

Linking Transformational Materials and Processing for an Energy-Efficient and Low-Carbon Economy

Lynne Robinson

Diran Apelian's goals for a new TMS-led project commissioned by the Department of Energy (DOE) Industrial Technologies Program (ITP) are ambitious, but straightforward: "We need to clearly identify the opportunities and solutions for materials science and engineering (MSE) in the energy sector to transform the 'way we do it now.'"

That transformation began in earnest on February 18 when TMS convened an Energy Materials Blue Ribbon Panel chaired by Apelian and consisting of 21 MSE thought leaders, selected, in part, said Apelian, because "they are individuals with a track record of being agents of change." (See sidebar "Meet the Energy Materials Blue Ribbon Panel" for background on the panelists.) The work of the panel, which is to develop a Vision Report, comprises the first phase of a two-part study coordinated by TMS and focusing on areas where new materials and processing breakthroughs can lead to transformational advances in energy efficiency, energy security, and carbon emission reductions. In addition to providing a valuable resource for the materials community, the study will support the DOE in launching two new university-led Manufacturing Energy Systems Centers intended to accelerate both knowledge development and dissemination in distinct manufacturing areas with critical technical needs.

Douglas Kaempf, program manager for the DOE's Industrial Technologies Program, hailed the advances that the TMS project will make possible in the areas of high impact materials and processing technologies used across the economy. "Finding ways to develop low-carbon products with a ubiquitous presence out in the public and on commercial shelves can lead

to truly impressive gains in energy efficiency and carbon reductions nationwide," he said. Kaempf went on to note that the Manufacturing Energy Systems Centers DOE is launching are intended to "dramatically accelerate our progress toward a low-carbon economy by compressing the time it takes for innovation to go from pure science through engineering and finally to production where it can have a real impact on our daily lives."

TMS' involvement with this project is a manifestation of the society's "Grow TMS" initiative that focuses on materials for energy as one strategic growth area. It is also part of Energy Materials Initiative, recently launched as a joint effort of TMS and ASM International. (See sidebar article, "Connecting the Materials Community.") Responsible for the initiative's "EnergyEvents" component, TMS engaged in an exploration of potentially valuable activities during 2009. In the process, said Warren Hunt, Jr., TMS executive director, "We became aware of the interest of the DOE Industrial Technologies Program to better understand what the materials opportunities and needs were for achieving the United States' energy goals." After a great deal of discussion and study, TMS submitted a technical proposal to the DOE to convene key leadership in the materials community for the purpose of identifying pathways to achieving the nation's energy goals from the MSE perspective. The DOE formally commissioned TMS to lead the one-year project in February 2010.

"This activity is a new one for TMS, although it fits well with our core activities of convening meetings and other events, as well as information dissemination through channels such

as *JOM*," said Hunt.

Providing a compelling vision for the current and future role of MSE is the charge of the Energy Materials Blue Ribbon Panel. "Materials bring enabling solutions to our nation's energy needs, but having said this, we need to identify the specific opportunities and essentially make the value proposition," said Apelian. At its February 18 meeting, the panel determined areas where MSE could make the most significant near- and long-term contributions in breakthrough improvements within the broad categories of energy sources, energy carriers and storage, and energy use. The panel also examined materials science and engineering areas critical to transformational progress, with a view toward cross-cutting materials systems and processing technologies. An area of specific discussion was the role of computational materials science and engineering in accelerating the realization of promising materials and processing technologies. In addition, the panel evaluated the strengths and weakness of the U.S. science and technology infrastructure and how these could affect the desired impact of the project's ultimate recommendations.

A preliminary summary of the panel's findings is expected in April, with the final Vision Report detailing the highest impact opportunities identified by the panel due in late May. The Vision Report will be presented publicly in a briefing to be held in Washington, D.C., sometime in June, while also being disseminated through *JOM* and other TMS communication channels.

Apelian likened the process to the one that produced the National Academies' groundbreaking *Rising Above the Gathering Storm* report

on ensuring U.S. competitiveness in science and technology. “We are taking the same broad-based approach to difficult questions with distinguished leaders from industry, government, and academia,” he said.

Armed with the findings of the Energy Materials Blue Ribbon Panel, TMS will then commence the second phase of the project by convening up to four Technical Working Groups charged with identifying and prioritizing the highest impact research and development areas that address the panel’s recommendations. The technology roadmaps that emerge from the Technical Working Groups’ deliberations will be analyzed and peer-reviewed to produce an integrated final report, due to be disseminated widely throughout the government and materials community in December 2010.

A particularly tall order for both the panel and Technical Working Groups will be to identify approaches to better integrate breakthrough materials with materials manufacturing in order to propel the most promising technologies across the so-called “valley of death” into application at scale. “We need to provide a fresh perspective on how MSE can advance energy issues in the longer term. Only through such inspiration will we move people to change,” said Ross Brindle, vice president of Energetics Incorporated, the technical and management consulting firm assisting TMS with structuring and analyzing the output of the collaborative strategic planning sessions that will drive the content of both the Vision Report and overall project document.

While Energetics has facilitated a number of planning, development, and assessment projects focused on energy technologies, Brindle said that the timing of the TMS initiative sets it apart. “Priorities at DOE and other federal agencies are still transitioning to the Obama administration’s priorities,” he said. “The panel and Technical Working Groups have the opportunity to inform and shape how DOE and other agencies view the potential contributions of MSE to energy and climate challenges. Our potential impact with this effort is quite high, and that is exciting.”

To ensure that the work of both

the panel and the Technical Working Groups can continue smoothly outside of the face-to-face meetings, ASM International, as a subcontractor to TMS, will customize, host, and support an online Collaboration Center, housed within the Energy Materials Network. The center provides a secure, centralized workspace for panel and Technical Working Group members to create, share, and edit documents and facilitate communications with TMS staff. Additional center features include email, calendaring, document sharing and revision history, polling, voting, messaging, and forums.

Apelian said that the recommendations of the panel and Technical

Working Groups may not only require development of new technologies, but also necessitate examination of public policy and funding priorities. He also noted that being at the epicenter of such an ambitious undertaking marks an important step in TMS’ evolution as the “home of our professional community.”

“It is significant that we are walking the talk,” said Apelian. “It is one thing to have a Materials and Society Committee or focus and another thing to come up with specific recommendations at the request of the DOE.

“We are not just talking about issues among ourselves—we are doing something about them.”

CONNECTING THE MATERIALS COMMUNITY

TMS and ASM International have come together to ensure that cross-cutting, transformational information on achieving an energy-efficient and low-carbon economy is available to the entire materials community. Called the Energy Materials Initiative, the effort takes advantage of both organizations’ core competencies to offer information and knowledge exchange on energy materials issues and technologies.

“ASM International and TMS have joined forces to tackle the challenges associated with materials for alternative and renewable energy,” said Stan Theobald, managing director, ASM International. “This unique and revolutionary collaboration will enable our members—scientists, engineers, and manufacturers—to interact directly with each other, accelerating the pace of information exchange and encouraging rapid materials innovation.”

The Energy Materials Initiative is comprised of three complementary and interconnected elements. “Energy Education” addresses changing workforce issues, with a particular emphasis on energy materials. It encompasses interdisciplinary educational requirements for curriculum development and undergraduate/graduate educational support, while also advancing professional development and certifications through workshops and seminars.

“Energy Events,” led by TMS, include specialty meetings, workshops, roadmapping sessions, and other venues that bring together technical experts to define and capture opportunities for next-generation energy materials technologies. Convening the Energy Materials Blue Ribbon Panel marks the first of these types of projects. “We see this as the base for building other energy events in selected areas, especially as the Blue Ribbon Panel’s recommendations become clear and the areas of primary emphasis are identified,” said Warren Hunt, Jr., TMS executive director. The ideas, research, and implementation results generated by these events will also serve to support current and future materials developments for energy applications.

Finally, the “Energy Materials Network,” managed by ASM, with content contributed by TMS and other society partners, serves as a hub of materials energy knowledge. Accessed at www.EnergyMaterialsNetwork.org, the network offers streamlined access to current information on traditional and emerging energy technologies, as well as academic and government research related to the materials community. Resources include an extensive compendium of peer-reviewed materials; modeling and computational tools for storing, managing, and mining material property data; and a collection of professional on-line collaboration tools.

For additional information on the Energy Materials Initiative, please visit www.EnergyMaterialsNetwork.org or contact Hunt at TMS or Laura Marshall at ASM International.

MEET THE ENERGY MATERIALS BLUE RIBBON PANEL



Diran Apelian

Diran Apelian, Chair

Professor, Mechanical Engineering and Director, Metal Processing Institute at Worcester Polytechnic Institute

Apelian, a TMS member since 1976, served as president of the society in 2008 and as a director from 2007 to 2010. He was named a TMS Fellow in 2006 and is active on several TMS committees, including the Public & Governmental Affairs Committee and the Materials and Society Committee. Apelian's research is focused on materials processing. His specific research interests include solidification of metals, thermal and plasma processing, particulate processing, and resource recovery and recycling. His teaching and advising interests include energy supply and demand, energy policy, strategic materials, the effect of technology on social systems, history of technology, innovation, and entrepreneurship. He is a pioneer in engineering education reform and the co-developer of a course for first-year students, "Sustainable Development for the 21st Century: Societal Grand Challenges."



William J. Bernard, Jr.

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President and Chief Executive Officer, Surface Combustion, Inc.

Bernard has more than 40 years of experience in the industrial equipment industry, joining Surface in 1969 following his graduation from Michigan Technology University with a B.S. in metallurgical engineering. In 1987, he participated in the successful management purchase of what was then the Surface Division of Midland-Ross Corporation and, in 1998, became the president, chief executive officer, and controlling shareholder in the company. Bernard is active in many industry associations and is the founding chair of the Center of Heat Treat Excellence (CHTE), past president of the Industrial Heating Equipment Association (IHEA), and past president of the ASM International Heat Treating Society. He has also served on the ASM Finance Committee, the Metal Treating Institute Board, and has been appointed a member of the Ohio Commodores by the governor in recognition of his outstanding contributions to the economic development of the state of Ohio. In addition, Bernard has received a number of awards, including the 2009 CHTE Distinguished Service Award, and is an inductee into the Michigan Technological University Academy of Materials Engineers.



Yet-Ming Chiang

Yet-Ming Chiang

Professor of Ceramics, Massachusetts Institute of Technology; Co-Founder, American Superconductor and A123 Systems

Chiang has focused his research on the design, synthesis, and characterization of advanced inorganic materials and related devices. He studies and teaches the role of advanced materials in technologies for energy storage and generation, medical devices, "smart" structures, and micro/nano electronics. Other research interests include new cathode and anode materials for lithium ion batteries, phase transformations in electroactive materials, electrochemical device design, electrochemical-to-mechanical energy conversion, self-assembling colloids, and the stability and defect chemical properties of interfaces in inorganic materials.



Leo Christodoulou

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Director, Defense Advanced Research Projects Agency (DARPA) Defense Sciences Office (DSO)

Prior to his role with DARPA, Christodoulou, a member of TMS since 1982, served as the program manager for several DSO materials programs, applying his research expertise to developing new materials capabilities for the United States military. He has worked extensively in materials processing, with a particular focus on its influence on the microstructure and properties of materials. His expertise encompasses the synthesis, processing, and performance of metallic, intermetallic, and composite materials. His specific research interests include understanding microstructural evolution through the processing and prediction of properties—in particular, fracture, fatigue, brittle fracture, hydrogen embrittlement, and stress corrosion cracking. Christodoulou is also the co-inventor and primary developer of a class of materials known as XD alloys.



Tomás Díaz de la Rubia

Tomás Díaz de la Rubia

Chief Research and Development Officer; Acting Principal Associate Director for Science and Technology, Lawrence Livermore National Laboratory (LLNL)

Díaz de la Rubia is responsible for the quality and strategic direction of the science and technology portfolio at LLNL and has been involved in the development of multiscale models of materials strength and aging in irradiation environments. His research interests include the application of dislocation dynamics to predict mechanical behavior of materials and the use of ab initio electronic structure methods to investigate the properties of defects and impurities in nanostructured materials. He has published and presented extensively on radiation effects in metals, defect and dopant diffusion in semiconductors, computer simulation of physical properties, and performance of materials. He joined TMS in 2009.



Michael J. Dolan

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Senior Vice President, Exxon Mobil Corporation

Dolan's career spans 34 years in the oil and petrochemical business. In addition to his position at Exxon, he is a member of the board of the U.S.-Saudi Arabian Business Council, the U.S.-China Business Council, and the American Petroleum Institute. He is also on the Board of Trustees of Worcester Polytechnic Institute and has served as director of the American Chemistry Council and the Society of Chemical Industry.



James W. Evans

James W. Evans

P. Malozemoff Professor Emeritus and Professor of Metallurgy Emeritus, Department of Materials Science and Engineering, University of California, Berkeley

Evans has been a member of TMS since 1970, served as a TMS director from 1986–1989, and was named a TMS Fellow in 2009. He has taught and conducted research at Berkeley since 1972 and is the principal investigator in the Environmental Energy Technologies Division of the Lawrence Berkeley National Laboratory. His research interests include fluid flow, reaction kinetics, mass transport, and the electrochemical and electromagnetic phenomena governing processes for producing materials and storing/distribution of energy. He has investigated an array of technologies, including aluminum reduction cells, electromagnetic casters, chemical vapor deposition, fluidized bed electrodes, and batteries. His current projects include wireless monitoring of the electrolytic cells used for producing aluminum; printing of batteries and capacitors for storing energy at scales ranging from wireless devices to wind farms; and the deterioration of cables used in electric power distribution.



Brian Gleeson

Brian Gleeson

Harry S. Tack Chair Professor, Materials Science and Engineering and Director, Center for Energy, University of Pittsburgh (Pitt)
Gleeson has been a TMS member since 1989. Under his leadership, Pitt's Center for Energy has focused its research on energy efficiency, delivery, and reliability; advanced materials for demanding energy technologies; energy diversification; and clean coal technologies. Gleeson's own primary research focus is the thermodynamics and kinetics of gas/solid and solid/solid reactions, with particular emphasis on the high-temperature degradation of metallic alloys and coatings. His other research interests include the active and passive high-temperature oxidation of alloys and coatings, deposition and characterization of metallic coatings, diffusion and thermodynamic treatments of both gas/solid and solid/solid interactions, and the structure/property relationships of materials. He currently serves as editor-in-chief of the international journal, *Oxidation of Metals*.



Joseph Goldstein

Joseph Goldstein

Distinguished Professor and Dean Emeritus of Engineering, University of Massachusetts, Amherst
A TMS member since 1959, Goldstein has been particularly involved in the development of the electron probe microanalyzer, scanning electron microscope, and analytical electron microscope for application to problems in materials science and engineering. With colleagues, he has developed methodologies and instrumentation for electron microscopes to improve spatial resolution, minimize the effects of spurious radiation, and improve light-element and trace-element analysis. He has used these techniques to measure diffusion coefficients and phase diagrams, study phase growth and ternary diffusion effects in iron base alloys and various diffusion coatings, and understand the metal phases in meteorites and lunar samples.



Kevin Hemker

Kevin Hemker

Professor and Chair, Mechanical Engineering, Johns Hopkins University
Hemker is currently serving as a TMS director, where he has been a member since 1991. He chairs the TMS Public & Governmental Affairs Committee and is a trustee of the Federation of Materials Societies. Hemker's research aims to identify the microstructural details that govern the macroscopic mechanical response of metals, alloys, and advanced structural materials. His general interests include high-temperature mechanical behavior, transmission electron microscopy, deformation behavior of intermetallic alloys, experimental characterization of dislocation core structures, and microsample testing. His recent research topics include the characterization and modeling of bond coat layers for thermal barrier coatings, deformation behavior of nanocrystalline materials, and characterization of materials for MEMS and energy applications.



Enrique Lavernia

Enrique Lavernia

Distinguished Professor, Provost and Executive Vice Chancellor, University of California, Davis
Prior to his current position, Lavernia was dean of the College of Engineering at Davis and a professor in the chemical and biochemical engineering, materials science, and mechanical and aerospace engineering departments at the University of California, Irvine. His research interests have included the processing of structural materials and metal matrix composites, with particular emphasis on solidification fundamentals, droplet-based manufacturing, spray atomization and deposition of structural materials, solidification processing of metal matrix composites, nanocrystalline materials, and mathematical modeling of advanced materials and processes. He has served on the International Activities Committee of TMS, where he has been a member since 1986, and has chaired both the Bradley Stoughton Award Committee and Henry Marion Howe Medal and Marcus A. Grossmann Young Author Award Selection Committee of ASM International.



Steven McKnight

Steven McKnight

Director of the Civil, Mechanical, and Manufacturing Innovation Division, Directorate for Engineering, National Science Foundation (NSF)
Before joining NSF, McKnight served as chief of the Army Research Laboratory Materials Division, where he directed a comprehensive interdisciplinary materials research program that encompassed materials science and engineering, chemistry, applied physics, process and manufacturing technology, and engineering mechanics. His personal research has focused on advanced polymer composite materials and polymer adhesion science, including innovative composites manufacturing techniques that use non-traditional consolidation and curing methods for structural composite materials and composite material repair. His other research interests include tailored nanoscale engineering of composite fiber reinforcement for ballistic applications and fundamental studies on the degradation mechanisms of multi-component, high-performance, military coating systems.



Cherry Murray

Cherry Murray

Dean, School of Engineering and Applied Sciences and John A. and Elizabeth S. Armstrong Professor of Engineering and Applied Sciences, Harvard University
Murray served as principal associate director for science and technology at the Lawrence Livermore National Laboratory (LLNL) prior to her post at Harvard. Before LLNL, she was the senior vice president for physical sciences and wireless research at Bell Laboratories, where she had launched her career in 1978 as a staff scientist. She is a past president of the American Physical Society and was elected to the National Academy of Sciences in 1999, to the American Academy of Arts and Sciences in 2001, and to the National Academy of Engineering in 2002. Her research interests include the study of soft condensed matter and complex fluids, semiconductors' optical phenomena, nanostructures, phase transitions, and controlled self-assembly of optical materials.



Alton D. Romig, Jr.

Alton D. Romig, Jr.

Executive Vice President, Deputy Laboratories Director, and Chief Operating Officer, Sandia National Laboratories
Romig joined TMS in 1972, served on numerous technical and administrative committees, and was named a TMS Fellow in 2005. At Sandia, his responsibilities encompass overseeing all business and operations, including the \$2.3 billion a year laboratory and an 11,000 member workforce, 8,500 of which are permanent regular employees. In addition to finance, safety and health, security, facilities, human relations, and communications, he manages all independent functions, including audit and ethics, export control, and counterintelligence. Romig is also responsible for institutional development, including government relations and strategic planning.



Mark A. Smith

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Chief Executive Officer and Board of Directors Member, Molycorp Minerals, LLC

Prior to his position at Molycorp Minerals, a rare earths products and technology company, Smith served as president and chief executive officer of Chevron Mining Inc., a wholly-owned subsidiary of Chevron Corporation. In that role, he was responsible for the company's three coal mines, one molybdenum mine, a petroleum coke calcining operation, and the Mountain Pass rare earth mine. Smith has also held numerous engineering, environmental, and legal positions within Unocal and Chevron.



David B. Spencer

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Founder, Chairman, and Chief Technology Officer, wTe Corporation

A TMS member since 2002, Spencer led wTe's entry into the waste-to-energy field in the 1980s and later guided the company into the recycling business. Prior to joining wTe, he worked for Raytheon and was a member of the team that founded that company's waste-to-energy business. With funding from the National Institute of Standards and Technology, wTe Corporation and its subcontractor, National Recovery Technologies, have developed a new suite of technologies, called Spectramet®, to accurately analyze, sort, and recycle scrap metals at high speeds using advanced optoelectronic techniques.



Alan Taub

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Vice President, Global Research and Development, General Motors Company (GM)

At GM, Taub is responsible for seven science laboratories focusing on technologies that include advanced powertrain systems, computer-based design and analysis systems for vehicle engineering, electronics- and information-based vehicle systems, new materials and fabrication processes, environmentally friendly fuels and lubricants, and efficient emission control systems. Before his tenure with GM, he spent 15 years in research and development at General Electric (GE), where he ultimately managed the GE materials properties and processes laboratory. A TMS member since 2007, Taub also worked at Ford Motor Company for eight years, where he was manager of the materials science department, manager of North American vehicle crash safety, and manager of vehicle engineering for the Lincoln brand.



John Vickers

John Vickers

Manager, National Center for Advanced Manufacturing (NCAM), NASA Marshall Space Flight Center

In addition to his role with NCAM, NASA's chief resource for aerospace manufacturing research and development, Vickers is also an engineering manager within the Marshall Materials and Processes Laboratory and responsible for the manufacturing engineering of space transportation systems, research and development, strategic planning, and building partnerships with government, industry, and academia. His primary interests include the creation of manufacturing technologies through research and development in science and engineering, as well as programs in manufacturing-related science, technology, engineering, and mathematics (STEM) to promote careers in the aerospace industry. He has participated in several national projects designed to support and strengthen the nation's manufacturing competitiveness, including The National Science and Technology Council Interagency Working Group on Manufacturing Research and Development.



Jeffrey Wadsworth

Jeffrey Wadsworth

Chief Executive Officer and President, Battelle Memorial Institute

Jeffrey Wadsworth joined TMS in 1982 and was named a TMS Fellow in 2000. He has served as a member of the White House Transition Planning Office for the U.S. Department of Homeland Security, and from 2003 to June 2007, he was director of Oak Ridge National Laboratory. His previous work includes positions at Stanford University, Lockheed Martin, and the Lawrence Livermore National Laboratory. He is also a director of Carpenter Technologies, a specialty metals company.



James C. Williams

James C. Williams

Professor, Department of Materials Science and Engineering, Ohio State University (OSU)

Before coming to OSU, Williams held research and leadership positions at General Electric, Boeing, and Rockwell. He also served as professor, president of Mellon Institute, and dean of engineering at Carnegie Mellon University. He has been a TMS member since 1960, serving on a number of committees, including the Public & Governmental Affairs Committee and the Integrated Computational Materials Engineering Committee. Williams' research has focused on phase transformations, processing, and structure-property relations in high-performance materials—mainly titanium, nickel, and aluminum alloys. His current research projects include working to understand the dwell-time fatigue of high-temperature titanium alloys; the relation between processing, structure, and properties of Thixformed™ magnesium alloys; the effects of casting and heat treatment variables on the residual stress of cast aluminum components; and the opportunities that direct laser deposition of titanium alloys afford for new alloy synthesis.



Steve Zinkle

Steve Zinkle

Director, Materials Science and Technology Division, Oak Ridge National Laboratory (ORNL)

In addition to his position at ORNL, Zinkle is a UT-Battelle Corporate Fellow. He joined ORNL in 1985 as a Wigner Fellow and, prior to his current role, led the ORNL Nuclear Materials Science & Technology Group, where he managed the fusion materials and space reactor materials programs. His research has focused on transmission electron microscopy and physical properties of metals, ceramic insulations, structural ceramics, and fundamental mechanisms of deformation and fracture. Zinkle joined TMS in 2003 and has served on the Structural Materials Division Council and the Nuclear Materials Committee.