Advanced Fabrics

Heidi L. Schreuder-Gibson and Mary Lynn Realff, Guest Editors

Abstract

This brief article describes the content of the August 2003 issue of *MRS Bulletin* focusing on Advanced Fabrics. The six articles will feature reviews of advanced fibers, new fabric constructions and design considerations, materials for novel fabric properties, and the incorporation of new elements within fabric structures to add multifunctional, wearable features to clothing.

Keywords: *advanced fabrics, chemical protection, electronics, textiles.*

Introduction

For thousands of years, clothing has consisted of passive layers, providing warmth and protection beyond our natural skin, that have participated only in limited ways in signaling our intentions to others. However, as materials of exquisite sensitivity to external stimulants or the wearer's physiology are coupled with techniques of microfabrication, the functionality of fabrics will be extended well beyond these historical limits. One can imagine clothing that senses and adapts to our surroundings much like a second skin. Embedding computational elements into fabrics will lead to "garment computers" enabled by adaptations of materials and weaves that go beyond the wearable computers of today. These innovations will build upon the current textile capability that is described in the following articles. What is clear is that textiles are on the cusp of a significant breakthrough in the way we will use clothing—our garments will become an integral part of us and will serve as a highly specialized layer, sensing and protecting us from the environment.

This issue of *MRS Bulletin* on Advanced Fabrics will describe recent advances in fabric construction and functionality that are expected to lead to innovative new garments, technical textiles, and fabric-based composites. Current work and interdisciplinary topics will be described, such as the use of electronics in fabrics; the use of new conductive, electrochromic, and luminescent polymers in fibers; chemical sensing; garments that monitor physiological status (i.e., blood pressure, body temperature, and blood oxygen levels); new developments in chemical and biological protective fabrics; engineering considerations for environmental control within fabrics; and new high-strength fibers for protective fabric-based armor.

As the functions of a textile become increasingly complex, it must be synthesized as a system rather than as a hierarchy of components. The invention of a new polymer or blend is only the first step in the process of developing new advanced functionality in fabrics. It is necessary to ask new categories of questions: What is the best place and length scale to add the new function to the fabric? Answering this question may result in a new fiber woven into a base textile or, in other cases, new materials specifically located and patterned onto individual fiber surfaces. Optimizing the interaction of new functions in fabrics to the size, needs, and preferences of the wearer requires a new paradigm, shifting fabric function from e-textiles (electronic) to i-textiles (interactive). Finally, how new textile construction and materials interact with the wearer can be modeled with computational fluid dynamics. The description of mass transfer from the body through the fabric in order to optimize comfort and maximize interaction between liquid or gas and sensing elements on the fabric becomes a key measure of performance for new designs of advanced fibers and textiles.

Fabrics reinforced with advanced high-strength fibers have been used to protect the wearer from impacts. Fabrics containing barrier layers or adsorbants can protect the wearer from toxic exposure. New materials and textiles are being designed to warn the wearer of threats such as the presence of chemical or biological contaminants, and they may ultimately adapt electronically or colorimetrically to protect the wearer. This issue will introduce some of the materials and design considerations for a new generation of interactive and protective textiles that perform these functions.

Specific materials-synthesis approaches for color-responsive fiber technology are described by Hardaker and Gregory in the first article, "Progress Toward Dynamic Color-Responsive 'Chameleon' Fiber Systems." They describe the coupling of fiber-based processing innovations with new polymer-based optical devices in smart, color-responsive fabric systems. The development of "chameleon" fiber systems follows from a deeper understanding of the physical and chemical processes that occur during color change and light emission in materials. This understanding is resulting in a systems view of textile structures that links materials synthesis with a chemical/physical design paradigm as opposed to a textile engineering design.

The impact of materials and fabric designs on wearing comfort and on the protective properties of a garment is summarized in "Computational Fluid Dynamics Modeling of Fabric Systems for Intelligent Garment Design" by Barry et al. Protective fabrics layered into a garment to protect hazardous-materials teams, firefighters, military personnel, and others can be sorptive, semipermeable, or impermeable. These characteristics, combined with irregular shapes and air gaps, variable wind and humidity conditions, and a wide choice of fit factors for clothing are addressed by computational fluid dynamics modeling to provide improved test methods for fabrics, optimal materials integration, and guidelines for future systems design.

"Chemical and Biological Protection and Detection in Fabrics for Protective Clothing," by Schreuder-Gibson et al., describes the need for combining the technology for fabric-based sensors with the goals for specific protective features in a fabric system. The authors describe the various protective features of current garments and suggest new characteristics that are desirable for the next generation of wearable chemical and biological protection. These features include new selectively permeable barriers, new reactive compounds that allow a garment to self-decontaminate, and novel conducting polymers for use in detecting toxic materials within the fabric.

Another vitally important aspect of personnel protection has always been the strength of wearable armor. High-strength fibers, ranging from silk and nylon to Kevlar and carbon fibers, have been used for decades to provide impact protection in both soft armor (ballistic vests) and hard armor (fiber-based composite helmets and

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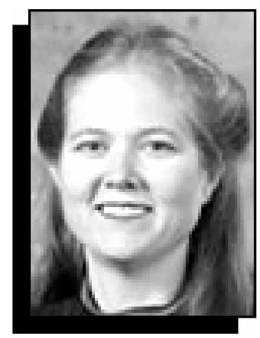
plates). Sikkema et al. review the chemistry and properties of these kinds of fibers in their article, "Assessment of New High-Performance Fibers for Advanced Applications." They discuss the importance of interchain bonding (exemplified by natural fibers) in the recent development of new synthetic high-performance polymers for protective fabric and composite applications.

In their article, "Smart Textiles: Wearable Electronic Systems," authors Park and Jayaraman elucidate important design considerations for "wearable motherboards." They show us that clothing is ever-present and can be designed to be a universal interface. Wearer–garment interaction and dynamics can be achieved if the designer transforms the traditional passive/protective textile into an information/infrastructure fabric. The example of the Georgia Tech Wearable Motherboard illustrates the development of this new class of interactive textiles.

The final article, "Concepts for Energy-Interactive Textiles," by Kim and Lewis, describes the ability of textiles to incorporate energy storage such as photovoltaics, energy conversion such as mechanical to electrical, and energy management through new conductive fibers. Again, the importance of integrating technologies is stressed. Switches, energy-conversion elements, storage elements, sensing devices, and the ability of the fabric to trigger a desired interactive effect are examined. The authors provide a review of the pertinent materials science and engineering areas that are important in the development of energy-interactive textile structures.

Unfortunately, there are some developments in textiles that cannot be reported in this issue. There are many new moisture-management fabrics that have greatly improved the lives of consumers that include new superabsorbing fibers and composite structures. In the medical field, new antimicrobial and thrombogenic dressings have been introduced with great success. Super filters that filter not only microparticles, but also nanoparticles, pollen, and even odors have been developed for auto and home filtration using nanofibers and electrically charged fabrics. Also, important new fabric constructions for soil management and agriculture have greatly reduced erosion and water loss in many regions over the past 10 years. These advances have been pioneered in industry, and many are considered proprietary by their inventors, so the fields of medical and personal-care textiles, geotextiles, and filtration fabrics, to name a few, have not been given full measure in this issue. Other areas, such as nanocomposites, are still in their early stages of development but are likely to play an increasing role in the fabrics of the future. Despite these limitations, we hope that readers will gain an appreciation from the following articles of some very important new capabilities that are being imparted to fabrics through the use of new materials, designs, and analytical tools. □

Heidi L. Schreuder-Gibson



Mary Lynn Realff

Heidi L. Schreuder-Gibson, Guest Editor for this issue of *MRS Bulletin*, is a research polymer chemist within the U.S. Army Natick Soldier Center's Materials Science Team, Supporting Science and Technology Directorate. She has been a research chemist for the U.S. Department of Defense for the past 24 years, working in the 1980s on solid rocket propellants, insulation materials, and adhesives at the Air Force Rocket Propulsion Laboratory, Edwards Air Force Base, California. Since 1990, she has worked on protective textiles and plastics for the Army Soldier Biological and Chemical Command at the Natick Soldier Center in Natick, Mass. Her research has focused on high-strength fibers for armor, biodegradable plastics for food packaging, new flame-resistant materials for clothing, and, most recently, the development of reactive textile membranes for protective clothing. Schreuder-Gibson holds a BS degree in chemistry from the University of California—Irvine and a PhD degree in polymer science from the University of Akron.

Schreuder-Gibson can be reached at the U.S. Army Natick Soldier Center, SS&TD, Kansas St., Natick, MA 01760-5020, USA; e-mail heidi.schreudergibson@us.army.mil.

Mary Lynn Realff, Guest Editor for this issue of *MRS Bulletin*, is an associate professor of polymer, textile, and fiber engineering (PTFE) at the Georgia Institute of Technology in Atlanta. She teaches graduate and undergraduate courses in the mechanics of textile structures and in polymer science and serves as director of undergraduate affairs for PTFE. Realff has made a significant contribution to the understanding of the mechanical behavior of woven fabrics. She continues her work in modeling the mechanical behavior of textile structures, using both theoretical and experimental approaches. She currently conducts research on the analysis and design of woven fabrics for the tufting process. Other projects include the simultaneous design of textile production systems and textile products, the development of quantitative descriptions of textile structures, and the evaluation of production processes using image-processing technology. Realff earned a PhD degree in mechanical engineering and polymer science and technology from the Massachusetts Institute of Technology and holds a BS degree in textile engineering from the Georgia Institute of Technology.

Realff is a co-director of the Center for the Study of Women, Science, and Technology. She also facilitates a student–industry mentoring program that matches industry mentors with Georgia Tech undergraduate students. She is a member of the Fiber Society, the American Association of Textile Colorists and Chemists, and the American Society of Engineering Educators. She is currently an associate technical editor of the ASME's *Journal of Manufacturing Science and Engineering*.

Realff can be reached at the School of Polymer, Textile, and Fiber Engineering, Georgia Institute of Technology, 801 Ferst Drive NW, MRDC 1, Atlanta, GA 30332-0295, USA; tel. 404-894-2490; e-mail marylynn.realff@ptfe.gatech.edu.

Jim Barry is a principal engineer at Creare Inc. in Hanover, New Hampshire. At Creare, Barry has been responsible for projects ranging from biomedical device development to two-phase flow and heat-transfer modeling in microgravity. He has led efforts in modeling and test-fixture development for textiles, technologies

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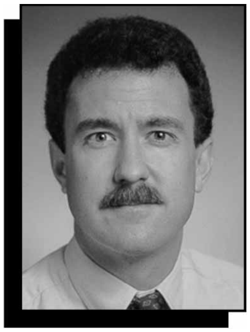
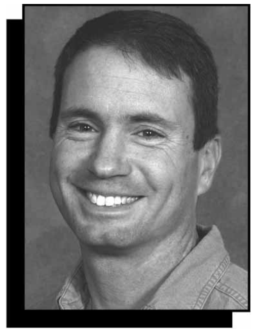
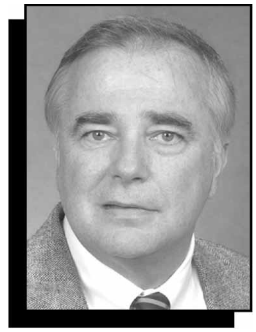


Jim Barry

Paul Brasser



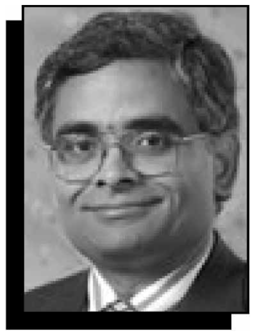
Phil Gibson



Richard V. Gregory

Stephen S. Hardaker

Roger Hill



Sundaresan Jayaraman

for mass vaccination campaigns, semiconductor equipment modeling, development of precision atomization hardware, simulation of aerosol dynamics, furnace design for materials processing, and development of cryosurgical instruments. His experience includes extensive applications of computational fluid dynamics for industrial flow and heat-transfer problems, and he is currently active in the development of modeling software, thermal/fluid hardware, and medical devices.

Barry received his BS, MS, and PhD degrees in nuclear engineering from the University of Wisconsin—Madison. His work there and at Sandia National Laboratories included nuclear reactor safety analysis and design, two-phase flow and heat transfer, and computerized data acquisition and reduction. Prior to joining Creare, Barry conducted experiments on exploding wire physics and aerosol formation.

Barry can be reached by e-mail at jjb@creare.com.

Paul Brasser is a scientific researcher at the TNO—Prins Maurits Laboratory in Rijswijk, the Netherlands. He received his MSc degree (modeling the burning velocity in dust explosions) and his PhD degree (in physical chemistry, studying the recycling of surfactants from the wastewater of laundry-washing plants) from the Technical University in Delft, the Netherlands. After serving in the Dutch army, he joined the Prins Maurits Laboratory in 1996, where he has worked on modeling the protective performance of nuclear/biological/chemical protective clothing. He has also participated in decontamination research and wastewater cleaning research. In 2002, he transferred to the threat analysis and risk assessment group, where one of his tasks is project leadership on research into the evaporation of chemical-warfare agents. Both experimental research in a wind tunnel and theoretical research are carried out in this project.

Brasser can be reached by e-mail at brasser@pml.tno.nl.

Phil Gibson is a materials research engineer at the U.S. Army Soldier Systems Center in Natick, Mass. He holds a DEng degree from the University of Massachusetts Lowell, an MS degree in mechanical engineering from the University of Washington, an MS degree in systems management from the University of Southern California, and a BS degree in engineering science and mechanics from Tennessee Technological University. While serving as an officer in the U.S. Air Force in the 1980s, Gibson conducted research on detonation and combustion of solid rocket propellant and high-energy explosives. He currently conducts studies to measure and model heat and mass transfer through porous materials. For the U.S. Army, he has conducted research on ballistic protection, thermoplastic composites for helmets, chemical protective uniform materials, and blast protection (transmission of shock waves through materials and their interaction with the human body).

Gibson can be reached by e-mail at phil.gibson@natick.army.mil.

Richard V. Gregory is the dean of the College of Sciences at Old Dominion University and the former director of the School of Materials Science and Engineering at Clemson University, where he also served as Thrust II leader in Clemson's National Science Foundation Center for Advanced Fibers and Films. Gregory's primary area of research is in electroactive and photonic polymeric fibers and films. He received his BS degree in chemistry in 1980 from Old Dominion University and a PhD degree in physical chemistry in 1984 from Clemson. He served as a research scientist with Milliken & Company in Spartanburg, S.C., prior to joining the Clemson faculty in 1990.

Gregory can be reached at the College of Sciences, Physics and Oceanography Building, Old Dominion University, Norfolk, VA 23529, USA; e-mail rgregory@odu.edu.

Stephen S. Hardaker is a research scientist with Battelle Memorial Institute's Advanced Materials Applications group in Columbus, Ohio. He received his BA degree in chemical engineering from the Georgia Institute of Technology, after which he spent several years as a process engineer for injection-molding and finishing of products for the consumer electronics industry before returning to Georgia Tech for his MS degree. His thesis work was related to the development of process–structure–property relationships in polyimides. He earned his PhD degree in polymer science from Clemson University in South Carolina, studying polyaniline, an electrically conductive polymer, and the development of a fiber spinning process and the associated process–structure–property relationships. Following his doctoral work, Hardaker remained at Clemson, studying a variety of electrically conductive and luminescent polymers and various processing methods for incorporating such materials into optical and electrical devices.

Hardaker may be reached at Battelle Memorial Institute, 505 King Ave., Columbus, OH 43201, USA; e-mail hardakers@battelle.org.

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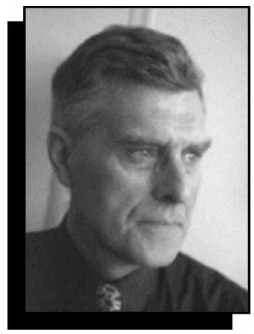
Wayne E. Jones Jr.

Yong K. Kim

Chris Kleijn

Armand F. Lewis



Maurits G. Northolt

Jeffery R. Owens

Sungmee Park

Roger Hill is an engineer at Creare Inc. in Hanover, New Hampshire, where he is involved in a variety of projects, including modeling of mass and thermal transport in chemical protective clothing, development of cryosurgical devices for cancer surgery, optimization of CVD reactor gas-flow distribution for improved film deposition on silicon wafers, and thermal and water management in hydrogen and direct methanol fuel-cell systems.

Hill received his BS degree in mechanical engineering from the University of Missouri—Columbia. Prior to entering graduate school, he served five years as a naval officer involved in fluid/thermal research and development at the headquarters of the U.S. Naval Nuclear Program. He received his MS and PhD degrees in mechanical engineering from the University of Texas at Austin, where his research involved the development of parallel Navier–Stokes DNS solvers and the study of transitional flows in several model systems. During his graduate studies, he was also employed at SEMATECH, where he contributed to the modeling of silicon wafer processing equipment for the semiconductor industry. Prior to joining Creare, Hill was a member of the Mechanical & Aerospace Engineering faculty at the University of Missouri—Columbia.

Hill can be reached by e-mail at rwh@creare.com.

Sundaresan Jayaraman is a professor of textile engineering at the Georgia Institute of Technology in Atlanta. He and his research students have made significant contributions in the areas of enterprise architecture and modeling methodologies for information systems, engineering design of intelligent textile structures and processes, design and development of knowledge-based systems for textiles and apparel, and multimedia educational systems. His group's research has led to the realization of the "Smart Shirt" technology.

Jayaraman holds a PhD degree in textile engineering with a minor in computer science from North Carolina State University and MTech and BTech degrees in textile engineering from the University of Madras, India. He was involved in the design and development of TK!Solver, the first equation-solving program from Software Arts Inc. He worked as a product manager at Software Arts Inc. and at Lotus Development Corp. before joining Georgia Tech in the fall of 1985.

Jayaraman is the recipient of the 1989 Presidential Young Investigator Award from the National Science Foundation for his research in the area of computer-aided manufacturing and enterprise architecture. In October 2000, he received the Georgia Technology Research Leader Award from the State of Georgia.

Jayaraman can be contacted by e-mail at the School of Textile and Fiber Engineering, Georgia Institute of Technology, 801 Ferst Drive NW, Atlanta, GA 30332-0295, USA; e-mail sundaresan.jayaraman@ptfe.gatech.edu.

Wayne E. Jones Jr. is an associate professor of chemistry at the State University of New York at Binghamton. He holds a BS degree in chemistry from St. Michael's College and a PhD degree in inorganic chemistry from the University of North Carolina at Chapel Hill, where he worked with T.J. Meyer. After a postdoctoral fellowship at the University of Texas at Austin with M.A. Fox, Jones declined an NIH postdoctoral fellowship to join the faculty at SUNY—Binghamton. He has more than 60 publications and invited chapters on his work in the area of photoinduced electron and energy transfer in macromolecular systems including molecular wires, electrically and thermally conducting nanomaterials, and fluorescent organic–inorganic hybrid polymer materials. Following a research sabbatical working with A. MacDiarmid at the University of Pennsylvania in 1999, Jones has been applying fundamental studies in inorganic and polymer chemistry to the preparation of chemosensory nanomaterials.

Jones can be reached at the Chemistry Department and Institute of Materials Research, State University of New York at Binghamton, Binghamton, NY 13902, USA; e-mail wjones@binghamton.edu.

Yong K. Kim is a professor of textile sciences at the University of Massachusetts—Dartmouth; he joined the faculty in 1981. His research interests include nanocomposite fibers, electrofiber coatings, digital textile printing, intelligent textile structures, and composite materials. Kim received BS and MS degrees in textile engineering from Seoul National University and a PhD degree in fiber and polymer science from North Carolina State University. He has more than 20 years of experience in industrial applied research.

Kim can be reached by e-mail at ykim@umassd.edu.

Chris Kleijn is a professor of transport phenomena in the Multiscale Physics Department of Delft University of Technology, the Netherlands. He obtained his MSc (1986) and PhD (1991) degrees in applied physics from Delft. His research fo-

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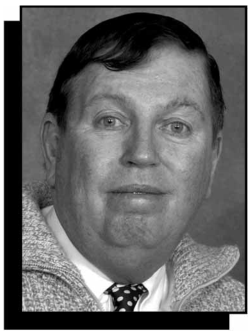
Behnam Pourdeyhimi

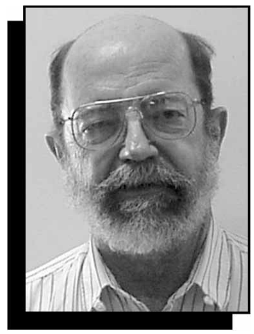
Doetze J. Sikkema

Michal Sobera

Quoc Truong



John E. Walker



Joseph D. Wander

cuses on multiscale computational modeling of reactive flow processes, with applications in chemical reaction engineering, thin-film technology, and materials processing. His current fields of interest are thin-film deposition techniques, chemical reactor miniaturization and process intensification, and NBC (nuclear, biological, and chemical) protective clothing.

Kleijn was a research fellow of the Royal Dutch Academy of Arts and Sciences (1992–1996), a visiting scientist at MIT (1993), and a visiting professor at the University of Karlsruhe (2001). He has authored and coauthored more than 60 publications in international scientific journals and refereed proceedings, three book contributions, and one book. He has given numerous invited presentations at international scientific conferences. He is co-organizer and proceedings editor of a biannual international ASME symposium on industrial applications of computational fluid dynamics.

Kleijn can be reached by e-mail at c.r.kleijn@tnw.tudelft.nl.

Armand F. Lewis is an adjunct professor of textile chemistry and environmental science at the University of Massachusetts—Dartmouth; he joined the faculty in 1993. His research interests include adhesion science, flocking materials and processes, composite materials, fibrous wiping of surfaces by nonwoven fabrics, and the electrical properties of polymers. He holds a BS degree in textile chemistry from the New Bedford Textile Institute (now UMass—Dartmouth), an MS degree in chemistry from Oklahoma State University, and a PhD degree in chemistry (surface) from Lehigh University. He has more than 25 years of industrial research and product development experience.

Lewis can be reached by e-mail at armlew@earthlink.net.

Maurits G. Northolt is a recognized authority on fiber physics and is currently employed at Magellan Systems International in Richmond, Va. His scientific interests include the structure and mechanical properties of polymers and fibers, x-ray diffraction, and optical microscopy.

Northolt holds a master's degree from Delft Technical University and a PhD degree from the University of Amsterdam. He served as a naval officer in the Royal Dutch Navy, including one year at the Dutch Naval Academy as a lecturer in physics, and one year at Delft conducting research on Al-Mg alloys. His postdoctoral appointment was as an invited research fellow in the crystallography group of L. Alexander at the Mellon Institute of Carnegie Mellon University in Pittsburgh.

He worked for more than 30 years at Akzo Nobel Central Research, serving as section head of solid-state rheology and crystallography and as group head of polymer physics. He also served as a member of the Steering Committee on Crystal and Structure Research of the SON (Chemical Research Organization of the Netherlands) and on the Abstracts Committee of the 10th International Congress on Crystallography in Amsterdam. He has more than 50 technical publications.

Northolt can be reached at Magellan Systems International, 8310 Shell Road, Richmond, VA 23237, USA; e-mail mafe.northolt@wxs.nl.

Jeffery R. Owens is a research chemist at the U.S. Air Force Research Laboratory's Force Protection Branch, Airbase Technologies Division. He holds a dual BS degree in chemistry and biology from Fort Hayes State University and is currently a graduate student in organic chemistry at Auburn University. Owens has been a research chemist for the Air Force for the past three years. He has worked in materials and methods for fire suppression and improvised explosive devices, and since 2001, he has been involved in studies of chemically reactive polymers that can be incorporated into fibers or surfaces for individual and collective protection against chemical/biological-warfare threats.

Owens can be reached at the U.S. Air Force Research Laboratory, AFRL/MLQF, 139 Barnes Drive, Suite 2, Tyndall AFB, FL 32403-5323, USA; e-mail jeffery.owens@tyndall.af.mil.

Sungmee Park is a research associate in the School of Textile and Fiber Engineering at the Georgia Institute of Technology in Atlanta. She received an MS degree from Georgia Tech in 1995 for her work on the comfort properties of fabrics and then joined the School as a research associate. She also holds an MFA degree from Georgia State University in Atlanta. At Georgia Tech, Park has worked on product design and development projects including specialty fabrics for the Atlanta Ballet and the "Smart Shirt." This invention was featured in a special issue of *Life* magazine titled "Medical Miracles for the New Millennium" (Fall 1998) as "One of the 21 Breakthroughs that Could Change Your Life in the 21st Century." In November 2001, *Time* magazine named the Smart Shirt one of the "Best Inventions of the Year 2001."

Park's publications include journal articles, book chapters, and patents. She also received an honorable mention in the upholstery fabric design competition organized by the Carnegie Foundation in 1992.

Park can be reached at the School of Textile and Fiber Engineering, Georgia Institute of Technology, 801 Ferst Drive NW, Atlanta, GA 30332-0295, USA; e-mail sungmee.park@ptfe.gatech.edu.

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Behnam Pourdeyhimi is a professor in the College of Textiles at North Carolina State University and director of the Nonwovens Cooperative Research Center. Prior to joining NCSU, he served as a professor at the Georgia Institute of Technology and the University of Maryland. Over the past 20 years, his research activities have focused on materials research, computer applications, composites, and nonwoven textiles. He has published more 200 scientific papers and conference proceedings. He is the recipient of the Distinguished Achievement Award from the Fiber Society.

Pourdeyhimi can be reached at the Nonwovens Cooperative Research Center, North Carolina State University, Raleigh, NC 27695, USA; e-mail behnam_pourdeyhimi@ncsu.edu.

Doetze J. Sikkema is employed at Magellan Systems International in Richmond, Va. He was educated as an organic and physical chemist at Leiden University and worked for more than 30 years at Akzo Nobel Research on monomers and polymers in various fields, often including the area of fibers. He holds adjunct professorships at the Technical University of Eindhoven, the Netherlands, and at North Carolina State University. Recently, he left Akzo Nobel and joined Magellan, where he is pursuing the M5 fiber project that he began while employed at Akzo Nobel.

Sikkema can be reached at Magellan Systems International, 8310 Shell Road, Richmond, VA 23237, USA; e-mail doetze.sikkema@m5fiber.com.

Michal Sobera is currently completing his PhD degree at the Kramers Laboratory within Delft University of Technology, the Netherlands, under the direction of C. Kleijn and H. Van den Akker. In 1998, he received an MS degree from the Institute of Thermal Machinery at the Technical University of Czestochowa in Poland. He also works at the TNO—Prins Maurits Laboratory in Rijswijk, the Netherlands, in areas related to his thesis research, which is focused on computational modeling and experimental measurements of the fluid dynamics and heat/mass transfer properties of the airflow over bluff bodies covered by a porous layer on different scales (meso and macro). He is also interested in microscale modeling of fluid flow and heat/mass transfer for individual fibers. His research has practical application for chemical protective clothing design as well as for cold-weather clothing and general sportswear.

Sobera can be reached by e-mail at m.p.sobera@klft.tn.tudelft.nl.

Quoc Truong is a physical scientist and RDT&E program manager at the U.S. Army Natick Soldier Center (NSC). He received BS (1984) and MS degrees (1999) in plastics engineering from the University of Massachusetts Lowell, an MS degree (2002) in engineering management from the Western New England College, and a certificate in project management (2002) from Boston University. He has worked at NSC since 1994. His current R&D emphasis focuses on chemical and biological (CB) protection and amphibious (land and sea) individual protection, which was preceded by more than 18 years of progressively responsible research and experimental developmental positions associated with the developments of air-permeable, semipermeable, and selectively permeable membranes; electrically polarizable materials; reactive and super adsorptive material containing membranes; novel closures/interfaces; smart temperature-responsive shape-memory polymer membranes; and specialty insulation materials for environmental and CB protective clothing. He has received various official commendations and invitations to speak at international conferences and universities. He has pioneered technological developments in selectively permeable membrane technologies for CB protection. He was also selected as a recipient of the 2001 U.S. Army R&D Achievement Award. He co-authored the best paper in the technical session at the 22nd Army Science Conference in December 2000.

Truong can be reached at the U.S. Army Natick Soldier Center, IPD, Kansas St., Natick, MA 01760-5019, USA; e-mail quoc.truong@us.army.mil.

John E. Walker is a research chemist in the U.S. Army Natick Soldier Center's Materials Science Team, Supporting Science and Technology Directorate. He holds a BS degree in chemistry from Boston College, an MS degree in inorganic chemistry from Northeastern University, and an MA degree in biochemistry from the Medical Sciences Division of the Boston University School of Medicine.

Walker has been a research chemist for the Department of Defense for the past 30 years. He has worked in environmental medicine (isoenzyme systems active in cold acclimatization) and biochemical effects of lysozomal enzymes on muscle proteins, and since 1982, he has been involved in studies of catalytic systems (both enzymatic and nonenzymatic) that can be incorporated into fibers or membranes for individual protection against chemical/biological-warfare threats.

Walker can be reached at the U.S. Army Natick Soldier Center, SS&TD, Kansas St., Natick, MA 01760-5020, USA; e-mail john.walker@us.army.mil.

Joseph D. Wander is a senior chemist in the U.S. Air Force Research Laboratory's Force Protection Branch, Airbase Technologies Division. He holds a BS degree in chemistry from Case Institute of Technology and a PhD degree in organic chemistry from Ohio State University.

Wander has been a research and development chemist for the Air Force for the past 16 years. He has worked in environmental compliance (materials and methods for particle and VOC control in high-volume airflows) and purification/decontamination of water, and since 1997, he has been involved in studies of chemically reactive systems (both consumable and catalytic) that can be incorporated into fibers, surfaces, or membranes for individual and collective protection against chemical/biological-warfare threats.

Wander can be reached at the U.S. Air Force Research Laboratory, AFRL/MLQF, 139 Barnes Drive, Suite 2, Tyndall AFB, FL 32403-5323, USA; e-mail joe.wander@tyndall.af.mil. □

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