# INTRODUCTION

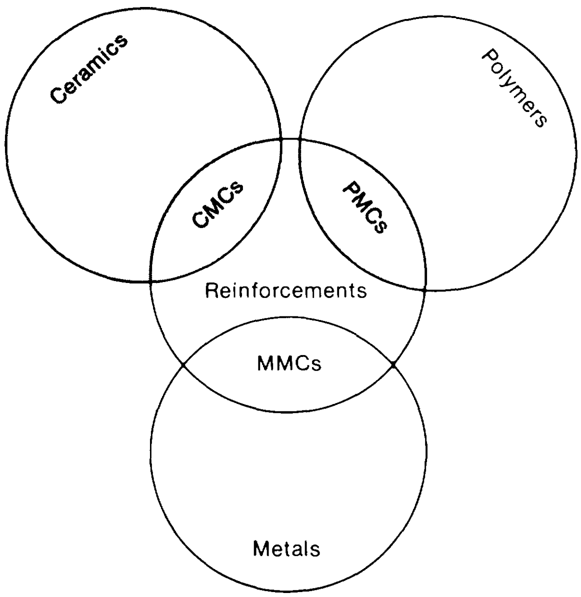
The past 25 years have witnessed an unprecedented explosion of new structural materials available to the designer and engineer. Polymers, ceramics, and composites promise to bring a revolution in the performance of a wide variety of engineering components and structures, and in the way those structures are designed and fabricated. Today the pace of technological change in this field is rapid, and the scope of the opportunity presented by the new materials is only beginning to be recognized.

In addition to changing the engineering landscape, advanced structural materials have also altered the boundaries of traditional policy concerns relating to materials. Historically, the Federal interest in materials has centered around the problem of shortages of supply of certain "critical" minerals. For example, the United States is dependent on foreign sources for virtually all of its chromium, manganese, cobalt, and platinum group metals. These metals are important ingredients in a variety of steel alloys and superalloy. To a limited extent, ceramics and composites, which are made from plentiful raw materials, can alleviate this problem through substitutional However, the potential of the new materials goes far beyond simple substitution; they provide performance advantages in both military and commercial applications which cannot be achieved with metals. Ceramics and composites are now considered to be "critical" in their own right, both for national defense and future economic competitiveness. Therefore, the appropriate Federal role in accelerating the development and commercialization of these materials is likely to be a subject of active debate in the years ahead.

Advanced materials are often ranked with microelectronics and biotechnology as the three most promising "high-tech" industries of the future. Many countries around the world have recognized the exceptional promise of these materials and have targeted them for priority development, with the result that the United States, having pioneered many of the basic technologies, now finds itself in a heated race with Japan and several countries in Europe to supply the growing world markets. Fundamental advances in these technologies are now being made overseas, so that the United States cannot afford to be complacent if it intends to be competitive. It is important to note that in most cases ceramic and composite structures do not stand alone, but are instead components that enhance the performance of much larger systems, such as automobiles or aircraft. Thus, the materials have a significance to the economy extending far beyond the value of the materials themselves.

Structural materials may be classified as ceramics, polymers, or metals, as shown in figure 1. Two or more of these materials can be combined together to forma composite having properties superior to those of the constituents alone.

**Figure 1.— The Family of Structural Materials**




The family of structural materials includes ceramics, polymers, and metals. Reinforcements added to these materials produce ceramic matrix composites (CMCs), polymer matrix composites (PMCs), and metal matrix composites (MMCs). Materials in the shaded regions are discussed in this report.

SOURCE: Off Ice of Technology Assessment

[1] U. S. Congress, Office of Technology Assessment, *Strategic Materials: Technologies To Reduce U. S. Import Vulnerability*, OTA-ITE-248 (Washington, DC: U.S. Government Printing Office, May 1985).

The most common form of composite is a host material (matrix) which is reinforced with particles or fibers of a second material. Composites are classified according to their matrix phase; thus, there are ceramic matrix composites (CMCs), polymer matrix composites (PMCs), and metal matrix composites (MMCs). Wood, jade, and oyster shells are natural composites which display remarkable strength and durability. A common manmade composite is glass fiber reinforced plastic (FRP), which combines the strength of the glass with the toughness and corrosion resistance of plastic,

Each type of structural material has its own advantages and disadvantages. For example, metals are strong, tough, inexpensive, and readily formable, but are also heavy, chemically reactive, and limited to service temperatures below about 1,900° F (1,038° C). Ceramics are hard, chemically stable, and useful at high temperatures, but are also brittle and difficult to fabricate. Polymers are light and easy to fabricate, but are relatively weak and restricted to service temperatures below about 600° F (316° C).

Frequently, composites offer an excellent opportunity to eliminate some of the undesirable properties while retaining the desirable ones. Metals can be reinforced with ceramic fibers to extend their useful strength to higher service temperatures; ceramics can be reinforced with ceramic fibers to reduce their brittleness; and polymers can be reinforced with ceramic or organic fibers to make them, pound for pound, the strongest materials known. The great value of composites is that the reinforcement type and geometry can be varied to optimize the performance and minimize the cost of the overall structure.

In the face of the challenge from ceramics and composites, metals technologies have not remained static. New steel and aluminum alloys and new processes such as rapid solidification and powder metallurgy techniques have been developed. Metal matrix composites promise to increase the hardness and service temperature of metals without requiring a large investment in new manufacturing plant and equipment. Also, various coatings and surface modification techniques can be used to protect the metal so that it will not deteriorate in hostile environments.

The diversity of structural materials available today offers many options to the designer. Typically, a given structure can be fabricated from any of a variety of candidate materials. Only rarely will the performance requirements dictate a single choice. Nor does the challenge to the primacy of metals come only from the most “advanced,” most expensive composites or ceramics: unreinforced engineering polymers such as nylons or polyamides, and chemically bonded ceramics (high performance cements) offer an inexpensive and effective alternative to metals in many applications. This capacity for materials substitution also complicates the task of projecting the future shares of materials in various markets. However, one can predict with confidence that the properties and manufacturing advantages of ceramics and composites will make them as familiar in the 21st century as metals are today.