Department of Materials Science and Engineering
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**AMSE502 Phase Transformations**

due Date: Jun. 01, 2021

Problem Set #7

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1. 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 $\lambda$ is $2\times10^{-9}$ 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

2. Use the Monte Carlo simulation code (KISSGG.exe) to answer to the followings: (20)
The average grain size can be represented by $\overline{R} = kt^n$.
Perform grain growth simulation at various time duration and temperature using the code and

a) Find the time dependence of the average grain size (40%)
b) Find the temperature dependence of grain growth and the activation energy (60%).

※ The code provides the average grain size.