8.4 Glasses

Glass is an amorphous solid with the structure of a liquid (Fig. 8.5), a condition that is obtained by supercooling (cooling at a rate too high to allow crystals to form). Technically, glass is defined as an inorganic product of fusion that has cooled to a

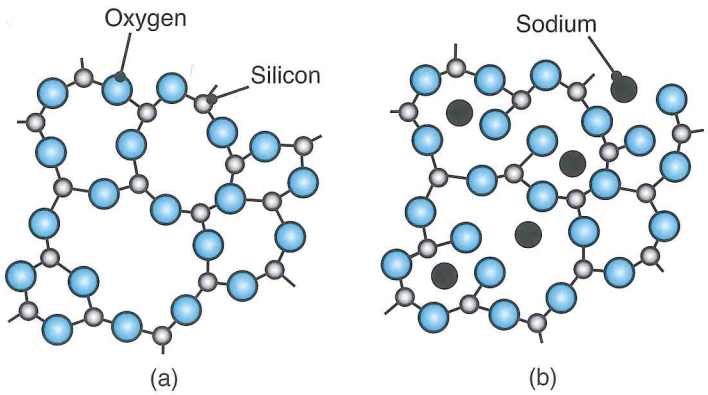

FIGURE 8.5 Schematic illustration of the structure of silica glass. (a) Pure silica glass, in the form of $(SiO_2)_n$ random structure and (b) partially depolymerized glass; note that a fourth bond for each silicon is outside the plane shown.

rigid state without crystallizing. Glass has no distinct melting or freezing point; thus, its behavior is similar to that of amorphous alloys (see metallic glasses, Section 6.14) and amorphous polymers (Section 7.2.2).

Glass beads were first produced in about 2000 B.C., and the art of glassblowing began in about 200 B.C. Silica solely was used for all glass products until the late 1600s. Rapid developments in glasses began in the early 1900s. There are about 750 different types of commercially available glasses, with applications ranging from window glass to glass for containers, cookware, lighting, and mobile phones, and to glasses with special mechanical, electrical, high-temperature, antichemical, corrosion, and optical characteristics. Special glasses are used in fiber optics (for communication by light with little loss in signal power) and in **glass fibers**, with very high strength (for use in reinforced plastics, Section 9.2.1).

All glasses contain at least 50% silica, which is known as a **glass former**. The composition and properties of glasses can be modified by the addition of oxides of aluminum, sodium, calcium, barium, boron, magnesium, titanium, lithium, lead, and potassium. Depending on their function, these oxides are known as **intermediates** or **modifiers**.

8.4.1 Types of Glasses

Almost all *commercial glasses* are categorized by the following types (Table 8.3):

- **Soda-lime glass** (the most common type)
- **Lead-alkali glass**
- **Borosilicate glass**
- **Aluminosilicate glass**
- **96%-silica glass**
- **Fused silica glass**

Glasses also are classified as colored, opaque (white and translucent), multiform (a variety of shapes), optical, photochromatic (darkens when exposed to light, as in some sunglasses), photosensitive (changing from clear to opaque), fibrous (drawn into long fibers, as in fiberglass), and foam or cellular (containing bubbles, thus a good thermal insulator). Glasses also can be referred to as **hard** or **soft**, usually in the sense of a thermal rather than mechanical property (see also hardness of glasses, Section 8.4.2); thus, a soft glass softens at a lower temperature than

TABLE 8.3

Properties of Various Glasses

Property	Soda-lime glass	Lead-alkali glass	Borosilicate glass	96% silica	Fused silica
Density	High	Highest	Medium	Low	Lowest
Strength	Low	Low	Moderate	High	Highest
Resistance to thermal shock	Low	Low	Good	Better	Best
Electrical resistivity	Moderate	Best	Good	Good	Good
Hot workability	Good	Best	Fair	Poor	Poorest
Heat treatability	Good	Good	Poor	None	None
Chemical resistance	Poor	Fair	Good	Better	Best
Impact-abrasion resistance	Fair	Poor	Good	Good	Best
Ultraviolet-light transmission	Poor	Poor	Fair	Good	Good
Relative cost	Lowest	Low	Medium	High	Highest

does a hard glass. Soda-lime and lead-alkali glasses are considered soft, and the rest as hard.