9.1 The Phase Rule

In this chapter we shall be quantifying the nature of microstructures. We begin with definitions of terms you need in order to understand the following discussion.

A **phase** is a chemically and structurally homogeneous portion of the microstructure. A single-phase microstructure can be polycrystalline (e.g., Figure 9.1), but each crystal grain differs only in crystalline orientation, not in chemical composition. Phase must be distinguished from **component**, which is a distinct chemical substance from which the phase is formed. For instance, we found in Section 4.1 that copper and nickel are so similar in nature that they are completely soluble in each other in any alloy proportions (e.g., Figure 4.2). For such a system, there is a single phase (a solid solution) and two components (Cu and Ni). For material systems involving compounds rather than elements, the compounds can be components. For example, MgO and NiO form solid solutions in a way similar to that for Cu and Ni (see Figure 4.5). In this case, the two components are MgO and NiO. As pointed out in Section 4.1, solid solubility is limited for many material systems. For certain compositions, the result is two phases, each richer in a different component. A classic example is the pearlite structure shown in Figure 9.2, which consists of alternating layers

FIGURE 9.1 *Single-phase microstructure of commercially pure molybdenum,* 200×. *Although there are many grains in this microstructure, each grain has the same uniform composition. (From* ASM Handbook*, Vol. 9:* Metallography and Microstructures*, ASM International, Materials Park, OH, 2004.)*

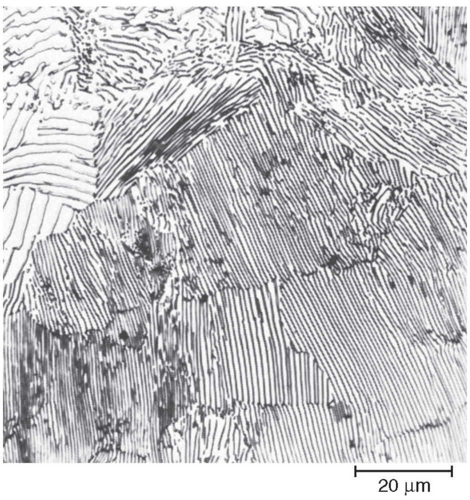

FIGURE 9.2 *Two-phase microstructure of pearlite found in a steel with* 0.8 *wt* % C, 650×. *This carbon content is an average of the carbon content in each of the alternating layers of ferrite* (*with* $<$ 0.02 *wt* % C) *and cementite (a compound,* Fe_3C*, which contains* 6.7 *wt* % C*). The narrower layers are the cementite phase. (From* ASM Handbook*, Vol. 9:* Metallography and Microstructures*, ASM International, Materials Park, OH, 2004.)*

of ferrite and cementite. The ferrite is α-Fe with a small amount of cementite in solid solution. The cementite is nearly pure Fe_3C. The components, then, are Fe and Fe_3C.

Describing the ferrite phase as α-Fe with cementite in solid solution is appropriate in terms of our definition of the components for this system. However, on the atomic scale, the solid solution consists of carbon atoms dissolved interstitially in the α-Fe crystal lattice. The component Fe_3C does not dissolve as a discrete molecular unit, which is generally true for compounds in solid solution.