Spring 2020: Mechanical Properties Materials Science (MPMS)

Take Home Exam IY: (Diffusional Deformation at High Temperature)
Given out on Monday 04/27/2020, due on Monday 05/04/2020

Each question carries equal points; Please give your answers on the enclosed pages.

Please note:

Keep you answers as short as possible without losing the essence of your answer. You are advised to redo your answer sheet the second time before you submit. You will realize how much better and clearer your response is.

Please write your answers on the pages in the print-out of this problem set.

1. A polycrystal is assumed to be constructed from simple cubes. Each cube contains 10^6 atoms. The crystal is pulled in uniaxial tension, so that boundaries with a horizontal orientation are under the applied stress, while the vertically oriented boundaries are stress free.

(i) Calculate the strain that would be produced by the transport of 1000 atoms from every vertical grain boundary into the adjacent horizontal grain boundary.

(ii) Now assume that the atoms are transported at the rate of 1000 atoms per second. What will be the strain rate of the deformation of the polycrystal.

Hint: You should not have to consider the volume of atoms (Ω).

2. Explain why the equation for strain rate for diffusional deformation by boundary diffusion in polycrystals with a grain size, d, given by

$$\eta = \frac{\sigma}{\dot{\varepsilon}} = \frac{k_B T d^3}{4\Omega \delta_{gb} D_{gb}}$$

reduces to the Stokes Einstein equation for the viscosity of amorphous materials such as glasses and liquids,

$$\eta_{StokesEinstrai} = \frac{\sigma}{\dot{\varepsilon}} = \frac{k_B T}{6\pi \Omega^{1/3} D_{glass}}$$

Note the difference in the numerical parameter of 6π instead of 4.

Give a possible explanation for this discrepancy.

3. (i) Write a short essay (less than 100 words) on the ramification of the grain size in the mechanisms of diffusional deformation.

(ii) Why does a small grain size promote superplastic deformation?

4. We have discussed two mechanisms of diffusional deformation, one by boundary diffusion and the other by volume diffusion. The activation energy for volume diffusion is higher than the activation energy for boundary diffusion. For example see

H. J. Frost “Deformation Mechanism Maps” (the link is given just above on this webpage)

Which mechanism would you expect to dominate at higher temperatures, and why?