3.40J/22.71J Physical Metallurgy Problem set 5 Solution

Problem A.

a. The solute cannot place an upper limit on grain size. It may just slow down grain growth. Particles will be much more effective as long as they do not coarsen or get dragged. Equations giving the limiting gain size as a fraction of volume fraction and something from Cahn would be suitable here.

b. The solutes are even less effective at high temperature as they segregate less to grain boundaries. Particles will still be fine as long as they do not coarsen or get dragged. Really insoluble particles are called for at high temperatures.

Problem B.

a. Pull out the equations for recrystallization time and mean grain diameter in terms of nucleation and growth rate. Recrystallization is over in about 6 sec. and the grain size is about 6 microns.

b. Use the equation for nucleation rate with the 80kJ/mole activation energy. You find that a non-physical temperature of about 3500K is needed to up the nucleation rate by a factor of 1000. I should have asked for an increase of ten fold.

c. This one is a bit tricky, figuring out the relative rates of increase in nucleation and growth rates. I accepted about anything. The fact is, nucleation rate increases a lot and growth rate a fair bit. Recrystallization time goes down a lot and so does grain size.

PROBLEMS

Problem A

A young scientist was given the task of limiting grain size during high temperature processing of aluminum sheet. Having taken 3.40J/22.71J in the past, this scientist recalled that fine particles tended to limit grain growth, and that finer particles were most effective. The scientist decided that the finest possible particle was single atoms, so introduced 0.1 at.% solute, rather that 0.1 vol% particles.

a) Is this approach likely to be effective? Why or why not?

b) Compare the effects of solute and particles on high temperature grain growth. For simplicity, answer in terms of disordered grain boundaries. A few equations would improve your explanation.

Problem B

Consider recrystallization in a metal cold worked to 40% reduction in area so that the nucleation rate in the untransformed volume is a constant, given by (Capital N dot) =(ten to the twentieth)exp.(-80kJ/RT) particles per meter cubed per second, and the constant isotropic growth rate is given by (Capital G dot) =exp(-120kJ/RT) meters per second.

a) At a temperature of 1000K, calculate:
(t sub r), the time for about 50% recrystallization.
The mean grain diameter.
(N sub v), the approximate number of grains per meter cubed when recrystallization is complete. (Approximate the grains as spheres)

b) At what temperature would you obtain a nucleation rate one thousand times that calculated in a)?

c) Suppose that instead of being coldworked 40%, the metal is coldworked 80%. What will be the approximate effect on nucleation rate, growth rate, time for 50% recrystallization, and number of grains per unit volume? Do not attempt to calculate these quantities, but state whether each would increase or decrease, greatly or moderately, and justify all your answers.

Given: R=8.3J/mol.K