Department of

MATERIALS SCIENCE AND ENGINEERING

Doctoral Written Exam

Day 1

Core Areas:

MATERIALS PHYSICS AND CHEMISTRY
ADVANCED MECHANICAL BEHAVIOR

Thursday, May 13, 2004

Department of Materials Science and Engineering

DOCTORAL WRITTEN EXAM – Day 1
May 13, 2004

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.

The free energy of system undergoing a phase transition can be described near a critical temperature T_c as a function of the order parameter S as:

$F = (1/2)(r S^2) - w S^3 + u S^4$

where r is a parameter that increases linearly with temperature T, that is, $r=a(T-T_c)$ with the value of a positive.

For a second order transition, w=0. If w is non-zero, there will be a first order transition.

a) For a 1st order phase transition it is possible to define two additional characteristic temperatures T^* and T^{**} near the critical temperature. What are these temperatures (in terms of the other parameters), and what do they correspond to physically?

b) Describe how the order parameter varies with temperature near the critical temperature T_c for a 1st order phase transition. Plot the variation in energy F as a function of S for several temperatures near T_c. Also plot the expected variation in S as a function of T.

c) Describe a system that undergoes a first order phase transition and define an order parameter appropriate for examining the change in order near the phase transition.

2.

Consider Ge, which has a bandgap of 0.75 eV doped with a small amount of an impurity.

a) If the acceptor level is 0.29 eV, calculate the fraction of impurities that are ionized at 300 K (assume that $E_F = (E_C - E_V) / 2$), where E_C and E_V are the conduction-band and valence-band energies, respectively.

b) Will the fraction of ionized acceptor impurities increase or decrease if a large concentration of donor impurities is added to the Ge? Explain.

3.

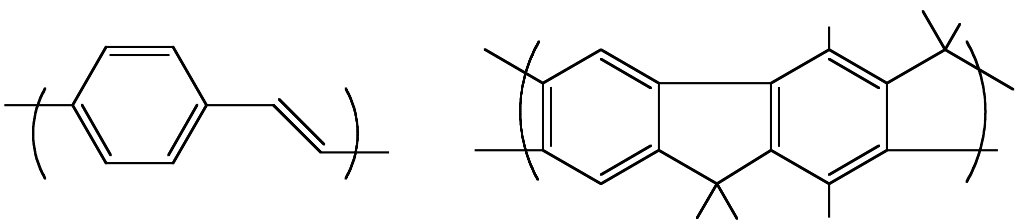
Conjugated polymers are emerging active materials for many useful applications. Many of these applications rely on their conducting and luminescent properties.

a) As the molecular weight of a conjugated polymer increases from a monomer, dimer, trimer, …, to a polymer, the absorption and emission λ_{max} of the conjugated material are gradually red-shifted and eventually level off. Explain why.

b) Charge mobility in inorganic semiconductors is much higher than that in semiconducting conjugated polymers. Explain why.

c) Electron mobility is always higher than hole mobility in inorganic semiconductors. On the contrary, hole mobility is known to be higher than electron mobility in most of conjugated polymers. Explain the reason.

d) Ladder-like conjugated polymers have a much smaller Stoke shift as compared to linear conjugated polymers. In terms of ground state and excited state energy states, explain the reason. The figure below shows an example of a linear conjugated polymer and a ladder-type conjugated polymer.



4.

Assume that an alloy with a modulus of 100 GPa exhibits steady-state power-law creep of the form $\dot{\varepsilon} = 7.4 \times 10^{-10} \sigma^{5} \exp(-Q/RT)$ s^{-1}, where Q = 160 kJ/mole, R = 8.31 J/mol.K, and σ is in MPa. Assume that a bolt made out of this alloy is loaded with an initial uniaxial stress of 100 MPa and subjected to a 600 °C environment. The bolt's position is held constant by initial tightening in the fixture.

a) What is the stress after 1,000 hours?

b) If the stress in the bolt is again made equal to 100 MPa in 2 minutes time, will there be any additional strain in the bolt? How much?

5.

A unidirectional lamina, with properties given below, is subjected to a biaxial stress state, with stresses applied along the x- and y-axes. The stress along the x-axis is 7.5 times greater than that along the y-axis. The fiber axis of the lamina is oriented at –16° away from the x-axis. Determine the **least magnitudes** of the stresses under which failure will occur according to the Tsai-Hill criterion.

Elastic constants: E_{11} = 38.6 GPa, E_{22} = 8.27 GPa, G_{12} = 4.14 GPa, ν_{12} = 0.26
Strengths: $\hat{\sigma}_{1T}$ = 1062 MPa, $\hat{\sigma}_{1C}$ = 610 MPa, $\hat{\sigma}_{2T}$ = 31 MPa, $\hat{\sigma}_{2C}$ = 118 MPa, $\hat{\tau}_{12}$ = 72 MPa

where $\hat{\sigma}$ denotes fracture strength in the orthogonal directions of the fiber.

6.

A single crystal of copper is extended in tension parallel to the x = [123] direction.

a) What would be the active slip system(s)?
b) If the lateral directions of the crystal were y = [111] and z = [541], what would be the ratio of the strains $\varepsilon_y/\varepsilon_z$?