Chapter 4

Mass Diffusion in the Solid State

Abstract

This chapter introduces mass diffusion in the solid state, the phenomena controlling the rate of most phase transformations and other processes. Examples include various surface hardening processes, silicon doping, precipitation hardening, and diffusion welding. Here a balance of solute flux (controlled by Fick's First Law of Diffusion) and solute storage is used to derive Fick's Second Law of Diffusion. A similar solute balance on a two phase boundary is derived, accounting for the net flux in and out of that interface and the rate at which solute is consumed or released from that boundary as it moves. Solutions to Fick's Second Law and the phase interface conditions are found in several practical problems, which are illustrated in the examples.

The effects of different rates of diffusion of constituents in an alloy (seen in their different chemical diffusion coefficients) are seen in Kirkendall's experiments and modeled using Darken's analysis. The interdiffusion coefficient and its general dependence on composition is shown in this analysis. The measurement of composition profiles in an infinite diffusion couple can be used in a Boltzmann-Mantano analysis to calculate the alloy's interdiffusion coefficient. These coefficients are also strong functions of temperature, generally taking the form of $D \propto \exp\left(-1/T\right)$.