Enhancing the Materials Role in Environmental Technology and Sustainability

by Eric W. Brooman

"Assessment of Linkages" was the theme of the second in a series of workshops organized by the Federation of Materials Societies (FMS), with assistance from The Interagency Environmental Materials Committee (EMAT), and sponsored by the National Institute of Standards and Technology (NIST). The Electrochemical Society (ECS) was represented at both workshops as an interested party. The latest workshop, held in December 1997, had as its focus an update and assessment of relevant activities in industry, government, and academe. Here are some highlights from the many thought-provoking presentations and discussions.

Three Plenary Addresses covered important topics and issues in industrial ecology and the links in place or needed between the environmental community and the materials community and how the two are inter-related and affect local, national, and global economies. The Panel Discussions focused on specific industry sectors or government agencies, including trends and requirements. It was obvious from the presentations and discussions that, while ECS does not have a single, specific focus, its interests covered a wide range of industries and it could make significant contributions to developing environmentally-friendly materials, processes, and products.

Plenary Addresses

Environmental Technology Links to Materials Science and Engineering Research—Robert A. Laudise focused on finding industry government linkages that will advance research on industrial ecology. For a sustainable economy and ecology, goods must be produced at one-tenth of the current environmental burden per unit of production. Laudise proposed that the new paradigm would be total quality and industrial ecology management (TQIEM). He said that "industrial ecology is not an option, it is a necessity." He also proposed that change would result only through economic drivers, and industry would still be driven by profits. The key is to make the new technologies cost-effective. Possible topics for "green research" included: "soft processing" (e.g., alternative solvents); elimination of organic solvents in synthesis; alternatives for lead in products; polymer recycling; and "soft energy" (e.g., photovoltaics).

Industrial Ecology: History and Background—Braden R. Allanby focused on "good technology, not the environment," because good technology takes into consideration environmental issues. However, good technology in an industrial ecology framework needs cultural, ethical, and institutional evolution for sustainable development. Allanby said that the goal of sustainable development relies on "dematerialization" (e.g., reducing use of resources, including materials, per unit quantity of life, and reducing the velocity of materials through the economy, i.e., extending life); "decarbonization" (e.g., improving energy efficiency, more use of renewable energy, better choice of materials and processes); and reduced "dispersive use of toxins" (e.g., materials substitution, product flow control, and recycling). He closed by discussing four challenges: (1) the need for a high level materials database, including "figures of merit" for materials to meet sustainability goals; (2) the need for life cycle materials management, including balancing impacts at various stages of the cycle, and access to enabling information systems; (3) the need for materials recycling and reuse, and using residuals and byproducts as raw materials for other applications/products; and (4) the need for a "functional economy" in which materials are managed by the service providers in the same way they are managed in the manufacturing sector.

Opportunities for Participating in Other Studies—Michael L. Knotek identified a number of activities that could provide direction for materials research and development. First was discussed the NSF/DOE workshops on new themes for basic research. Topics addressed were: (1) vehicles for the future; (2) environmentally-responsive technologies of the future; (3) organizing for R&D in the 21st Century; and (4) science needs for a sustainable future. With respect to Item 2, cross-cutting (cross-industry) themes will develop, such as the need for sensors, monitors and controls, and the need for new approaches, such as design for the environment and life cycle assessment. With respect to the third item, Knotek mentioned that systems, institutions, and cross-discipline programs, during the strategic planning stage, should be tied to national goals understandable by the public and politicians if funding is to be obtained.

Part of Knotek's address focused on the roadmaps developed by federal agencies. The Presidents' Committee on Advanced Science and Technology (PCAST) was mentioned in terms of its report on "Federal Energy R&D for the Challenge of the 21st Century." This report emphasized economic well-being through reliable, affordable energy, the role of energy in national security, and the need for the US to establish leadership in energy technology worldwide.

Panel Presentations

At the beginning of each panel discussion, the panel members were asked to provide some introductory comments, summarized here.

Materials Flow in the US Economy—**Eric Rodenberg** of the **World Resources Institutes** talked about the environmental impact of materials in economic terms on a national scale. The flow of materials in an economy also is being studied at three levels: "macro" (country); "meso" (sector); and "micro" (product). He mentioned the "Factor Four" concept from the book by Lovins, et al. That is, for a sustainable economy, materials use per capita has to be reduced by a factor of

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four. In Europe, the goal is a factor of 10! (As a baseline, materials use in the US is about 85 metric tons per person per year, or about 3 kg per dollar of GNP.) The US, Germany, and Holland have all converged to about the same per capita materials use, which is about twice that of Japan.

David Allen of the **University of Texas at Austin** provided a slightly different perspective. He defined "macro" as a sector; "meso" as a unit operation; and "micro" as molecular interactions. He pointed out that macro studies could be used to focus R&D at the micro level, and gave two examples: (1) wastes as raw materials, and (2) toxicity versus cost to select environmentally favorable processes. The problem of institutional, regulatory, and policy barriers to implementing clean technologies was discussed briefly.

Dan Arvizu of **Sandia National Laboratories** talked about changes that had occurred over the last 20 years, such as the change from waste treatment to pollution prevention, and the trend toward an integrated approach between R&D and applications using multidisciplinary teams. He talked about the Sandia vision, which is "the right atom in the right place, at the right time," and mentioned the "sense, think, talk, act" paradigm for developing products. Finally, he provided some examples of environmentally-conscious manufacturing, such as non-cyanide silver plating, chromium-free conversion coatings, alternative cleaning methods, alternatives to lead-based solders, intelligent inductive processing (heating), and laser engineered net shaping (LENS) for rapid prototyping.

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R&D Strategies for Environmental Technologies—Frank Princiotta of the **Environmental Protection Agency** provided information about two case studies. The first was the effect of regulations on materials use, with CFCs as the example, and the switch to alternatives. However, some of the latter are "greenhouse" gases and cause problems with degradation of seals and gaskets. The second case study was the "Environmental Resource Guide," which uses a life cycle costing approach to select building materials. This was developed in conjunction with American Institute of Architects, and is scheduled to be released by John Wiley & Sons in the spring of 1998.

John Stringer of the **Electric Power Research Institute** talked about the "characteristic time" for change in the utilities sector being of the order of 20 years because of capital investment needs. He noted the paradox between the public wanting cheap, reliable energy but pushing for controls and legislation. About 75% of energy use is related to fossil fuels, and this drives environmental impacts. Examples of moves toward cleaner technologies and materials substitution by electric utilities were presented. The thrusts in the industry are increased generation efficiency (lower CO_2 emissions); increased use of natural gas; improvement in utilization factor, and end-use efficiency; and better storage technologies.

Geoff Frohnsdorff of **NIST** commented on issues relating to the (building) construction industry and described the National Construction Goals. The latter are: a 50% decrease in delivery time, operating and maintenance costs, energy costs, waste and pollution, and occupant illnesses and injuries; a 30% increase in productivity and comfort; as well as an increase in flexibility of use and durability. He mentioned three tools in use or being beta site tested. These are a life cycle costing methodology; a tool for determining the economics of new construction materials; and the building for economic and environmental sustainability (BEES) tool. NIST also has formed a consortium for coating service life prediction, and has developed multi-attribute, decision-making software.

Denise Swink of the **Department of Energy** presented information on "Industries of the Future" and how technology roadmaps, based on an organization's vision, can influence technology implementation. She mentioned how the DOE is now making "radically different" decisions based on roadmaps. She also stated that technologists should not establish a company's vision because they are too focused. The CEO or their top executive should formulate the vision and let the technologists find ways to implement it. Coming back to industries of the future, these would exhibit a number of characteristics, such as: energy and resource savings; minimal waste generation; process oriented, multidisciplinary; multiple partners; leveraging technology and resources; and developing "leapfrog" technologies.

Lewis Sloter of the **Department of Defense-Pentagon**, provided details of three relevant DOD programs. The Strategic Environmental R&D Program, which is jointly supported by the DOE and EPA, focuses on science and technology. The Environmental Security Testing and Certification Program focuses on technology transitioning. Both involve industry stakeholders or partners. The third is the DOD Environmental Quality Programs, which focus on specific Army, Air Force, and Navy needs. The DOD focuses on four areas of interest: compliance, pollution prevention, clean-up, and conservation. Of these, materials play the largest role in pollution prevention activities.

John Green of the **Aluminum Association** talked about industry-government relationships and the skepticism of working with government. He said the industry is energy and capital intensive, as well as technology driven. Developments being evaluated include wettable titanium diboride cathodes and inert anodes. Any improvements have to be drop-in replacements. Over the next three years, industry focus will be on using modeling to reduce energy use, especially in smelting, because new smelters cost $1-2 billion. Green also mentioned some issues with aluminum use in the automotive industry, including: formability; recycling of scrap; developing recycling tolerant alloys; and joining of dissimilar materials. A life cycle assessment for automobiles was planned for publication by the USCAR consortium in the spring of 1998.

Panel Discussion

The workshop was concluded with a general session, moderated by **Robert Eagan**, in which all were invited to comment on what they had heard, and provide their own perspective of materials role in the environment and sustainability. Much of the general discussion during the workshop focused on the issues of materials data acquisition, storage, and use. Barriers included no one wanting to take ownership to generate materials property data, and if someone did, how would ownership rights be handled. Funding was another issue, as was the problem with assessing (verifying) data quality. It was agreed that industrial ecology makes sense, and will be the new paradigm. To support this, information must be made available on material flows and life cycles. Both should provide direction for R&D strategies. Finally, there was a role for all, which was summarized as follows:

- Administration — provide vision for country;
- Government Agencies — help develop technologies, provide data framework, devise and enforce regulations;
- Professional Societies — educate members, broker partnerships, advise and assist researchers, communicate with funding agencies;
- Trade Associations — provide focus on industry needs, advocate the vision, educate industry about the options;
- Industry — establish partnerships, implement the clean technologies; and
- Public — become better educated, push for change.

Implications for ECS

The content of the workshop suggested several implications and opportunities for ECS, and suggestions have been made to the ECS Executive Committee for its consideration.

ECS should educate its members about the importance of materials, environment, and sustainable development. The Society does not have a single industry or product focus, but the scientific and technical focus of the Divisions and Group cuts across, and plays a significant role in, a wide range of industries. Tailored symposia, monographs, and courses could use materials on the environment in a structured way to increase awareness of industrial ecology and sustainable development. A start already has been made with the Ad Hoc Subcommittee on Environmental Technology tasked to integrate and coordinate environmental symposia.

There is an opportunity to team with other societies and/or associations to provide joint symposia or courses. Topics, such as materials flow, life cycle assessments, and materials figures of merit, may be of interest to some when considering an integrated approach to materials/process development and technology transitioning. Similarly, the Society could offer to bring a scientific or technical focus to materials related issues to those that focus on socio-economic issues.

ECS needs to communicate better its involvement with aspects of industrial ecology and sustainable development, in the context presented in the workshop. The members magazine, ***Interface***, is one tool, but consideration should be given to other ways to communicate what members have accomplished. Perhaps the first step would be to select two or three Divisions, and have them address this issue. If the experiment is successful, then the effort could be expanded to other Divisions and Groups, and perhaps become a Society-wide activity. Another approach would be to submit selected ***Interface*** articles to other publications for a wider dissemination of ECS contributions and accomplishments.

Technology roadmaps appear to be playing a more significant role in industry and the government in directing R&D focus and funding. It is not clear what role ECS may play in developing technology roadmaps, especially for an industry. Perhaps one or two industry sectors could be selected (e.g., primary metals, electronics) and a dialogue established with interested parties. Another approach might be to expand the "Report of the Electrolytic Industries" activity to make it more proactive and get involved with technology planning. This effort also might be transitioned to other industries or industry sectors. The Society should consider letting its members know about funding opportunities for research in this area of sustainable development. This might consist of announcements in ***Interface.***

Finally, ECS should encourage FMS to set up a special committee of member society representatives, reporting to the FMS Board of Trustees, to coordinate, organize, and integrate courses, symposia, and the like, on materials and environmental topics related to industrial ecology and sustainable development. This special committee, reporting to the FMS Board of Trustees, also should be responsible for following up and implementing the recommendations from the workshops. ■