Spring 2021: Mechanical Properties Materials Science

Take Home Exam II: (Plasticity)
Assigned: Mon 04/26/2021,

Due (by email) Fri 05/06/2021, by the end of the day

rishi.raj@colorado.edu

Each question carries equal points.

This is the final version of this HW-Exam

Suggestions:

(i) Clearly state the assumptions in your analysis.

(ii) Submit a well written paper, one that you yourself find pleasure in reading.

Question 1.

Give three examples of iconic figures, or equations that pertain to the understanding or are the important features of deformation in solids at high temperatures.

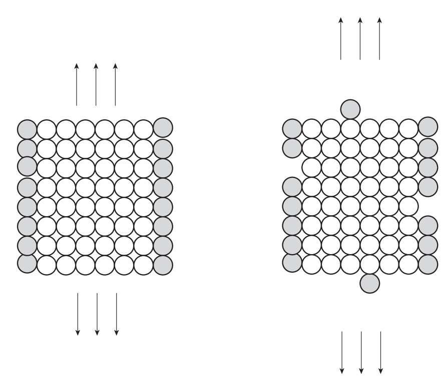
Question 2.

In class we derived the strain arising from the transport of one atom from the stress-free face to the face under tension

Average growth of each face

$$\frac{\text{the size of one atom*2(two faces)}}{\text{(size of the crystal)}} x \frac{\text{one atom}}{\text{total number of atoms on the face}}$$

$$\frac{2\Omega^{1/3}}{d}\frac{1}{(d^2/\Omega^{2/3})}=\frac{2\Omega}{d^3}$$



(i) If N atoms are transported, then calculate the strain that will be achieved.

(ii) Now consider that N atoms are etched and transported from each of the four side faces of the crystal. What is the equation for the strain achieved in this way.

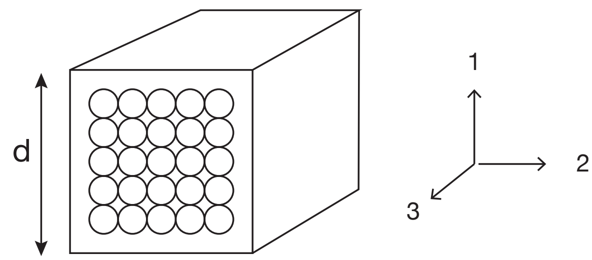
Question 3

Why do atoms prefer to move in the direction of the plane that is under tensile traction?

Question 4

Consider two cases for the applied principal stresses to the cube crystal on the right.

Taking Case I as the baseline calculate the atoms transported in Cases II and III (as a ratio with respect to Case I



Principal stresses

	σ_1	σ_2	σ_3
Case I	$+\sigma$	0	0
Case II	$+\sigma$	$-\sigma$	$-\sigma$
Case III	$+\sigma$	$+\sigma$	$-\sigma$
Case IV	$+\sigma$	$+\sigma$	$+\sigma$

Question 5

During class lecture we discussed that grain boundaries can serve at sites where atoms can be added or removed (etched) so that every crystallite in the polycrystal can deform as if it were a free single crystal.

(i) Explain the significance of the above assumption in understanding diffusional deformation in a polycrystal?

(ii) Is it possible that under some circumstanced the assumption that "grain boundaries can serve at sites where atoms can be added or removed (etched)" may not be reasonable. Think instinctively, not precisely to answer this question.

Question 6

$$D = D_o \exp(-\frac{Q}{RT})$$

where,

$$D_O = \frac{1}{6}\nu_D(10^{13}s^{-1})\Omega^{2/3}$$

Give a physical meaning for the three quantities, ν_D, $\Omega^{2/3}$, Q according to the following guidelines,

(i) Show how you will obtain a value for Ω from information for copper with information generally available in Wikipedia.

(ii) Give a short (<couple of lines) definition for ν_D.

(iii) Give a short (<couple of lines) definition for Q.

Question 7

Calculate the value for Q (in clearly stated units) from the data for the diffusion coefficient of copper as a function of temperature, given on the right. The diffusion data is in units of cm^2s^{-1}. Note that the x-axis is written as $\frac{1000}{T(K)}$.

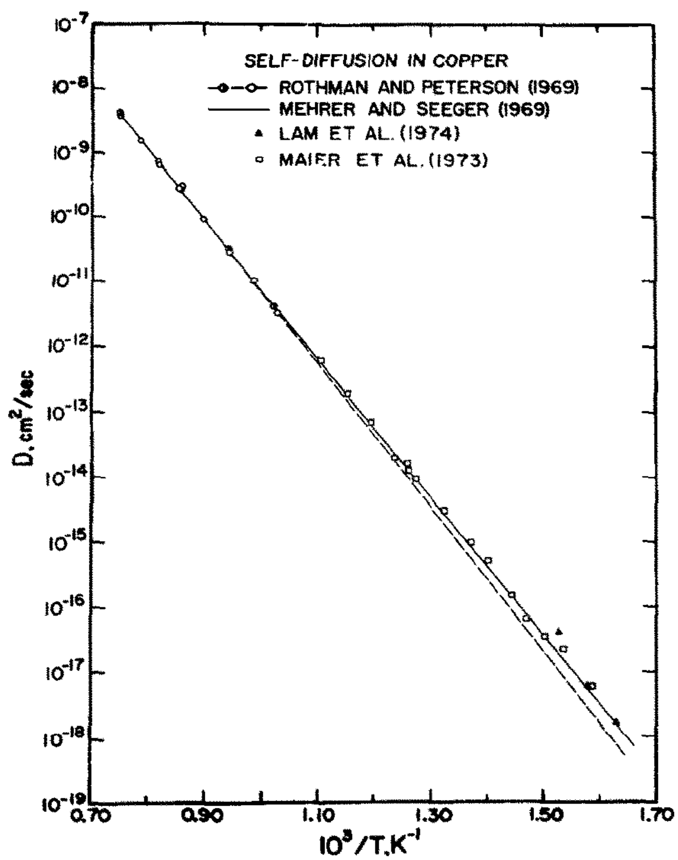


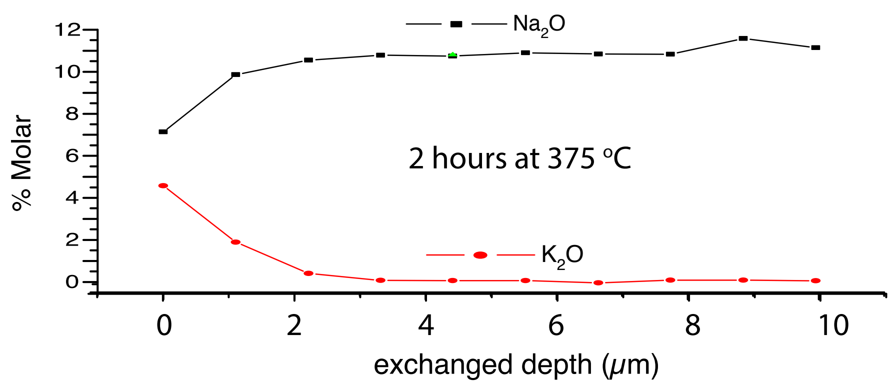
Fig. 7. Log D vs. reciprocal absolute temperature for tracer self-diffusion in copper that shows the data of ○: Rothman and Peterson [61], ▲: Lam et al. [80], □: Maier et al. [81]. The solid line is from the analysis by Mehrer and Seeger [59] of the results of Rothman and Peterson [61]. The dashed

Question 8

$$6Dt = L^2$$

(i) In the above equation, explain the meaning for each parameter, and their units.

(ii) Data for the inward diffusion of K+ and the outward diffusion of Na+ in an ion exchange process is given below.



Obtain a value for (i) the diffusion coefficient of Na+ and (ii) the diffusion coefficient of K+ in this glass. The data was obtained at 2 h in a experiment at 375°C. Pay attention to which ion diffuses more slowly than the other (your answer?).

(iii) Explain how the above ion exchange process leads "Gorrilla Glass" that is glass that resists fracture.

Question 9

A small crystal of size "d" is subjected to the following stress tensor

$$\begin{bmatrix} +\sigma & & \\ & -\sigma & \\ & & -\sigma \end{bmatrix}$$

Write down an expression for the driving force in terms of the gradient of the chemical potential from the side faces to the tensile face of the crystal.

Question 10

The following equation was derived for diffusional creep under a uniaxial tensile stress by volume diffusion

$$\dot{\varepsilon}_1 = 14\frac{\sigma\Omega}{k_B T}\frac{D_V}{d^2}$$

Explain the physical origin for the inverse square grain size dependence of the tensile strain rate.