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Materials Science and Engineering

Given high-quality materials and superior designs for function and for manufacturing, superior products can be created at minimal cost. The Japanese have been more vigorous than we in exploring the potentials of materials, but activity in the United States is expanding. A symposium at the recent AAAS meeting in Philadelphia permitted a glimpse into some of the activities in progress.* Major fields of materials include polymers, composites, magnetic materials, semiconductors, fiber optics, and ceramics. In general, while new materials are still being discovered, major emphasis now is on processing.

New insights were presented about the behavior of mixtures of polymers and especially the behavior of composites containing strengthening fibers. Highly complex shapes and structures can be made by injection moulding, and this technique will be used increasingly in automobiles and in making other items. The strength of such items in any given direction is highly dependent on the placement of fibers. Computer modeling of fiber orientation would permit improved designs. Computer analysis of many facets of behavior of polymers and mixtures of polymers under stress is now beginning. Increasingly composites are being used in airplanes and their large-scale adoption would be hastened were they better conductors of electricity and thus less susceptible to lightning strikes. Graphite fibers used in composites can be made nearly as conductive as copper through incorporation of substances such as CuCl₂ between the layers of the graphite structure.

For most applications involving semiconductors, silicon will continue to be the prime choice. But gallium arsenide can emit light. Silicon cannot. Gallium arsenide circuits have speeds 10 to 100 times those of silicon. The drawbacks are many, including difficulty of creating perfect single crystals. Experiments on the space shuttle indicate that perfection can be achieved in a microgravity field. Precise conductor connections between semiconductor circuits can be made by laser irradiation of organometallic films. This process is being improved through research.

An increasing number of techniques are available for rapid solidification of metals. These permit production of very fine grained metals and alloys that can be sintered together to create objects with superior strength and resistance to creep. The fast cooling techniques and subsequent metal forming of powders can be used to construct turbine blades with internal air cooling. These blades can function in gases at temperatures 500°C higher than the melting point of the metal.

Advances in ceramics were also discussed. The current technology for transmission of information through SiO₂ fibers involves repeater stations required at roughly 100-kilometer intervals. A goal worth achieving is transmission from London to New York without a repeater. Such a goal is theoretically possible with the use of fluoride-containing glasses—for example, a mixture of ZrF₄, BaF₂, LaF₃, AlF₃, and NaF. Good progress is being made toward the goal. A powder of Al₂O₃ can be sintered at temperatures approaching its melting point of 2050°C to form a very strong and transparent glass for use in high-pressure sources of light. The process now in use requires hours. By sintering in a plasma (at temperatures on the order of 5000°C) the time required can be reduced to some seconds.

For detecting changes in pressure or pressure waves, single crystals of substances such as lead zirconium titanate (PZT) have long been employed. However, for undersea applications single crystals are not very sensitive. A design methodology has been found that combines ceramics and polymers in composite piezoelectric transducers highly sensitive to pressure changes. The new transducers have potential applications in medical ultrasonics and will allow robots to “feel” the objects they grip.

The dominant materials of a decade ago are being supplemented or replaced by new superior combinations. Computer modeling is improving designs. A materials science and engineering revolution is under way that will be a key factor in determining the outcome of global economic competition.—PHILIP H. ABELSON

*The symposium, “The Changing World of Materials,” was organized by Witold Brostow of Drexel University in Philadelphia. The speakers and topics are listed in the meeting program.