Department of

MATERIALS SCIENCE AND ENGINEERING

Doctoral Written Exam

Day 1

Core Areas:

MATERIALS PHYSICS AND CHEMISTRY
ADVANCED MECHANICAL BEHAVIOR

Thursday, January 27, 2005

Department of Materials Science and Engineering

DOCTORAL WRITTEN EXAM – Day 1
January 27, 2005

Your exam packet for day I contains a total of six (6) questions from two (2) core areas, MATERIALS PHYSICS AND CHEMISTRY and ADVANCED MECHANICAL BEHAVIOR, plus 10 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 4 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 12:30 P.M.

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

GOOD LUCK!

CODE NUMBER __________________

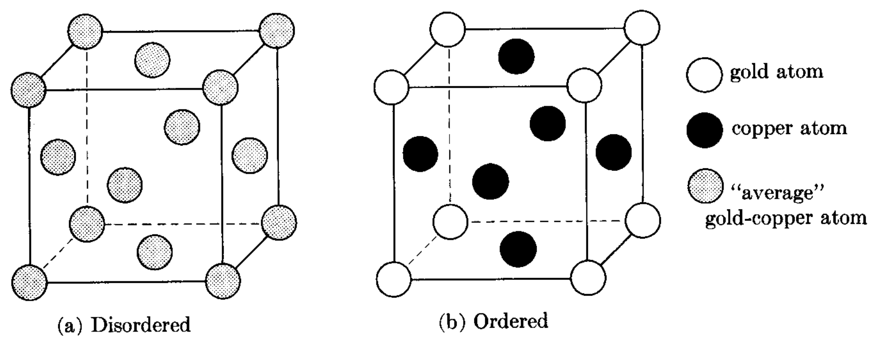
CHECK THE 4 QUESTIONS YOU WISH TO HAVE GRADED.

MATERIALS PHYSICS AND CHEMISTRY:	ADVANCED MECHANICAL BEHAVIOR:
1. ____	4. ____
2. ____	5. ____
3. ____	6. ____

Day I – MATERIALS PHYSICS AND CHEMISTRY **CODE #_______**

1.

$AuCu_3$ alloys undergo a 1st order solid-state order-disorder phase transition at a temperature T_d that is below the melting point T_m. Above T_d, the system is disordered, with a random chance of finding the atoms on any lattice site. Below T_d, the system orders, with the gold atoms preferentially occupying the corners and the copper atoms the faces of the FCC unit cell (see schematic).



a) How would the scattering pattern change (or not) when the sample is cooled from above T_d to below T_d?

b) Provide a suggestion for a quantity that could be used as an order parameter for this phase transition.

c) Plot qualitatively the expected change in the order parameter in the vicinity of T_d.

2.

a) Describe the difference between a direct band gap and an indirect band gap semiconductor.

b) Is silicon a direct band gap or an indirect band gap semiconductor?

c) Is gallium arsenide a direct band gap or an indirect band gap semiconductor?

d) Describe qualitatively how the optical absorption of a semiconductor is expected to vary with incident photon energy, and compare a direct band gap semiconductor with an indirect band gap semiconductor.

3.

a) Rank these in order of increasing electrical conductivity: Copper, Gold, Copper-Gold eutectic alloy. Explain.

b) Rank the materials in a) in order of their increasing thermal conductivity. Explain.

c) Rank these in order of their electrical conductivity: Diamond, Graphite, Buckyballs (C_{60}). Explain.

d) Rank the materials in c) in order of their increasing thermal conductivity. Explain.

4.

For this problem consider a block consisting of a face-centered cubic single crystal. The block is sectioned such that it has {100} faces.

a) The crystal is subjected to a hydrostatic pressure that reduces the volume of the crystal by 0.1%. Assuming C_{11} = 186 GPa, C_{12} = 157 GPa and C_{44} = 42 GPa, what is the magnitude of the applied hydrostatic pressure?

b) The crystal is compressed in uniaxial compression along the [001] direction. Yielding occurs when the stress applied along this direction is 320 MPa. What is the critical resolved shear stress?

c) Using the critical resolved shear stress calculated in (b), determine the stress at which yielding would occur if the crystal were loaded along the [123] direction.

d) A hydrostatic pressure of 500 MPa is applied to this block of material. Considering your answers in parts (a) – (c), will this material undergo plastic deformation? Justify your answer quantitatively.

5.

Answer the following concept-based questions:

a) In your own words, describe what you understand by the term "dynamic recrystallization". State three (3) important characteristics of dynamic recrystallization, and say how it differs from static recrystallization.

b) Dislocation creep process involves motion of dislocations. How does it differ from thermally activated glide process for creep? (State as many different characteristics as you can.) Is there any role of diffusion in either process, if so how?

c) In the deformation mechanism maps for crystalline materials, the boundary between Coble creep and Nabarro-Herring creep is usually given by a vertical straight line in a typical plot of normalized stress versus homologous temperature. Why is this line vertical when other boundaries are not vertical? How would you determine the temperature boundary separating these mechanisms?

6.

When a fast-breeder reactor is shut down quickly, the temperature of the surface of a number of components drops from 600ºC to 400ºC in less than a second. These components are made of a stainless steel, and have a thick section, the bulk of which remains at the higher temperature for several seconds. The low-cycle fatigue life of this steel is described by

$$N_f^{\,0.5}\,\Delta\varepsilon_{pl} = 0.2$$

where N_f = number of cycles to failure and $\Delta\varepsilon_{pl}$ is the plastic strain range. Estimate the number of fast shut-downs the reactor can sustain before serious cracking or failure will occur. (The thermal expansion coefficient of stainless steel is $1.2\text{x}10^{-5}\ K^{-1}$, the appropriate yield strain at 400ºC is $0.4\text{x}10^{-3}$)