2.6 Materials—The Bonding Classification

A dramatic representation of the relative bond energies of the various bond types of this chapter is obtained by comparison of melting points. The **melting point** of a solid indicates the temperature to which the material must be subjected to provide sufficient thermal energy to break its cohesive bonds. Table 2.4 shows representative examples used in this chapter. A special note must be made for polyethylene, which is of mixed-bond character. As discussed in Section 2.3, the secondary bonding is a weak link that causes the material to lose structural rigidity above approximately 120°C. This is not a precise melting point, but instead is a temperature above which the material softens rapidly with increasing temperature. The irregularity of the polymeric structure (Figure 2.15) produces variable secondary bond lengths and, therefore, variable bond energies. More important than the variation in bond energy is the average magnitude, which is relatively small. Even though polyethylene and diamond each have similar C−C covalent bonds, the absence of secondary-bond weak links allows diamond to retain its structural rigidity more than 3,000°C beyond polyethylene.

We have now seen four major types of atomic bonding consisting of three primary bonds (ionic, covalent, and metallic) and secondary bonding. It has been traditional to distinguish the three fundamental structural materials (metals, ceramics/glasses, and polymers) as being directly associated with the three types of primary bonds (metallic, ionic, and covalent, respectively). This is a useful concept, but we have already seen in Sections 2.3 and 2.5 that polymers owe their behavior to both covalent and secondary bonding. We also noted in Section 2.3 that some of the most important ceramics and glasses have strong covalent as well as ionic character. Table 2.5 summarizes the bonding character associated with the five fundamental types of engineering materials together with some representative examples. Remember that the mixed-bond character for ceramics and glasses referred to both ionic and covalent nature for a given bond (e.g., Si—O), whereas the mixed-bond character for polymers referred to different bonds being covalent (e.g., C—H) and secondary (e.g., between chains). The relative contribution of different bond types can be graphically displayed in the form of a tetrahedron of bond types (Figure 2.24) in which each apex of the tetrahedron

TABLE 2.4

Comparison of Melting Points for Some of the Representative Materials

Material	Bonding type	Melting point (°C)
NaCl	Ionic	801
C (diamond)	Covalent	~3,550
$(C_2H_4)_n$	Covalent and secondary	~120[a]
Cu	Metallic	1,084.87
Ar	Secondary (induced dipole)	−189
H_2O	Secondary (permanent dipole)	0

[a]Because of the irregularity of the polymeric structure of polyethylene, it does not have a precise melting point. Instead, it softens with increasing temperature above 120°C. In this case, the 120°C value is a "service temperature" rather than a true melting point.

TABLE 2.5

Bonding Character of the Five Fundamental Types of Engineering Materials

Material type	Bonding character	Example
Metal	Metallic	Iron (Fe) and the ferrous alloys
Ceramics and glasses	Ionic/covalent	Silica (SiO_2): crystalline and noncrystalline
Polymers	Covalent and secondary	Polyethylene $-(C_2H_4)-_n$
Semiconductors	Covalent or covalent/ ionic	Silicon (Si) or cadmium sulfide (CdS)

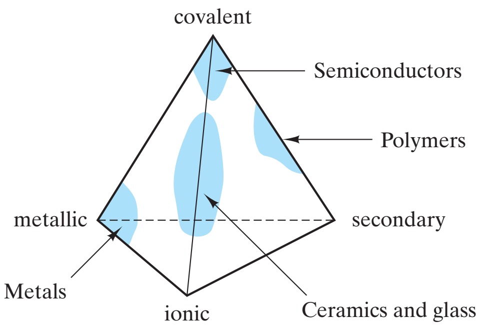

FIGURE 2.24 *Tetrahedron representing the relative contribution of different bond types to the five fundamental categories of engineering materials (the four structural types plus semiconductors).*

represents a pure bonding type. In Chapter 13, we shall add another perspective on materials classification, electrical conductivity, which will follow directly from the nature of bonding and is especially helpful in defining the unique character of semiconductors.