nature

10 October 2002 Volume 419 Issue no 6907

Materials for sustainability

Whether in energy generation or environmental protection, materials research has already made many contributions. But the community has further to go to reduce the impacts of entire cycles of materials use.

Researchers working on materials have played an active role in cleaning up the environment over the past 30 years. Materials scientists have improved the quality of released effluent and exhaust plumes, the use of catalysts to avoid unwanted by-products in chemical processes, and the treatment of waste. They have moved from solvent-based coatings to powder coatings and biodegradable materials, and are helping to generate cleaner energy. For example, they are developing photovoltaic materials with improved conversion efficiencies, and materials that form components of the various types of fuel cell under development.

But those designing materials for such purposes should weigh up environmental impact as well as material functionality, and both the costs and benefits of synthesizing and processing materials. There also needs to be a shift in the materials community at large towards technology sustainability, specifically in terms of energy and environmental impacts. For example, it has been estimated that solar cells take between three and eight years to pay back their energy costs. Significant energy input stems from the aluminium or steel frames in which the cells are placed. Additional costs come from the manufacture of solar cells, the disassembly and recycling of components, and finally from chemicals that might pose occupational health risks to workers and are difficult to dispose of. It could be argued that the energy delivered and the lack of carbon dioxide produced eventually outweighs these costs. But careful analysis of the life-cycle assessment of solar cells will pinpoint areas of improvement in material and device design to maximize the environmental benefit.

Metal recycling is an important aspect of sustainability. The mining and processing of aluminium ore yields large quantities of carbon dioxide, oxides of sulphur and nitrogen, and volatile organic compounds, not to mention waste for disposal in landfill sites and the large-scale consumption of water. Research is required to ensure that, by 2008, there is a significant amount of recycled aluminium in use. The mining and production of virgin aluminium should be reduced considerably, although elimination is sure to be a distant goal.

Meeting of minds

Industrial companies must address the sustainability of materials and technologies to help ensure their long-term survival. At the First Materials Science Forum for Sustainable Technologies (MATFORUM) last month at the University of Augsburg in Germany, some of the world's largest manufacturing companies — including Ford, Schott Glass, Pfizer, Motorola and TotalFinaElf — came head to head with members of the World Wide Fund for Nature, the United Nations, the US Environmental Protection Agency and others. The meeting presented an opportunity to discuss complex and interesting sustainability problems in technology, and to find solutions.

Too many presentations were simply company advertisements or a defence of the industry under discussion. But there were also significant moments in the meeting when the presenters were honest and open, and these led to some productive discussions.

Delegates were invited to embrace strategies directed towards 'de-materialization'. Here, production and consumption cycles of materials and devices are designed to be closed loops, where the goals are the extraction of the energy content of waste, the recycling of materials, and the re-use and re-integration of components. Other discussions focused on misuse or misunderstanding of terminology, such as 'recycling'. Formally, this is a process in which material is returned to a previous stage of a cyclic process, so it must be re-usable in the same function that it had before being re-processed. This is not to be confused with downcycling, in which a used material is processed for a lower-technology application, shifting the disposal problem further downstream but not removing it.

There were many university researchers at MATFORUM from the traditional fields of environmental materials science (such as recyclability and clean energy), but the broader academic materials research community missed a significant opportunity to apply their knowledge and experience to solving some of these sustainability problems.

New technologies

Researchers must also help to ensure that new problems are not created. After all, the likely long-term commercial success of technologies being conceived in the lab now could depend on their sustainability properties, as well as their functional properties. This may sound obvious, but how many researchers in the materials community, other than those involved directly in sustainable technologies, really pay due attention to such notions?

It is time for the broader materials community to think through the environmental implications of its work, and even to consider taking on the demanding challenges placed on industry. These are exciting projects, presenting new problems to be solved in many well-established materials disciplines, such as steel and cement technologies, as well as high-technology and novel materials.

Some universities and government initiatives are already fostering new thinking. Undergraduate materials courses are including consideration of the environmental implications of materials manufacture. The European Commission places sustainability as one of the main technological objectives in its "New Materials and Production Technologies" themes. The US National Science Foundation and Environmental Protection Agency have formed a partnership, providing funds for fundamental research in the physical sciences, which, it is hoped, will lead to the discovery, development and evaluation of new industrial methods that are environmentally benign.

In a very different context, materials researchers in Africa are slowly becoming more active globally, with the African Materials Research Society due for launch in December. Perhaps these researchers will be instrumental in the pursuit of sustainable technologies.

But convincing everyone in the materials community of the value of this shift in perspective is likely to be a slow process. One tangible outcome of MATFORUM is the preparation of an Augsburg declaration (under revision at the time of going to press; see http://www.amu-augsburg.de/matforum/augsburg_materials_declaration.pdf), which asks scientists to consider all of the sustainability issues arising from the large-scale manufacture of their materials. As the old English proverb has it, fine words butter no parsnips. It is to be hoped that more materials researchers will rise to the challenges embodied in the declaration. ■