Symposia Summary

Materials and Society: Linking Science and Technology for Global Energy Solutions

Organizer: Christina Meskers, Umicore

Sponsored by the TMS Materials and Society Committee, the plenary session of the Materials and Society technical track of the TMS 2011 Annual Meeting, made a deliberate attempt to include materials experts from the full suite of energy sectors that are alternatives to conventional fossil fuels. The leadoff talk by Mark Z. Jacobson of Stanford University, "A Plan for a Sustainable Future Using Wind, Water, and Sun," was a thought provoking exposition of possible renewable energy sources and the prospect for a total transition to them in the next 20-40 years. Jacobson's study reviewed the effects on the environment, climate, and energy security of each energy option and evaluated a scenario for powering the world with wind, water, and solar technologies, while considering the technical feasibility for materials and transmission infrastructure, as well as cost estimates and the challenge of developing political will.

As a prime example of the sustainable energy technologies reviewed in the first presentation, materials issues in solar photovoltaics were discussed in "Metallurgical Considerations in the Photovoltaic Module" by Funsho Ojebuoboh of First Solar, Inc. Rather than the common crystalline or amorphous silicon photovoltaics that many people think of in this field, Ojebuoboh focused on continued development of thin film CdTe photovoltaic (PV) modules, even as they begin to be deployed as a commercial power source on the cutting edge of a drive to achieve grid parity with common fossil fuel fired power plants. He discussed the sources, synthesis and characterization of input materials (raw materials) for the thin film CdTe PV modules and the management of output materials, including spent process materials. Together, these issues stand as challenges to the widest implementation of clean, affordable solar electricity.

Since our increasing reliance on solar and wind-derived electrical energy will demand a means to store large quantities of energy for dispatch through the electrical grid during times when the sun is not shining and the air is calm, Gary Yang of Pacific Northwest National Laboratory presented "Electrical Energy Storage for Renewable Integration and Grid Applications: Status, Challenges and Opportunities." He briefly described the many potential technologies for grid-scale electrical energy storage, including batteries, super-capacitors, flywheels, compressed air storage, pumped hydropower, and others. Unfortunately, in their current state, many of these technologies either cannot meet the performance and cost requirements for broad market penetration or are simply limited by site selection or environmental constraints. Strong motivation exists for materials research in several storage technologies, particularly batteries, and Yang discussed the status, challenges and research needs in this area.

An attractive alternative to direct energy storage in battery banks can be enabled by the cheap conversion of a renewable or carbon-free energy source to stored hydrogen, a key "energy carrier." Teruhisa Horita from AIST addressed this potential in "Materials Challenges for Solid Oxide Fuel Cells: Application of Metallic Materials and Analysis of Oxide Ionic Diffusion at the Component Interfaces." Horita reviewed solid oxide fuel cells (SOFCs) that can convert the chemical energy carried in elemental hydrogen to electricity directly with high efficiency. Perhaps the major materials challenge to SOFC operation and durability is their high operating temperatures, around 600-1000˚C. As Horita explained, this requires the SOFC component materials to be high temperature resistant alloys and ceramics with the ability to accommodate thermal stress mismatch and to maintain electrical

and mechanical integrity. He also discussed design of high temperature oxidation resistant alloys, development of cell components for oxygen ionization and oxide ionic diffusion, and tolerance for small amounts of impurities. His presentation included a short technological review of a SOFC demonstration project in Japan.

Because rare earth (RE) metals are involved in essentially all of the methods of harvesting renewable energy and in several of the approaches to improve energy efficiency, Karl A. Gschneidner, Jr., of Ames Laboratory and Iowa State University delivered a talk on "The Rare Earth Contributions to Global Energy Solutions." As he explained, the rare earths have many unique physical and chemical properties that make them important, if not critical, components in a variety of energy technologies. Gschneidner described how La is used in NiMH batteries, Ce is used (as Ce oxide) in gasoline "cracking" catalysts and in three-way catalytic converters, Nd is used (as Nd-Fe-B permanent magnets) in electric motors and generators, and Y is used (primarily as yttria stabilized zirconia) as an oxygen sensor to control lean/rich fuel mixtures in IC engines and as an oxidation resistant coating in aircraft gas turbine engines. In the energy generating and transmission sectors, Nd-Fe-B permanent magnets also are used for high output, direct-drive (low maintenance) generators in large wind turbines and Y is used (as $YBa_2Cu_3O_7$oxides) in "high temperature" (liquid nitrogen cooled) superconductors for both wind generators and electrical transmission lines. Gschneidner included several types of improved energy efficiency applications in his review, as well, especially phosphors (Y, Gd, Lu are used as the hosts and Eu, Tb, Dy and Er are used as the activators) in lighting and displays and La, Nd and Gd are used in magnetic refrigeration, an energy efficient replacement for conventional gas cycle refrigeration.

As part of a balanced portfolio of sustainable energy options, Steven Zinkle of Oak Ridge National Laboratory explained that nuclear energy offers significant promise as a proven, cost-effective, and reliable baseline power option. In his lecture, "Materials R&D to Enable a Nuclear Energy Renaissance," Dr. Zinkle explored the potential to enhance the nuclear power contribution beyond its current level of 20 percent of electricity production in the United States. He detailed three key initiatives, including first examining the potential to safely and reliably extend the operational lifetime of existing nuclear power plants by quantifying the key materials degradation mechanisms and identifying materials replacement or damage mitigation solutions. He then described a broad range of new fission reactor concepts, especially small (<300 MW) modular reactor designs that may be attractive for replacement of aging fossil energy plants and "Generation IV" reactor concepts that offer further improvements in fuel sustainability, economics and safety. Finally, Zinkle briefly reviewed the daunting materials challenges for realizing practical fusion energy systems.

In one of the most widely quoted talks of this keynote session, Ken Somers of McKinsey & Company presented "Energy Efficiency, A Transformational Journey." He detailed how energy efficiency is a tremendous opportunity for industry, but various reasons have made this difficult to capture. His years of practice at helping companies unlock significant energy efficiency gains in their assets stresses the use of a "transformational journey" that encompasses a three-tier approach including the technical system, the management infrastructure, and the company mindset and capabilities. Dr. Somers highlighted the critical enablers for an energy efficiency transformation on each of these three dimensions with a focus on managerial aspects, such as building ownership of solutions, establishing a zero waste mentality, and setting up meaningful energy key performance indicators.

As a summary for the keynote session, Diran Apelian of Worcester Polytechnic Institute delivered "The Pivotal Role of Materials Science and Engineering for an Energy Efficient and Low Carbon Economy." Apelian declared that the most critical issue in achieving a sustainable 21st century is energy, due primarily to an increasing global population (1.4 percent/year) and an even more rapidly growing demand for energy (1.7 percent/year) predicted for this population. He described how innovation in sustainable materials and material processing technologies are critical to achieving the longer term objectives of an energy-efficient and low-carbon world. While significant efforts have been made to identify "breakthrough materials" and their benefits, less attention has been given to integration with materials manufacturing, which is vital to propelling promising materials candidates into cost-effective application at scale. Under this theme, Apelian provided an overview of a study that TMS has been conducting on behalf of the U.S. Department of Energy Industrial Technologies Program that is focused on

identifying those areas where materials science and engineering can have the most significant impacts on energy efficiency and carbon reduction. Copies of related reports, as well as additional information on this initiative can be accessed at the TMS Energy website at http://energy.tms.org.

One indication of the success of this keynote session was its outstanding audience attendance and retention. The Materials and Society Committee plans to offer similar keynote sessions at each TMS Annual Meeting for the foreseeable future.

—Submitted by Iver Anderson, TMS Materials and Society Committee chair