Problem Set 9 E-344
Spring 2004

1. The diffusion coefficient of gallium (Ga) in silicon (Si) has been measured giving the following values for a range of temperatures:

Temperature (^oC)	Diffusion Coefficient (cm^2/sec)
1080	$3.4x10^{-13}$
1165	$2.1x10^{-12}$
1266	$1.9x10^{-11}$
1303	$3.4x10^{-11}$
1355	$6.2x10^{-11}$

Draw two plots of the diffusion coefficient against T (in K). First make a LINEAR plot (D vs T). Then make an ARRHENIUS plot (ln(D) vs 1/T) of the same data. Calculate the activation energy for diffusion of Ga in Si. Quantitatively estimate the value of D for T= 1200^{o}C.

2. A. Why does a diffusion coefficient depend on temperature?
B. Would you expect the diffusion coefficient of an Al atom along an Al-Al grain boundary to be higher, lower, or the same as the diffusion coefficient of an Al atom through the bulk of an Al grain? Briefly justify your answer.

3. Ohring problem 6-11

4. Ohring problem 6-15

5. A) a 1 cm dia and 20 cm long rod of Cu is joined at one end to an identical rod of Ni to form a rod 40 cm long with a perfectly sharp interface in the middle. Suppose this couple is heated to 1000 ^{o}C and held there for several hours. Sketch profiles of Cu concentration across the interface for t=0 and for three subsequent times. No calculations are needed, simply a well-labeled sketch.

B) Suppose an identical couple is made from rods of pure lead and pure tin and heated to 175 ^{o}C. Draw a similar set of composition profiles.

You should refer to the Cu-Ni and Pb-Sn phase diagrams in Ohring.

6. (after Ohring 5-34) Using a gas atomization process, liquid metal is broken into fine droplets by blowing high velocity gas onto a stream of liquid metal. The kinetic energy of the gas is used to create the new surface associated with the droplets. The droplets subsequently solidify to give solid powders which are used in printer toners, paints, and as precursors in powder-metallurgy processing to make fully dense solid parts (Ohring section 8.4).

Consider a charge of liquid copper that weighs 10 g. The surface energy of copper in air is 1.4 J/m^2 and its density is 8.94 g/cm^3. Make a table that summarizes the total surface energy for the three cases: (1) the liquid is allowed to solidify to a single spherical ball; (2) the liquid is atomized into powder where each particle with a diameter of 100 μm; and (3) the liquid is atomized into powder where each particle has a diameter of 100 nm.

What would happen if the either of the powder lots (2 or 3) were compressed in a container so the powder particles were packed as densly as possible and then the temperature were raised to say 0.8 of T_m?

7. A solid cube-shaped nucleus forms homogeneously within a liquid where the volume free energy difference ΔG_v is -6.5×10^6 J/m^3 and the surface energy between the liquid and solid phases is 0.2 J/m^2.

(A) derive an expression for the critical nucleus size.

(B) assuming the density of the material is lead whose solid density is 11.3 g/cm^3 and whose atomic weight is 207.2 g/mole, calculate how many atoms are in the critical nucleus.

8. How is it possible that the temperature setting in an ordinary home freezer of say -1^{o}C is adequate to make ice cubes when the homogeneous nucleation temperature of ice in pure water is well below -1^{o}C?