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Advanced Technology Materials

Major industries with total annual sales of over $500 billion are intensively engaged in the development of new and better materials. Their efforts are crucial to innovations that will render this nation more energy-efficient and more capable of meeting international competition in the future. The internal atmosphere of the best R & D laboratories is favorable to the speedy translation of research results into applications. Because the companies recognize that their future depends on research, the scientists involved enjoy excellent support and are provided with abundant facilities. Some of their equipment defines the state of the art. In many areas of science pertinent to materials, industrial scientists are the pioneers. They have contributed most of the articles for this issue.

Three general groups of materials are involved: (i) polymers, (ii) metals, alloys, oxides, and silicates, and (iii) electronic materials, primarily semiconductors. New kinds of polymers continue to be discovered having special properties such as great strength, high thermal and chemical stability, or electrical conductivity. Fundamental understanding of the behavior of polymers is being obtained by use of NMR and other experimental tools, which give quantitative guidance in efforts to formulate superior products. Major activity, though, is devoted to combining already available monomers and polymers to form objects with desired properties superior to those of a pure polymer. For example, combinations of layers of polymers can lead to containers that are tough, strong, and resistant to passage of oxygen. Mechanical properties can be greatly altered by incorporation of reinforcing fibers, inert materials, or gases. The new products are finding many uses in energy-saving applications.

In their studies of materials, chemists and physicists have roamed throughout the periodic table and have made countless combinations of elements and tested them in various proportions. Such work has led to new superconductors and to improved permanent magnets that require less imported cobalt than earlier types. Major advances are being made in improving the strength of materials. One method takes advantage of the fact that some crystals have great unidirectional strength. Another development is the creation of low-alloy, high-strength steels. Even more spectacular has been the development of glassy metals. When liquid mixtures are cooled very rapidly, the resultant solids may have strengths 15 times that of products cooled more slowly. At the same time, other properties such as magnetic permeability and freedom from corrosion may also be greatly improved. A research effort of great importance is the work to develop superior specific catalysts. This involves detailed understanding of the interactions among atoms at surfaces. Improvements of as much as a factor of 10^{12} have been obtained in speeds of reaction. When combined with high specificity, such performance leads to major energy savings. The research effort on catalysts has also led to the development of zeolite cage structures capable of catalyzing the conversion of methanol to gasoline.

During the past decade the most dynamic area of technology has been in exploitation of the potential of semiconductors such as silicon. The electronics revolution continues with considerable emphasis on obtaining more transistors per chip and better, lower cost computer memories. But other frontiers are under scrutiny. Semiconductors such as GaAs (III-V compounds) may be the key to even faster, better computers. Such compounds have already proved useful for lasers and light-emitting diodes. A different approach to increasing the speed of computation is through the development of Josephson-type devices that function at cryogenic temperatures. Another activity is work to develop superior photovoltaic materials.

One of the fastest growing applications of new materials is in prosthetic devices. This year, between 2 million and 3 million such devices will be implanted in humans, creating an interesting set of interactions between living and nonliving substances.—PHILIP H. ABELSON