MATE 313

Fall 2019

Homework # 4

Due: November 28th, 2019 (lecture time)

Group submission (up to 3 students per group) is allowed.

Question 1:

Estimate the energy (in J/m^2) of a semicoherent (100) interface between FCC Co precipitate and FCC Cu matrix. Ignore the energy of the coherent regions.

Info:
Energy of a dislocation is $T = Gb^2/2$ where G is the shear modulus and b is the Burgers vector.

The lattice parameter of Cu is 0.364 nm and that of (cubic) Co is 0.352 nm. Take G = 45 GPa.

Question 2:

Cu can dissolve in Ag to form a substitutional solid solution. Cu atoms are, however, smaller than Ag atoms and each Cu atom therefore distorts the surrounding Ag lattice, i.e. a coherency strain field effectively exists around each Cu atom. Estimate the misfit strain energy in kJ/mol.

	Radius (nm)	Shear Modulus (GPa)
Ag	0.144	27.8
Cu	0.128	44.7

Question 3:

An A-B alloy system contains cube shaped β precipitates of almost pure B with a side length "a" of 11 nm. Based on the information given below, determine whether these precipitates have coherent or non-coherent interfaces with the A-rich α matrix. State any assumption you will make.

a_α (lattice parameter of α) = 0.143 nm
a_β (lattice parameter of β) = 0.151 nm
γ_{st} (structural contribution to the interfacial energy) = 0.45 J/m^2
μ (shear modulus of the matrix) = 25 GPa

Question 4:

In a material, homogeneous nucleation of β phase in α phase is found to occur at an undercooling, ΔT = 170°C.

Given that the α grain boundary has an energy of 0.66 J/m^2 and the α/β interface has an energy of 0.44 J/m^2, at what undercooling will heterogeneous nucleation be observed along the grain boundaries?

Assume that the driving force is proportional to the undercooling ($\Delta G_v \propto \Delta T$). Also neglect differences in the density of potential nucleation sites between homogeneous and heterogeneous nucleation.

The formula for the shape factor, $S(\theta) = 0.5(2 + \cos\theta)(1 - \cos\theta)^2$

Question 5:

Assume that a spherical precipitate forms in an age hardening alloy and that the volume-free energy change associated with the formation of a particle is -7.3x10^7 J/m^3. The surface energy of the interface between the particle and the matrix is 0.44 J/m^2.

a) Assuming the misfit strain energy to be zero, determine the critical nuclei radius (r*) and critical energy (ΔG*) for precipitation.

b) Calculate the number of particles per m^3 if the precipitates have a total volume fraction of 1.5% and they are of the same size with a radius equal to the twice of the critical radius size.

c) Calculate the total change in free energy due to the formation of all the precipitates in one m^3.

Question 6:

For an A-B alloy system with precipitates that are pure element B, a solvus line is described by $\log(X_B) = 2.853 - 2.875\times10^3/T$, where X_B is the composition in atomic %.

What is the growth rate (in μm/h) at T = 727°C for a matrix composition of X_{0B} = 2.5% five minutes after the nucleation has taken place?

Assume 1D growth (e.g. of a slab of precipitate nucleated on a grain boundary). The pre-factor and activation energy for the diffusion of B in A are 7.4x10^{-5} m^2/s and 257.4 kJ/mole, respectively.