Materials Science Takes on Responsibility for Future Sustainable Developments

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"The outcome of the UN World Summit in Johannesburg is not very encouraging for future sustainable development of our environment. Thus, we as materials scientists must intensify our efforts for the development of both materials and technologies in accordance with requirements posted by sustainability and reasonable environmental protection," said Bernd Stritzker as he organized MATFORUM 2002 with his colleague Armin Reller. Held September 17–19, at the University of Augsburg in Germany, and supported by the European Materials Research Society (E-MRS) and the Materials Research Society (MRS), the meeting brought together political, industrial, and scientific experts from around the world to discuss materials, not only in terms of their scientific and economic requirements, but also in terms of sustainability. Attendees focused not only on the optimum use of materials, production with minimum energy expenditure, reduced environmental effects, and high-quality recyclability but also on socioeconomic effects and the feasibility of introducing these technologies in less industrialized countries.

(From left to right): Bernd Stritzker (Co-Chair, MATFORUM 2002), Alex King (2002 Materials Research Society President), Giovanni Marletta (President of European Materials Research Society) at MATFORUM 2002, held in Augsburg, Germany.

Materials Science: To Promote Protection of Resources and Environment

The MATFORUM conference was conceived at the 2000 E-MRS/MRS consultation meeting in Boston as the first forum that would focus on the environmental and socioeconomic effects of materials. The meeting was organized as a workshop with more than 30 invited speakers. Augsburg was chosen as the location for this meeting because it has become an "environmental city," as the rector of the University of Augsburg pointed out during the opening session. The university is home to the Application Center for Materials and Environmental Research and the Environmental Science Center, as well as the European office of the World Environment Center (New York).

Introductory Session

Recognized international leaders from the United Nations Environmental Program, World Wildlife Fund, and aluminum and oil industries reviewed the current global situation. Increasing consumption, traditional business methods, and lack of technical expertise all place a burden on sustainability. While consumers are concerned about health and the environment, investors and managers seek to minimize business risk. Among the issues highlighted were treatment and prevention of pollution, particularly greenhouse gases, such as carbon dioxide (CO_2); cleaner and safer production processes and products; and life-cycle economics. Key resources, such as clean water and energy supply, are also of concern. Water is a scarce commodity in many parts of the world. Agriculture and aquaculture place heavy demands on limited supplies and also contribute to increasing pollution and deforestation.

Environmental footprints can be reduced by integrating industrial operations into communities, taking cultural diversity into account and offering local populations adequate education and health and safety training as well as transportation. The energy industry is focusing on community relations. In the chemical industry, product life cycle and industry image are important. On a corporate level, procurement policy, social aspects, and regulatory agencies must be considered.

Sustainable development is a strategic vision that cannot be measured; but economic, social, and environmental indicators can be quantified. Sustainable development must be based on tangible achievements to be credible, and it is more an evolution in corporate culture than a revolution.

Materials for Communication Technology

The demand for environment-friendly products is fueled by public and consumer opinion as well as government regulations, which vary widely in different parts of the world. In the production of electronic and optoelectronic components, integrated and cost-optimized solutions are needed; thus, economy and ecology are not contradictory. In the past, the industry focused only on the end use of the product; now each process must be considered to reduce waste. The environmental concept must be introduced in the research and development (R&D) phase.

Attendees debated the statement: It is a management decision, for example, to use a lesser quantity of dangerous chemicals instead of a larger quantity of less hazardous chemicals. Many participants thought that this is a moral decision that should be the responsibility of each materials researcher/developer. Nevertheless, a general agreement was reached: full life-cycle analysis is important; therefore, even the use of toxic materials may be justified if there is a substantial technological advantage and if the risks of the whole system can be handled securely and economically.

Another issue discussed was: What is the responsibility of the company that produces the product? Solutions similar to that devised by airplane turbine producers may be applicable to different industries. The airlines no longer own the turbines; they buy engine running time from the turbine producer, who is responsible for the maintenance, safety, and recycling of the product. Thus, the producer is interested in the safe and long-lasting performance of his product—a very favorable solution.

Materials for Energy Technology

The speakers covered developments in solar cells, advanced batteries, fuel cells, and adsorption heat pumps. It is clear that optimum sustainability can be reached in principle by solar energy conversion, the only truly renewable energy. The price of solar energy conversion systems is a much larger issue than the environmental quality of the materials involved.

In electricity generation, low efficiency and the use of fossil fuels are problems. A static system such as a fuel cell or heat pump may be more efficient. Clean fuels can be used, but materials with specific features have to be developed. Even if world oil reserves last for another 40 or more years, which is a matter of debate, it should not be used as an energy source because of the CO_2 problem. The consensus was that there should be more support for small- and medium-sized enterprises to allow the introduction of new technologies and that support should not be restricted to large companies.

A topic for debate was: Is fresh water or energy more important, especially in developing countries? It was concluded that solving the energy problem would lead to a solution to the possibly even more urgent problem of limited fresh water supplies.

Materials in Sustainable Manufacturing and Processes

The water issue was also discussed in the context of sustainable supply and production chains. Within the last 100 years, fresh water consumption increased from 500 to 5000 cubic kilometers per year. Today about 65% is used for agriculture, 25–30% for industry, and the remainder for domestic use, though these rates vary from country to country. For example, India and other developing countries use more than 90% of the available fresh water for agriculture, whereas in highly developed countries, industrial use prevails. Because water of appropriate quality is unevenly distributed on the planet, both socioeconomic and strategic problems arise. Water could become a future energy problem because it must be "produced" by means of desalination, purification, or reclamation—all energy-consuming processes that dictate not only the price of drinking water, but also that of agricultural and industrial products.

The recycling and reuse of materials was illustrated by examples from the automotive industry. For example, in Italy about 1.4 million cars are dismantled, resulting in more than 1 million tons of waste to be treated. This waste contains a 75% metallic fraction, which can easily be recycled. Some fluids and nonmetallic components (about 5%) can also be recycled. The remaining 20% is organic plastics consisting of different components. Recycling of this fraction is not profitable; however, pending regulations direct that the recycling rate for cars must reach 85% in 2006. The responsibility for reaching this goal is assigned to the car producers. Thus, optimization of polymers and composites will be crucial: the variety of polymers used must be reduced, and a trend toward thermoplastics with a broad spectrum of application is expected. Recycling techniques will be chosen on the basis of economical and ecologically feasible reuse of these polymers.

The supply chain for the production of future materials plays a crucial role; both minimizing resource consumption and optimizing efficient production and functionality of materials should pave the way to sustainable manufacturing and processes.

Materials for Efficient Mobility

Transportation not only accounts for a large share of energy use but also influences the development of new materials. In turn, the propulsion and materials systems for future vehicles will be crucial for a more or less sustainable development. Starting with the question of future fuels, hydrogen was discussed. Its chemical and physical properties make it an ideal candidate fuel and also an important resource for many industrial processes. But there are still obstacles to be overcome,

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MRS Materials Research Society

E-MRS

AMU

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ZWW

WEC World Environment Center

The Augsburg Materials Declaration

Sustainable and secure production and utilization of goods gain an ever increasing significance for the welfare of the world's population. In this context the materials implemented into production chains, their resources and their life cycles play a crucial role. Based on these realities the participants of the *First Materials Science Forum on Future Sustainable Technologies, the* ***"MATFORUM 2002"*** in Augsburg propose the following materials declaration. It summarizes recommendations for the goals for research, development and implementation of novel materials and processes.

For sustainable product realization, materials, their supply and process chains, production, utilization and consumption must address the three pillars of sustainability:

economy, ecology and society

Consequently every single step in materials flows, including exploration, mining, production, distribution, utilization and recycling must not only fulfill the "usual" functional and economic requirements but must also meet the ecological and social demands of sustainability.

In order to achieve sustainable product realization, the materials research community must consider the following factors:

- Integration of environmentally benign design, materials, and manufacturing over all stages of the life-cycle
- Exploration and mining of raw materials respecting socio-economic standards and preserving the eco-sphere
- Optimal exploitation of raw materials and natural resources including synergetic utilization of by-products
- Energy efficient production technologies and product distribution, if possible based on regenerative energy sources
- Minimal harmful effects caused by the emission of secondary products
- Durability, recyclability and closed loops
- Traceable and accountable waste management
- Appropriate information and education of the stakeholders in the materials and products

These issues represent general principles for the implementation of sustainable materials, products and processes.

Augsburg, September 19, 2002

on behalf of the participants:

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Chairing MATFORUM 2002

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such as storage.

Sustainable transportation depends on three key factors: technology, infrastructure, and consumer behavior. In contrast to the present practice of considering only economic factors, environment and society must be brought into the debate. The responsibility for efficient mobility systems rests not only on technology but also on the customer. The use of new materials introduces new challenges: the need to understand how they interact, economical recycling and reuse, and infrastructure and legislative issues.

Materials in Eco-Efficiency and Life-Cycle Design

Life-cycle assessment, though a well-known process, is still an efficient method for evaluating materials and energy flow to determine the environmental impacts of a product "from cradle to grave." However, this wholistic approach may be too complicated, and new methods, such as material flow cost accounting and material flow analysis, have been introduced. Both procedures yield valuable criteria for decision-makers in industry, but the results only identify economic advantages for choosing ecologically benign materials for "the decision is made on money." The ultimate solution would be a switch to industrial production completely based on ecomaterials.

Materials in Biological and Medical Systems

Two issues were highlighted: the future of pharmaceutical R&D and the use of biomaterials for tissue engineering and implants. Progress in pharmaceutical products is in the hands of private industry, which invests up to US$30 billion per year (about 17% of sales) in R&D. The development and marketing of new drugs is both time-consuming (about 7 years of research, 6.3 years of clinical studies, and 1.8 years for legal approval) and cost-intensive (US$500–800 million per drug development). Genomically driven drugs have much potential for innovation, fueling a trend toward "personalized medications." The problem of making drugs available to poor people was discussed, but without practical solutions. The environmental risks of new drugs, such as those that contain hormones or radioisotopes, will become a major criterion for researchers and regulators.

Advances in tissue engineering implants depend on the successful use of biocompatible materials that can be accommodated in living cells. A major problem is that living tissue and bones grow and change. Adaptive, preshaped, and "intelligent" (composite) biocompatible materials will be needed to overcome the shortcomings of conventional materials. Environmentally benign manufacturing and processing systems for these materials are also needed. Knowledge of the properties of a material, engineering, recyclability, and reuse will drive innovative solutions. Diagnostics, risk assessment, and prevention are crucial criteria for the development and implementation of new materials in biological and medical systems. Biocompatibility may therefore be the most challenging task of functional materials science.

La Rose performed during the conference dinner concert.

Materials Issues in Regionalization/Globalization

The effect of materials flows on both the regional and the global scale was outlined, and suggestions for better control were proposed. For example, the European paper industry produces 40 million tons per year, accounting for 28% of global production. Its supply chain is complex and connected to a network of related industries, such as forestry, packaging, printing and publishing, and furniture. About 54% of the fibers are recovered and reused from recycled paper (50% worldwide), and between 1990 and 2000, forest use decreased by 9.4 million hectares. Paper production is a heavy industry, and its ecological performance is remarkable: through the use of advanced waste management systems, sustainable forest man-

Opening panel of the conference (from left to right): Peter Saalfrank, General Manager CCI Augsburg; Madame Jaqueline Aloisi de Larderel, Assistant Executive Director, United Nations Environment Programme, France; Claude Martin, General Director, World Wide Fund for Nature International, Switzerland; Klaus Kirchner, Mayor of Augsburg; and Heinz Fischer-Heidelberger, Bavarian State Ministry for Development and Environmental Affairs. Alex King (2002 Materials Research Society President), Giovanni Marletta (President of European Materials Research Society) were also on the panel. The panel covered a status report of the current situation regarding sustainable development; news from the Rio+10 conference (World Summit for Sustainable Development) in Johannesburg; and conclusions for the future, especially in materials science.

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agement, and use of renewable energy sources (waste wood), CO_2-neutral production can be realized. This example shows the potential of creative environmental strategies.

Supply chain and life-cycle system factors, such as time, regional impacts, the dynamics of material and energy flows, and risk, are difficult to control. A global approach could improve the situation. For example, in the United States between 1970 and 1997, the use of mercury decreased by 75% and its price dropped. Although mercury recycling could cover the global market, this bio-accumulated element is still mined in some countries. This fact highlights the need for a global mercury strategy.

Bernhard Wernau, a student at Augsburg University, during a coffee break in the lecture hall.

Closing Session

An "Augsburg Materials Declaration" was finalized (see Sidebar on page 384). This declaration would serve as a self-commitment for scientists in materials research. This declaration has been approved by the appropriate boards of both E-MRS and MRS.

The future of MATFORUM was discussed. The participants were very much in favor of a continuation. They decided that these meetings should be held every two years and asked the Augsburg Organizing Committee to host MATFORUM 2004 again in Augsburg. MATFORUM 2004 will be held in Augsburg, Germany, on September 14–17, 2004. Details about MATFORUM are available at www.amu-augsburg.de/matforum/.

From the Silicon Era to the Era of Sustainable Materials

"With this Augsburg MATFORUM 2002, we as materials scientists actively want to take on responsibility for the future development of mankind. We want to gather interdisciplinary knowledge and then discuss the resulting questions on a scientific basis to find solutions for reasonable ways to achieve sustainability despite Johannesburg and the current political situation," said Stritzker. He continues, "We want to strengthen the sustainability of materials science. Thus, after eras called Bronze, Iron, Fossil Fuel, and Silicon, we hope future generations will think of the 21st Century as of the Era of Sustainable Materials!"

Wilfried Bottke, Rector of the University of Augsburg (front left) and Paul Wengert, Lord Mayor City of Augsburg (front right), during a reception held in the Townhall of Augsburg.

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Joint [NA]PMRC 2003 Meeting Emphasizes the Readiness of Perpendicular Magnetic Recording for "Prime Time"

The Joint [NA]PMRC 2003, a meeting organized by the North American Perpendicular Magnetic Recording Conference (NAPMRC) and the Japanese Perpendicular Magnetic Recording Conference (PMRC), and sponsored by the Institute of Electrical and Electronics Engineers, the National Science Foundation, the Japanese Society for Promotion of Science, and the Magnetic Society of Japan, was held in Monterey, Calif., January 6–8. Planned as a highly interactive meeting serving as an open forum to evaluate the readiness of perpendicular magnetic recording technology for the prime time, the conference attracted more than 150 top leaders in the field of magnetic data storage. The Joint [NA]PMRC 2003 had a single-session format, with all-invited speakers representing the major industrial research and development (R&D) centers and several academic research facilities. A poster session showcased contributed work.

Joint [NA]PMRC 2003 honorary chair S. Iwasaki of the Tohoku Institute of Technology (center) and North American Perpendicular Magnetic Recording Conference organizers S. Khizroev of Florida International University (left) and D. Litvinov of Seagate presented a program facilitating connections between technology developers and decision makers. Other organizers included honorary chair Stanley Charap of Carnegie Mellon University, and Japanese Perpendicular Magnetic Recording Conference organizers Hiroaki Muraoka of Tohoku University and Hajime Aoi of Hitachi (not pictured).

Conventional magnetic recording technologies, already several decades old, are rapidly approaching their fundamental limits. The need for alternative recording schemes is paramount. As explained by Sakhrat Khizroev of Florida International University, a conference program co-chair, "The transition to perpendicular magnetic recording—a technology capable of extending the fundamental limits of conventional longitudinal recording—is a major milestone in the history of [the] magnetic recording industry, calling for major innovations and rapid implementation of innovative concepts."

Shun-ichi Iwasaki of the Tohoku Institute of Technology, an honorary co-chair, opened the conference with an overview talk on the status of perpendicular recording. He stressed the crucial role of the NAPMRC in shifting the focus of the magnetic storage community onto perpendicular recording technology. Iwasaki commended the conference organizers, Dmitri Litvinov (Seagate) and Khizroev, for their efforts to bring together leading experts in the field in order to open direct communication between technology developers and decisionmakers, thus facilitating the rapid maturation of the technology.

Among the highlights of the conference were the record areal-density demonstrations presented by Read-Rite and Seagate. This was the first time that the areal densities utilizing perpendicular recording were higher than the highest areal densities achieved with conventional longitudinal recording. Francis Liu of Read-Rite presented a 145.7 Gbit/in.^{2} demonstration and Ned Tabat of Seagate presented a 135 Gbit/in.^{2} demonstration. Impressive results on granular CoPtCr-SiO_2 perpendicular media were presented by Hiroyuki Uwazumi of Fuji Electric. Yan Wu of Maxtor and Sooyoul Hong of Samsung presented promising results on hard-drive integration. A number of talks were devoted to the extendibility limits of perpendicular recording. At the close of the conference, Mark Kryder of Seagate gave the industry outlook for the next 4–10 years.

Above: Attendees discuss perpendicular magnetic recording issues during poster presentations at the Joint [NA]PMRC 2003 held in January in Monterey, Calif.

Right: Prominent magnetic recording leaders enjoy a reception at the Sardine Factory Restaurant in Monterey, Calif. (left to right) D. Speliotis of ADE, C. Lodder of the University of Twente, G. Tarnopolsky of Tarnotek, and E. Murdock of Seagate.

Selected invited papers from the conference will appear in the July issue of *IEEE Transactions on Magnetics*.

Stanley Charap of Carnegie Mellon University served as the honorary chair for NAPMRC, and Hiroaki Muraoka of Tohoku University and Hajime Aoi of Hitachi served as program chairs for PMRC. The conference was endorsed by the Information Storage Industry Consortium, the Materials Research Society, and the American Physical Society. □

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