the School of Engineering. However, since its inception, it has turned into much more. “The basic idea is to create a new type of cooling system for personal computers, implementing a chilled, electrically inert liquid, spraying through jet impingement heads at the major heat producing elements of a common computer,” says Project Leader Matthew Swartout. “We intend for it to be stable, safe, and able to work with any commercial off-the-shelf product available on the market,” says Business Plan Director Tim Alexander.

The project, advised by Professors Hamid Hadim from Mechanical Engineering, Nader Mohamed from Electrical and Computer Engineering, and Bernard Skown from Business and Technology, and sponsored by 3M Corporation, came to fruition with a working prototype at the end of the spring 2005 school semester. Swartout is a USAF cadet in his fourth year at Stevens studying Electrical Engineering, with a continuing interest in commercial computer hardware, modifications, cooling methods and overclock- ing. He gained experience in development- mental engineering through work at Science Applications International Corporation in his freshman and sophomore years. Matthew is currently an editor at a popular computer hardware website.

Alexander is in his fifth year as a Business & Technology major. His expertise lies in project management, marketing, and market research. Tim has built various connections in the entertainment industry, and has strengthened his management skills by creating a successful concert production organization on campus as well as producing various fundraisers and comedy events. He has interned at Muze, Inc., and worked as an Agent Assistant at the Central Entertainment Group, both located in New York City.

Other members of the InnertCHILL project team include Peter Michelli (Electronics), a fifth year student studying Electrical Engineering; Andrew Dullas and Dan Furey (Mechanics), students in their fourth year studying Mechanical Engineering; and John-Paul Kosmyra (Software), a fifth year student studying Computer Science.

**Annual Event - Senior Design Day**

April 27, 2005 • Noon to 2pm
Schaefer Athletic Center - Canavan Arena

This annual event gives the senior undergraduate engineering students an opportunity to showcase their design projects to the Stevens community, sponsors, and the general public.

**The HeliOS Project**

For their senior design project, nine students advised by Professor Bruce McNair in the Electrical and Computer Engineering Department at Stevens and Professor Ken Perlin of New York University, are designing a system to enable an electric radio controlled helicopter to hover autonomously. The goal of the system is to avoid the use of GPS for position reference, which will allow the system to operate in areas that most other autonomous systems cannot. To accomplish this, the system uses on-board cameras and machine-learning algorithms in addition to the traditional suite of analog sensors. The design team hopes to achieve stable hover by Design Day; they see their work as a cornerstone upon which future students can build. They have also started a “Remote Controlled Flight Club” advised by McNair through the Stevens SGA, and they fly micro RC helicopters in Walker Gymnasium every Friday afternoon. A group of underclassmen have already expressed interest in taking over the project and the club next year.

Ultimately, the team would like to see the project compete in the International Aerial Robotics Competition in which some of the premier engineering schools in the country participate.

**The HeliOS Project Members:**

Sensor System Team
Steven Hakusa
William Lem
Christian Pulla
Karl Schmidt

Guidance & Control Team
Oliver Kennedy
Rayad Khan
Eton Kwok
Jason Poulos
Hesham Wahbah
Working with Professor Matthew Libera, graduate student Peter Krsko’s main research interest is the patterning of bioactive hydrogels on surfaces in order to carefully control the interactions between synthetic materials and physiological systems. Together, they have a patent pending entitled "Patterned Polymer Micro-gel and Method of Forming Same."

"Patterning of biological molecules on micro- and nano-scales is increasingly essential to high-throughput proteomic arrays, biosensor, and studies of cell adhesion," says Krsko. "Knowledge of cell-material interaction mechanisms and a better understanding of extra-cellular and intra-cellular phenomena during the adhesion of cells on biomaterials will help in the development of new biocompatible materials."

Various methods have been developed to place the molecules on the surface directly or indirectly. "Electron-beam patterning has been traditionally used in the IC industry," says Krsko, "but because of its high resolution, ability to generate arbitrary pattern and to chemically modify the irradiated material, I use it to control surface structure and chemistry at length-scales ranging across both the nano- and microscales. "The biologically relevant polymers can be used as resins and subsequently as templates for adsorption and covalent binding of proteins and directed cell growth."

"Besides serving as a technique for scientific research," he says, "it can also be used for producing creative micro- and nano-masterpieces."

Peter Krsko started at Stevens in 1998 and received a B.S. and M.S. in Applied Physics. While working in Dr. Libera’s Lab, the research became so interesting that he decided to stay for his Ph.D. studies.

"What else could I say? I really enjoy this research because it’s truly interdisciplinary work. I don't study just one science field...there are problems to figure out and I learn everything that I need to achieve the solution...physics, polymer chemistry and cell biology."

An example of patterned protein on glass surface. Our technology allows us to transform any grey scale image (A) into a surface with controlled distribution of protein (B). Various shades of green correspond to different concentrations of protein.
GENERATING INTELLECTUAL PROPERTY

On October 5, 2004, US Patent #6,801,131 was awarded to Dr. Dimtri Donskoy and Dr. Nikolay Sedunov for a "device and method for detecting insects in structures," utilizing a plurality of transceivers, each of which generates separate and distinct microwave signals and receives separate and distinct signals reflected from a structure being tested.

On November 16, 2004, US Patent #6,818,193 was awarded to Dr. Christos Christodoulatos; Dr. George R. Korfiatis; Richard Crowe; Dr. Eric E. Kunhardt; Plasmasol Corporation; and Stevens Institute of Technology for a "Segmented electrode capillary discharge, non-thermal plasma apparatus and process for promoting chemical reactions."

From IP to the Marketplace: HydroGlobe

HydroGlobe, a Technogenesis® environmental technology company incubated at Stevens, which produces patented products for the removal of heavy metals from water, including lead and arsenic has been acquired by Graver Technologies, a leading manufacturer of filtration and separation products.

HydroGlobe was founded in 2000 by three professors based on research conducted at the Center for Environmental Systems (CES), directed by Dr. Christos Christodoulatos. The other founders include Dr. George R Korfiatis (CES founding director and Dean of the Schaefer School of Engineering) and Dr. Xiaoguang Meng, CES Director of Technical and Academic Development.

"This is a validation of our philosophy at Stevens, real-world solutions can be found for major real-world problems through technology innovation," said Stevens President Harold J. Raveché. "The Technogenesis philosophy holds that innovation is the key to enriching the marketplace and creating new kinds of employment...this is exactly what we are seeing with the acquisition of HydroGlobe."

CES-HydroGlobe Prize

The three co-inventors of the patented technology that goes into the HydroGlobe/Graver products (and now also a home filter product) have established a new prize for entrepreneurial juniors and seniors at Stevens. The award has been endowed by Professors Christodoulatos, Korfiatis and Meng, with proceeds from the sale of the Technogenesis company that they founded.

The annual award will be given to a student or student team that presents an idea or invention judged to have a high probability of commercial application. Finalists will be determined by a committee consisting of the founding donors, one Stevens Trustee (J erald M. Wigdortz ’69) and one faculty member from the School of Technology Management (Dr. Audrey Curtis) and the School of Sciences and Arts (Dr. Kurt Becker).

SSOE NEW ARRIVALS

Jon K. Miller joins the Center for Maritime Systems as a Research Associate. Miller's major research interests include coastal processes, storm response, shoreline modeling, and remote sensing. Miller received a 2003 Fulbright Fellowship to continue his doctoral research on large-scale shoreline changes at the University of Queensland, Australia. Miller earned his doctorate and master's degree in Coastal Engineering from the University of Florida, and a Bachelor of Engineering degree in Civil Engineering from Stevens.

Yinian Zhu received his B.Sc. degree in physical chemistry from Zhongshan University, China, and his M.Phil. & D.Phil. degrees in electrical and electronics engineering from Rand Afrikaans University, South Africa. He is currently working as a post-doctoral Research Associate in the Department of Chemical, Biomedical, and Materials Engineering at Stevens. From 1982 to 1987, he was a teaching assistant and lecturer with Wuhan University of Technology, China and from 1987 to 1997, he was a senior research engineer with Shanghai Electric Cable Research Institute, China. Zhu was also a visiting research engineer with the Laboratory for Lightwave Technology at Brown University. His research interests are primarily in fiber Bragg gratings, long-period gratings, photonic crystal fibers, and rare earths doped optical fibers, as well as their applications in sensing systems and optical fiber communications.

Brian J. Sauser joins the Department of Systems Engineering and Engineering Management as a Research Assistant Professor. Sauser earned his doctorate in Technology Management at Stevens and a Master of Science degree in Bioresource Engineering at Rutgers University. He has also received advanced training in Technology Assessment, as well as in Commercialization and Marketing Technologies, at the Robert C. Byrd National Technology Transfer Center. He also participated in the NASA Advanced Project Management Training Program at the NASA Academy of Program and Project Learning.

John T. Boardman is an accomplished senior executive in academic and management consultancy with practical experience in functional management and consulting projects. He joins SSoE as a Distinguished Service Professor. Boardman also has broad experience in corporate-level academic policy making, innovation management, fiscal management, and decision-making. He is an experienced consultant and acclaimed expert in collaborative project design and management. He has planned and led numerous large-scale academic/industry collaborative RTD initiatives. He successfully initiated and nurtured the establishment of an entirely new School of Systems Engineering at the University of Portsmouth, UK. Boardman holds a doctoral degree from University of Liverpool, UK.
Building a Future of Complex, Intelligent and Interactive Systems

The Design & Manufacturing Institute (DMI) integrates intelligent product design, materials processing, and manufacturing expertise with modern software and embedded technologies for defense and commercial applications. DMI's researchers are focusing on systems-level research dealing with complex military and commercial systems with embedded intelligence, human interaction and command and control functions. "DMI is working on a spectrum of technologies with applications to military systems," said Dr. Kishore Pochiraju. "We are collaborating with the Picatinny Arsenal and the Air Force Research Laboratory in developing intelligent electromechanical systems and engineered material systems." DMI is working with Picatinny on developing integration methodologies for complex, intelligent and interactive systems; with the Air Force Research Laboratory, Penn State and Boeing under the MEANS (Materials Engineering for Affordable New Systems) Program on the design of lightweight structural materials for high temperature applications and with Marotta Controls, a NJ valve manufacturing company, on developing lightweight and affordable valve bodies for highly corrosive environments seen in commercial and US Navy applications.

Stevens Instrumental in Lightweight Armor Development for Operation Iraqi Freedom

The Design and Manufacturing Institute's team of engineers and scientists worked with the US Army Armament Research, Development and Engineering Center (ARDEC) in the rapid design and development of a lightweight armor protection system for the Stryker Armored Vehicle. DMI's work was instrumental in the evaluation and selection of material systems and integrated product and process design for the lightweight armor system.

"This armor system provides soldiers with critical protection not currently available on Stryker vehicles," said DMI's Lead Project Engineer, Mr. Thomas Kiel, "Advanced lightweight material developments along with rapid systems engineering and prototyping have enabled the Stevens/ARDEC team to provide a technologically advanced system within a significantly compressed timeframe."

CIESE, the Center for Innovation in Engineering & Science Education, adds to their list of achievements:

- $50,000 from the AT&T Foundation to support "Research & Innovation in Engineering Education (RIEE): Creating an Environment of Excellence in Teaching & Learning at Stevens." Dr. Ken Bain, author of "What the Best College Teachers Do," kicked off the RIEE AT&T Distinguished Speaker Series in January, attended by 75 Stevens faculty.
- $254,996 in four grants from the NJ Department of Education and school district partners to improve mathematics achievement in Piscataway, Passaic, and Elizabeth through teacher professional development programs and classroom support in the use of technology-based curriculum materials in middle school mathematics.
- $81,548 from the Connecticut Department of Environmental Protection for curriculum development and online/face-to-face teacher training for the CT Air Quality/Clean School Bus project.

"We have seen dramatic increases in students' science achievement scores—averaging 10% growth sustained over three years—in those schools that worked with Stevens in the (NJ High Technology Workforce) program. In fact, in 2004, science scores increased by almost 10% district-wide and by 20% in the participating schools. This demonstrates the value and impact of the CIESE training. As teachers became more facile with their computer skills and their ability to integrate real time projects into their teaching, the impact has, over time, added value." - Dr. Gayle W. Griffin, Assistant Superintendent of Teaching and Learning, Newark Public Schools

Modeling an America's Cup Racer

A member of Stevens' Ocean Engineering faculty is evaluating some of the computational tools that will help the BMW Oracle (BOR) Team perfect a winning vessel design for the 2007 America’s Cup race.

That faculty member is Professor Len Imas, a native of Forest Hills, Queens, who holds a doctorate from MIT. Working in Stevens' Davidson Laboratory, Imas is an expert in numerical analysis of marine craft aerodynamics. He supports the BOR Team by researching and assisting with the selection of numerical simulation and visualization tools which may be used for evaluating the team’s IACC yacht concepts.

With the BOR Team’s design well underway, the excitement is mounting on all fronts. Prof. Imas is uniquely poised to offer insights into the precise preparations for the America’s Cup competition, as well as into the advanced modeling technology that helps create Cup-winning vessels - the original of which, the yacht America, belonged to and was piloted by members of the Stevens family in the 1850s.
Stevens Hosts Third Annual Conference on Systems Engineering (SE) Research

On March 23-25, the Schaefer School of Engineering, in cooperation with the University of Southern California, presented this year’s conference focused on secure, intelligent network-centric systems, and agile deployment and development in the aerospace, defense, finance, banking, IT, telecommunications, pharmaceutical, and healthcare domains. Also, acting as a conference organizer was the Air Force Center for SE of the Air Force Institute of Technology.

Dr. Rashmi Jain, Chair of the Technical Program, said, “Our objective was to provide practitioners and researchers in academia, industry, and government a common platform to present, discuss and influence SE research with the intent to enhance SE practice and education.”

Day One kicked off with remarks from Co-Chair Dr. Dinesh Verma, Associate Dean and Dr. George R Korfiatis, Dean of Engineering. The conference featured three keynote addresses by experts in the field of SE: Mr. Mark Schaeffer, Principal Deputy, Defense Systems, OSD (AT&L), and Director of Systems Engineering, US Department of Defense; Dr. John Boardman, Distinguished Service Professor, Stevens; and Mr. Kelly Miller, Chief Systems Engineer, National Security Agency.

Original research papers were delivered throughout the three-day conference addressing the conception, design and architecting, development, modeling and simulating, production, operation and support of these systems; definition of metrics of performance and improvement methods; assessment and mitigation of risks; definition of critical success factors; and best practices.

Dr. Rashmi Jain, Stevens Associate Professor, was appointed Head of Research and Education for the International Council on Systems Engineering (INCOSE), comprised of more than 5,000 members worldwide, and more than 40 Advisory Board members from government, industry, and academia. In this new role, Dr. Jain will identify major education and research initiatives such as: becoming a participating body for ABET Accreditation of SE programs; forming an SE curriculum committee; creating a meaningful research strategy and an agenda for INCOSE; and creating a repository of SE research and educational resources. In this capacity, she will also participate on the Academic Council of INCOSE.

31st Annual Northeast Bioengineering Conference Hosted by Stevens

The Spinal Cord Injury and Repair conference was held at Stevens on April 2-3, 2005. Speakers presented an overview of the subject, research at the cellular and molecular biology level and clinical research on emerging regenerative and prosthetic therapies. The conference included poster sessions and talks in all areas of Biomedical Engineering.

Among the speakers: Dr. Noami Kleinman, Program Director, Extramural Research Program, NIH, National Institute of Neurological Diseases, Topic: Scientific and Programmatic Overview of Spinal Cord Injury; Dr. Herbert M. Geller, Head, Developmental Neurobiology, NIH; National Heart, Lung and Blood Institute, Topic: Neural Development and Regeneration after SCI; and Dr. P Hunter Peckham, Executive Director, Cleveland Functional Stimulation Center at MetroHealth Medical Center and Professor of Biomedical Engineering and Orthopedics at Case Western Reserve University, Topic: Neural Prostheses.

Dr. Yu-Dong Yao and his team in collaboration with Jackson State University were awarded an Undergraduate Research Program funded by the National Science Foundation (NSF) where undergraduate students research and design integrated test beds to develop software-defined radio and frequency transmitters and receivers. Their research aims to increase spectrum utilization significantly for both military and commercial applications. The project includes mentorship by experienced electrical engineering and computer science faculty including Co-PIs (Professor Bruce McNair and Dr. Yan Meng), weekly presentations, seminars, and other professional development opportunities during a ten-week summer program at Stevens.

Stevens Forges Alliance in Ireland

On December 7, 2004 a cooperative agreement between Stevens and the Institute of Technology Tallaght (ITT) in Dublin, Ireland was signed by Dr. Tim Creedon, Director of ITT and Dr. George R. Korfiatis, Dean of Engineering at Stevens. The agreement leverages the strengths of both organizations towards the development of an educational initiative in the form of an International Center for Pharmaceutical Education which will deliver technical education to the pharmaceutical/health care industry worldwide; including the delivery of online courses with remote/virtual experiments and joint faculty/students exchanges.

Scott Zederbaum, a Senior Account Manager for Tektronix, donated a $70K WCA 380 real-time spectrum analyzer to the Electrical and Computer Engineering Department. Professor McNair explained, “This device is a research tool that will also be used in education to examine Radio Frequency (RF) signals in the time domain, the frequency domain, and also provides the capability of exploring the internal structure of cellular, PCS and other signals.”

Drs. Yu-Dong Yao, Hong Man and Yan Meng are investigating the remote detection and diagnosis of prostate cancer through Internet and wireless networks to provide prostate cancer screenings to men in rural and developing countries. Funded by the US Army Medical Research and Material Command, they are taking advantage of the explosive development of telecommunications infrastructures and information processing technologies to develop techniques that reduce the costs of telepathology through computer-aided detection and diagnosis. By examining the roles of pathology, telepathology, medical imaging and the requirements of Internet and wireless systems in telepathology and teleconsultation, they hope to provide significant advances in the early detection of prostate cancer.
Olympic Sailing in 2012


To help win the bid, NYC2012’s plan for Olympic Sailing was designed to provide the best possible conditions for Olympic and Paralympic Sailors. They worked with numerous experts to acquire detailed meteorological and current data to select a preliminary location for the Olympic Regatta. A proposed Olympic Marina (modeled on the one in Sydney, Australia) would be located off Breezy Point, a short 34-minute ferry ride from the proposed site of the Olympic Village. Olympic Class racing has never been conducted in this area, so extensive regional data regarding the proposed site was integral to winning the Olympic bid.

Among the experts sought by NYC2012 was Dr. Alan F. Blumberg of the Center for Maritime Systems (CMS) and the Department of Civil, Environmental and Ocean Engineering. Dr. Blumberg is one of the world’s most respected and experienced oceanographers with his own Olympic sailing experience. During the 1996 Olympics in Atlanta, he assisted yachting teams by providing regional wind, current, and water level forecasting services at the Savannah, GA sailing area. Today, Dr. Blumberg leads the CMS’s Urban Ocean Observatory that maintains a host of in-situ sensors and networked computers with estuarine and coastal ocean forecasting models, which automatically monitor and predict weather and water conditions in the NY/NJ Harbor and adjacent coastal areas (www.stevens.edu/maritimeforecast).

Dr. Blumberg visited the potential sailing venue off Rockaway, NY with the IOC Evaluation Commission, answering questions on wind and current patterns and variabilities. He believes that, “having the Games in the NY area will enable Stevens to shine by using the accumulated knowledge and experience of our diverse faculty in many different areas, from secure communications, to sensor development and network design, to information dissemination technology, and port security.”

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LET THE DREAMS BEGIN

On July 6, 2005, the 117 members of the IOC from 79 countries will vote on the host city for the 2012 Games. For more information please contact: Joshua Jackson Project Planning Coordinator NYC2012 1 Liberty Plaza, 33rd Floor New York, NY 10006 http://www.nyc2012.com/

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