

Problem set 8

Problem 1. Consider homogeneous nucleation in a solid solution with the physical properties of copper. Assume spherical nuclei which are nearly pure solute. The solubility of some solute is 0.1 a/a at 1000K. Assume a pre-exponent in the solubility equation of unity. From this you can get the solubility at any temperature.

Below plot the natural logarithm of $\Delta G^*/kT$ for the temperature range $200K < T < 800K$. Indicate the temperature range for which my ROT nucleation criterion that $\Delta G^*/kT < 60$ holds.

Consider the following three cases.

- Incoherent nucleation with no strain energy. Assume that the particle:matrix interfacial energy is 0.5 J/m^2 (typical of an incoherent grain boundary). COMMENT on your answer.
- Repeat a for homogeneous coherent nucleation with a particle:matrix interfacial energy is 0.1 J/m^2 (typical of a coherent interface). Assume that there is no strain energy. COMMENT on your answer.
- Repeat b, except that there is a strain energy corresponding to $\Delta a/a = 0.04$. COMMENT on your answer. Compare the results of the three calculations.

Problem 2. Martensitic steels gain their strength from a dispersion of fine carbides. In plain carbon steel, these are (approximately) cementite. In a hot working steel they might be (approximately) WC. Assume that in both steels the initial particles are spheres of 1 nm radius. The temperature is 923K (red heat) and the coarsening time is 1 hour. You may assume a surface energy of 0.5 J/m^2 , a molar volume of $10^{-5} \text{ m}^3/\text{mole}$.

The equilibrium solubility of cementite in ferrite is (at least at this temperature) given by eq. 9.14 in the text. The diffusivity of C in ferrite may be calculated from $D_0 = 10^{-4} \text{ m}^2/\text{s}$ and $Q = 100,000 \text{ J/mole}$.

The solubility of WC is given by $X_c X_w = \exp(-90,000/RT)$, in SI units. Enough excess tungsten is added so that the tungsten concentration is fixed at nearly 0.01 a/a, at all temperatures. The diffusion coefficient of tungsten is calculated from $D_0 = 10^{-4} \text{ m}^2/\text{s}$ and $Q = 280,000 \text{ J/mole}$.

The material in the posting "Particles GG" around Eqs. 61, 62 may be useful.

- a. What is the final particle size in each case? Be sure to determine which element is rate controlling in the case of WC.
- b. Suppose that carbides above $0.1\ \mu\text{m}$ in radius are ineffective in strengthening. Estimate the useful lifetimes of the two steels at 923 K. Comment on your answer.