Department of

MATERIALS SCIENCE AND ENGINEERING

Doctoral Written Exam

Day 2

Core Areas covered:

MSE 532
MSE 535
MSE 560

Friday, May 13, 2005

Department of Materials Science and Engineering

DOCTORAL WRITTEN EXAM – Day 2
May 13, 2005

Your exam packet for day 2 contains a total of nine (9) questions from three (3) core areas, MSE 532 MSE 535, and MSE 560, plus 20 answer sheets. Each question is on a separate page. A copy of the Table of Constants is included for your reference. **You must submit 2 questions from each core area for grading**. You will have 6 hours to complete the questions. 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 the proctor, or Renee if you finish before 2:30 P.M.

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

GOOD LUCK!

CODE NUMBER ________________

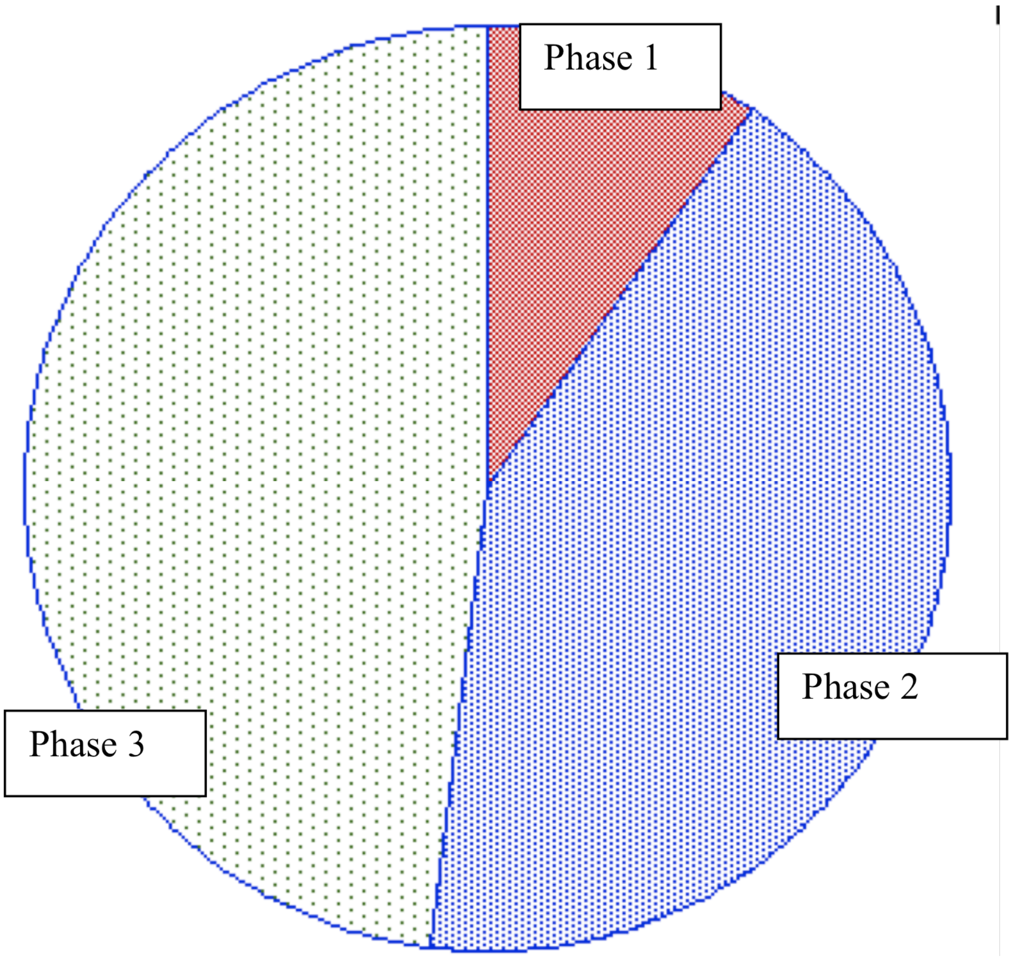
CHECK THE 6 QUESTIONS YOU WISH TO HAVE GRADED.

ADVANCED THERMODYNAMICS OF MATERIALS:	KINETICS AND PHASE TRANSFORMATIONS:	STRUCTURE OF MATERIALS
1. _______	4. ________	7. ________
2. ________	5. ________	8. ________
3. ________	6. ________	9. ________

Day 2 – ADVANCED THERMODYNAMICS OF MATERIALS CODE #________

1.

A polydomain material containing three different isotropic phases is annealed until the interphase boundaries are all approximately at thermodynamic equilibrium. A section of the sample is taken perpendicular to a triple line between phases (1), (2) and (3), resulting in the micrograph shown below.



The diameter of the field of view is 100 microns. If the surface energy of the interface between phase 2 and phase 3 is 100 J/m^2, estimate the surface energy of the other two interfaces.

Day 2 – ADVANCED THERMODYNAMICS OF MATERIALS CODE #________

2.

Discuss the relative contributions of thermal vibrations and electronic excitations to the heat capacity of a typical metal near room temperature. What is the expected value of the heat capacity of a metal well above its Debye temperature? For a given material, what physical characteristics control the value of the Debye temperature?

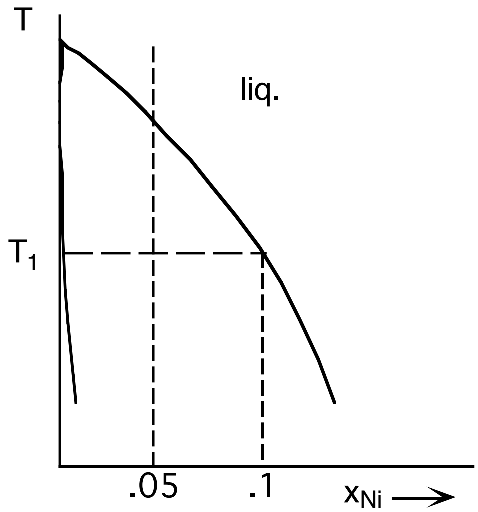
Day 2 – ADVANCED THERMODYNAMICS OF MATERIALS CODE #________

3.

A dynamical system contains three species, A, B, and C. A chemical reaction can occur such that $A + B \leftrightarrow C$. From the expression for Gibbs free energy, show that a necessary condition for thermal equilibrium is $\mu_A + \mu_B = \mu_C$, where μ_i is the chemical potential for species i.

Day 2 – KINETICS ND PHASE TRANSFORMATIONS **CODE #________**

4.



Consider the solidification of a binary material. A liquid Ni-Ti alloy containing 5 mol% Ni is rapidly cooled and then held at T_1 = 1300 ˚C, as indicated in the adjacent (schematic) phase diagram. At this temperature the solubility of Ni in Ti is negligible, whereas the melt is saturated with 90 mol% Ti. Assume that the solidification front is planar, and progresses strictly perpendicular to the interface. Assume furthermore that the solidification process is entirely controlled by the diffusion of Ni into the melt. Derive a formalism that describes the amount of solidified Ti as a function of time during the early phase of the solidification process, i.e., as long as the concentration of Ni far away from the interface remains unchanged. (Hint: It may be most convenient to choose a coordinate system that migrates with the solid/liquid interface.)

Day 2 – KINETICS ND PHASE TRANSFORMATIONS CODE #________

5.

A tube of Zirconia stabilized with 5 mol% Yttria is used as solid oxide fuel cell. The oxygen partial pressure on the outside is maintained at 0.21 and on the inside at 10^{-4}. At 1000 ˚C the diffusion coefficient of oxygen in Zircona is $2 \cdot 10^{-9}$ cm^2/s. Derive the expression for the steady state power output per unit length of this device. How large is the power output, given that the inside and outside diameters of the tube are 10 and 12 mm respectively. The density of Zirconia is 5.3 g/cm^3, Faraday's constant is 96400 Cb/mol and the gas constant is 8.31 J/molK.

Day 2 – KINETICS ND PHASE TRANSFORMATIONS **CODE #________**

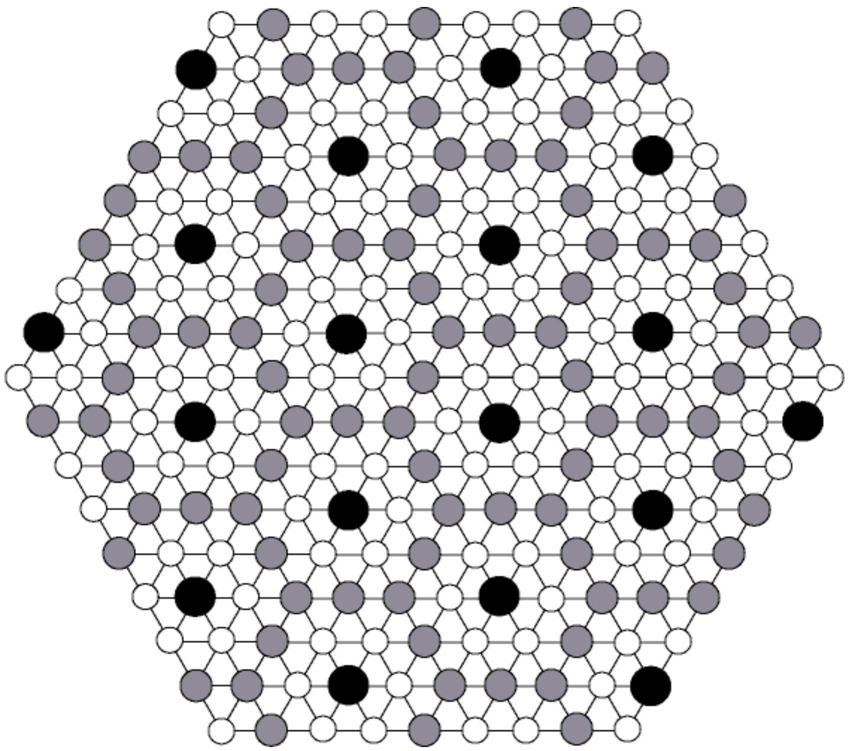
6.

A steel ball of outside diameter = 0.6 m and inside diameter = 0.4 m is cooled inside by a fluid at 15^oC. The heat transfer coefficient at the inner wall is 150 W/m^{2}K and the temperature of the outer wall is 50^oC. Calculate the temperature of the inner wall?

Day 2 – STRUCTURE OF MATERIALS **CODE #________**

7.

In the two dimensional arrangement of three types of atoms (see below) indicate the unit cell and list the symmetry operations.



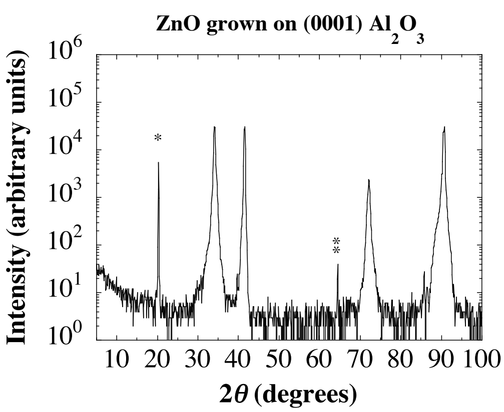
8.

An epitaxial ZnO thin film is grown on the (0001) surface of sapphire. Figure A shows the x-ray diffraction pattern (ϑ-2ϑ scan) of the sample. Figure B is the ϕ-scan of the sample film using the $10\bar{1}1$ reflection of ZnO. (i) Index all (six) peaks appearing in Figure A. (ii) Explain the origin of the two peaks marked by * and **. (iii) Find the orientation relationship between the ZnO film and the sapphire substrate.

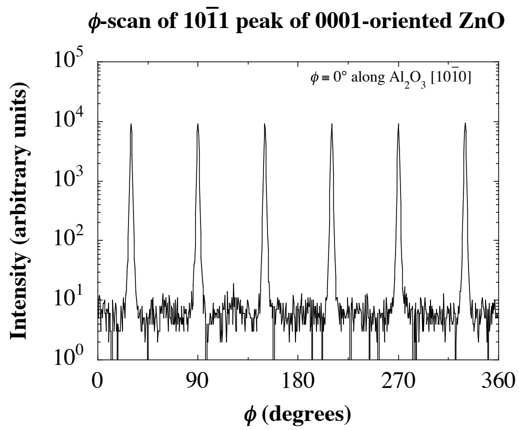
ZnO: hexagonal (*wurtzite*), a = 3.2495 Å, c = 5.2069 Å

Al_2O_3: hexagonal (*corundum*), a = 4.7628 Å, c=13.0032 Å

The wavelength of x-ray was 1.5406Å.



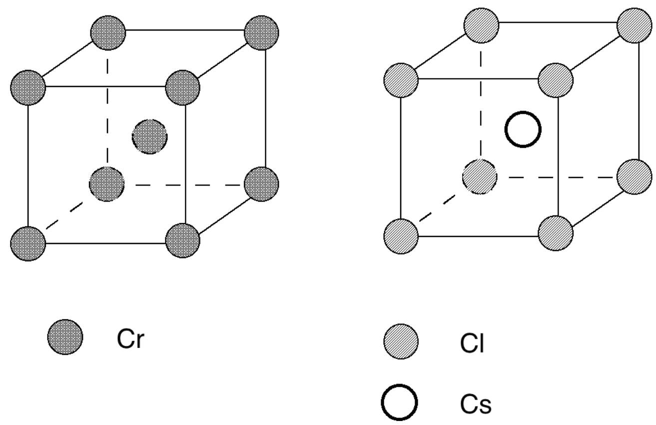
(A)



(B)

9.

Chromium (Cr) and cesium chloride (CsCl) have a very similar structure (see Fig. a & b), yet Cr has forbidden reflections, while CsCl does not. Calculate the structure factors for both crystals and find the forbidden reflections.



(a) (b)