

Department of
MATERIALS SCIENCE AND ENGINEERING

Doctoral Written Exam

Core Areas:

**Materials Physics And Chemistry
Advanced Mechanical Behavior
Advanced Thermodynamics Of Materials
Kinetics and Phase Transformations
Structure Of Materials**

Friday, May 30, 2008

Department of Materials Science and Engineering

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Your exam packet contains 3 questions from each core area for which you signed up, along with several answer sheets. A copy of the Table of Constants is included for your reference. **You must submit 2 questions from each core area you are taking for grading.** You will have 2 hours to complete each section. You can obtain extra answer sheets from the proctor, if needed. Please use the following procedure:

Write a four (4) digit code of your choice, and your name on the 3 X 5 card provided. Use this code in place of your name to identify all answer sheets you submit for both days of the exam. Renee will keep the code information, sealed in an envelope, until after the exams are graded.

For each answer, use the question sheet as the first page of your answer. If additional pages are required, use the blank answer sheets provided. At the end of the examination, staple each question sheet and corresponding answer sheets for each question separately, put this instruction sheet on top of the questions you are turning in, and place them in one side of your exam folder. Place all other exam pages in the other side of your folder, and return everything to Renee if you finish before your time is up.

Please be sure to complete the information required on each page.

CODE NUMBER _____

CHECK THE QUESTIONS YOU WISH TO HAVE GRADED:

Materials Physics
And Chemistry:

1. _____

2. _____

3. _____

Advanced Mechanical
Behavior:

4. _____

5. _____

6. _____

Advanced Thermodynamics
Of Materials

7. _____

8. _____

9. _____

Kinetics and Phase
Transformations

10. _____

11. _____

12. _____

Structure of Materials

13. _____

14. _____

15. _____

4.

Anisotropic sheet materials are often characterized by in-plane plastic isotropy and anisotropy normal to plane. During uniaxial tensile test, the normal anisotropy parameter, R , is determined by a ratio of width strain divided by thickness strain. A localized neck usually forms in ductile metal sheets before fracture, along a direction of zero length change in the sheet plane.

- a) Determine the angle of inclination between tensile axis and the direction of localized neck for $R = 0.6$, and $R = 1.5$.
- b) Under equibiaxial tension, the value of biaxial yield strength is expected to be $a \times Y$, where $Y =$ uniaxial yield strength. Determine the value of a for the above two different values of R .

5.

Part A

1. Draw a (001) standard stereographic projection for cubic crystal.
2. On the projection identify (412) pole.
3. Using the projection above (or long calculations if you so wish), identify the active slip system for an f.c.c. single crystal having a tensile axis along [412] direction.
4. If critical resolved shear stress for the crystal is 25 MPa, what is the magnitude of tensile stress to cause yielding?

Part B

A 1 cm³ cube of NaCl is subjected to a shear stress such that slip takes place on a $(\bar{1}10)$ plane and in a [110] direction. The crystal is oriented so that the slip planes are parallel to the top and bottom surfaces. For NaCl, the lattice parameter, a , is 0.544 nm.; the slip plane spacing is $a/\sqrt{2}$.

1. An edge dislocation with $\bar{b} = (a/2)[110]$ passes halfway through the crystal on every sixth slip plane. What is the shear strain?
2. What is the dislocation density after deformation of the type described above?

6.

Part A

In a continuous fiber reinforced composite under elastic loading, if fiber's elastic modulus is 50 times that of the matrix. If fiber volume fraction is 40%, the fibers will carry x times the force carried by the matrix. Find the value of x .

Part B

Identify the correct answer and show your calculations:

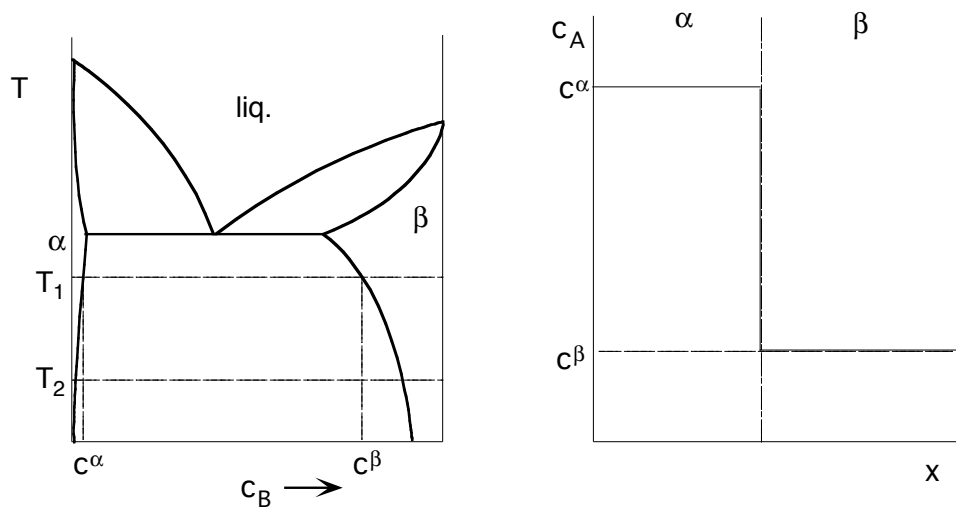
The maximum strength of a bundle of ceramic fibers divided by the average fiber strength in the bundle increases if fiber strength distribution frequency

- i. Is uniform between σ_1 and σ_2 ($\sigma_2 > \sigma_1$)
- ii. Has a peak at σ_2
- iii. Has a peak at σ_1

10.

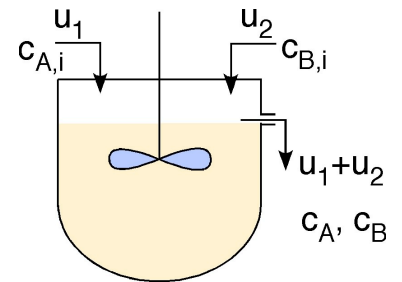
Consider the geometric configuration of two phases α and β given in the diagram below (right hand side). This configuration corresponds to a situation in equilibrium at T_1 of the adjacent phase diagram. The system is cooled abruptly to T_2 .

- Superimpose the concentration profile after some time (sufficient for the effects to be visible, but still far from equilibrium). Make sure the direction of migration of the interface is obvious from your sketch.
- Develop an expression for the velocity of migration of the interface based on the diffusivity of A in β . For this part of the question, assume that the change in solubility of B in α is negligible.



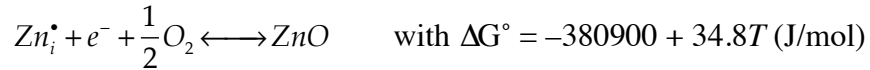
11.

Consider two chemicals A and B that react with each other according to a second order reaction to form product AB. The process is designed to take place in a continuously stirred tank reactor (CSTR) with a capacity of 100 liters. The two reactants enter the CSTR in separate streams, each at a volume flow rate of 1 l/s. The concentration of A in the incoming stream is 15 mol/l and that of B is 25 mol/l, respectively. Calculate how many moles of A and B have been converted to product after flowing through the reactor. The reaction rate coefficient is $0.02 \text{ s}^{-1}/\text{mol}$.



12.

The oxidation of Zn to form ZnO occurs via interstitial diffusion of Zn in ZnO towards the oxide/gas interface. The defect equilibrium is described by



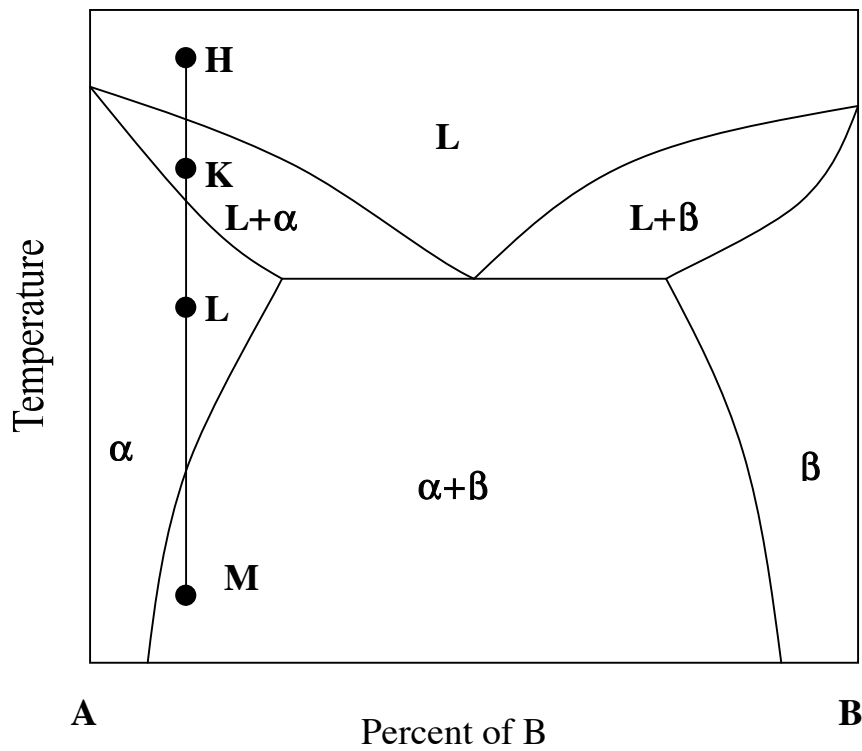
At 800K the fraction of occupied interstitial sites in ZnO at the metal/oxide interface is $2 \cdot 10^{-5}$. ZnO has a density of 5.58 g/cc at this temperature. Assuming an average distance between interstitial sites of 2.8 Å, a Debye temperature of the compound of $\theta_D = 416$ K, and an activation energy of migration for interstitial Zn of 400 kJ/mol, calculate the time it takes for the oxide layer on Zn to reach a thickness of 1 μm.

13.

- a) Determine the packing fractions of fcc and diamond cubic crystals.
- b) Calculate the structure factor of fcc and diamond cubic crystals.

14.

Figure 1 is a phase diagram of two metals A and B which are partially soluble. Draw schematics and show the characteristics of electron diffraction patterns of the (polycrystalline) solid solutions at H, K, L, and M, respectively. Assuming the α phase has a f.c.c. structure with $a=0.4$ nm, while the β phase has a b.c.c structure with $a=0.3$ nm.



15.

TiO₂ has a tetragonal crystal structure with $a = 4.59 \text{ \AA}$ and $c = 2.96 \text{ \AA}$.

- a) Along what direction does the (121) plane intersect the (110) surface?
- b) What angle does this direction make with the [001] axis?
- c) Write the indices of all planes in the family {110}.