

Homework #1

Due Monday August 29 by noon

Reading

- Kasap, Chapter 1

Videos

- MSE Content Review Part 1 and Part 2

Problems

1. (Kasap 4th Ed. Problem 1.38) **Vacancies in Metals**

- The energy of formation of a vacancy in the copper crystal is about 1 eV. Calculate the concentration of vacancies at room temperature (300 K) and just below the melting temperature, 1084 °C. Neglect the change in the density, which is small.
- The table below shows the energies of vacancy formation in various metals with *close-packed* crystal structures and their melting temperatures T_m . Plot E_v (in eV) versus T_m (in Kelvins), and explore if there is a correlation between E_v and T_m . Some materials engineers take E_v to be very roughly $10k_B T_m$. Do you think that approximation is justified? (Explain.)

Table 1.12 Energy of formation of vacancies for selected metals

	Al	Ag	Au	Cu	Mg	Pt	Pb	Ni	Pd
Crystal	FCC	FCC	FCC	FCC	HCP	FCC	FCC	FCC	FCC
E_v (eV)	0.70–0.76	1.0–1.1	0.90–0.98	1–1.28	0.89	1.3–1.5	0.50	1.63–1.79	1.54–1.85
T_m (°C)	660	962	1064	1085	650	1768	328	1455	1555

2. (1.40) **Pb-Sn solder**

Consider the soldering of two copper components using a Pb-Sn solder. When the solder melts, it wets the metal surfaces. If the surfaces are not clean or have an oxide layer, the molten solder cannot wet the surfaces and the soldering fails. Assume that soldering takes place at 250 °C, and consider the diffusion of Sn atoms into the copper (the Sn atom is smaller than the Pb atom and hence diffuses more easily).

- The diffusion coefficient of Sn in Cu at two temperatures is $D = 1.69 \times 10^{-9} \text{ cm}^2 \text{ hr}^{-1}$ at 400 °C and $D = 2.48 \times 10^{-7} \text{ cm}^2 \text{ hr}^{-1}$ at 650 °C. What is the activation energy (in eV/atom) for the diffusion of Sn in Cu?
- What is the pre-exponential constant, D_o (in m^2/s)?

- c. Calculate the rms distance diffused by an Sn atom into the copper at 250 °C, assuming the process takes 10 seconds.
- d. What should be the composition of the solder if it is to begin freezing at 250 °C? (Consult Fig. 1Q40-1 below).
- e. What are the components (phases) in this alloy at 200 °C? What are the compositions of the phases and their relative weights in the alloy?
- f. What is the microstructure of this alloy at 25 °C?

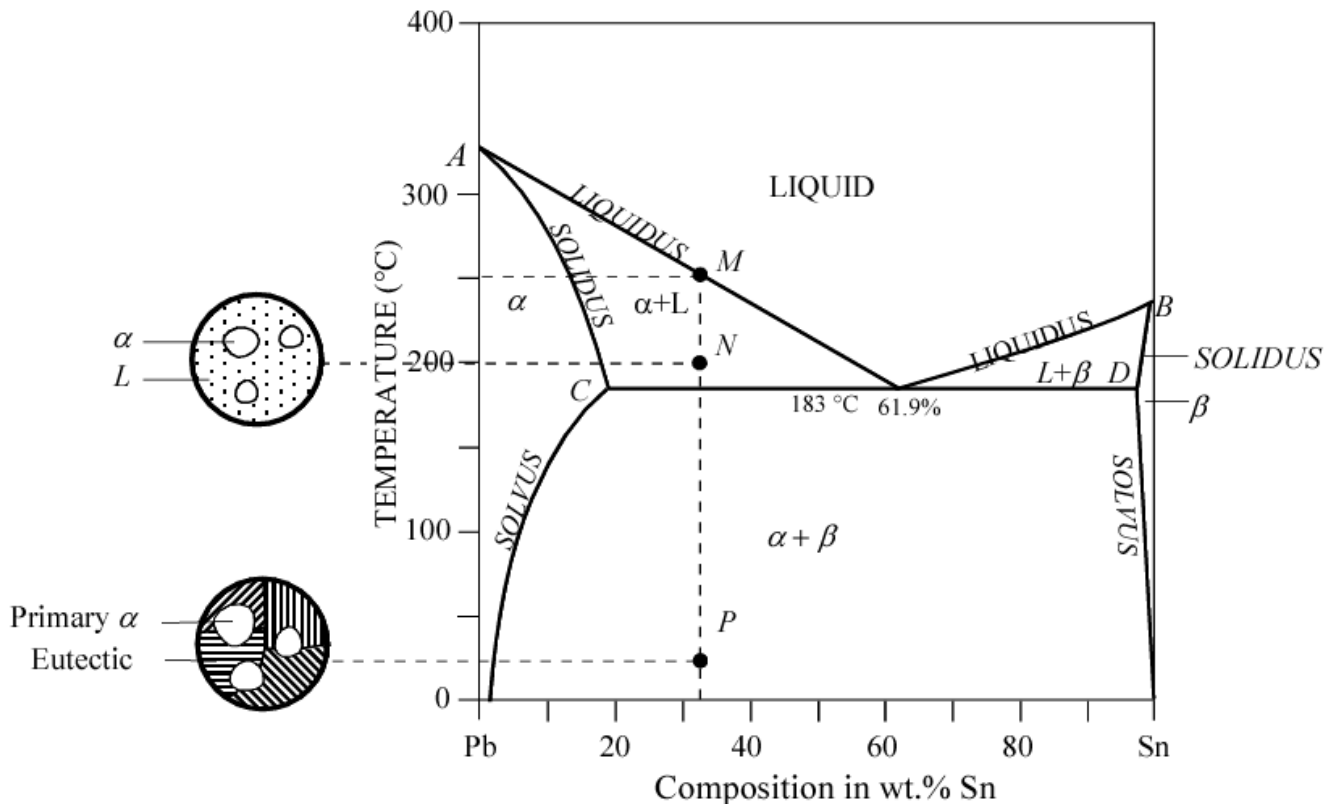


Figure 1Q40-1: The equilibrium phase diagram of the Pb-Sn alloy.