Department of Materials Science and Engineering
Pohang University of Science and Technology

AMSE502 Phase Transformations

due Date: Dec. 16, 2014 Prof. Byeong-Joo Lee

Problem Set #6

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Room 1- 311

1. The system A-B exhibits regular solution behavior in the solid state. Answer parts (a) through (e), each when η, the linear strain per unit composition difference, is equal to (i) 0 and (ii) 0.06.

   a) Calculate the critical temperature for solid miscibility.

   b) What is the temperature of the spinodal for the solutions of composition X_B= 0.75 and X_B = 0.60?

   c) What is the critical wavelength at T = 775 K for the two solutions of part (b)?

   d) What is the fastest growing wavelength at T = 775 K anywhere in the A-B system?

   e) What is the maximum value of the amplification factor, R(β), at 775 K anywhere in the A-B system?

   Data

regular solution interaction parameter,	Ω = 15 KJ/mol
gradient energy coefficient,	$K = 10^{-9}$ J/m
Young's modulus,	$E = 10^{11}$ Pa
Poisson's ratio	$\nu = 0.3$
self-diffusion coefficient,	$D_A^* = D_B^* = 10^{-3}$ exp(-100 kJ/RT) m^2/sec
atomic masses,	M_A = 195 g/mol; M_B = 197 g/mol
densities,	ρ_A = 21.5 g/cm^3; ρ_B = 19.7 g/cm^3

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2. A Ag-38at%Au alloy at 510K is a single-phase solid solution at equilibrium. A multilayer thin-film Ag-Au diffusion couple is prepared by evaporation. The initial composition of the film varies sinusoidally with distance in one dimension according to:

$$C(x,0) = (38 \text{ at\% Au}) + (12 \text{ at\% Au}) \cos \beta x$$

where the wave number $\beta = 2\pi/\lambda$ and the wavelength λ is 2×10^{-9} m.

Estimate the time that it will take to homogenize the diffusion couple to the extent that the maximum composition difference in the sample is 2 at% Au. Assume a solution to the diffusion equation having the form:

$$C(x,t) = (38 \text{ at\% Au}) + (12 \text{ at\% Au}) \exp[R(\beta)t] \cos \beta x$$

Perform two calculations :

(a) Use Fick's second law as the diffusion equation: (5%)

$$\frac{\partial c}{\partial t} = \tilde{D} \frac{\partial^2 c}{\partial x^2}$$

(b) Use Cahn's modified diffusion equation: (5%)

$$\frac{\partial c}{\partial t} = \tilde{D} \frac{\partial^2 c}{\partial x^2} - \frac{2K\tilde{D}}{f''} \frac{\partial^4 c}{\partial x^4}$$

(c) Comment on the difference between your answers to parts (a) and (b). (10%)
[Note that the Ag-Au system favors bonds between unlike atoms (ordering), and has a negative gradient energy coefficient.]

Data:

$\tilde{D} = 10^{-23}$ m^2 s^{-1}
$f'' = 5 \times 10^9$ J m^{-3}
$K = -2.6 \times 10^{-11}$ J m^{-1}
$\lambda = 2 \times 10^{-9}$ m