Uva Wellassa University, Sri Lanka
End Semester Examination – March 2011
SCT 341-3 Solid State Materials Science

Time: Three (03) hours

Total 06 questions
Answer all questions

01). i. Describe the characteristic properties of crystalline materials and explain how they differ from amorphous materials.

ii. The "unit cell" of a crystal structure is its fundamental building block. Illustrate this statement using a simple 3-D lattice.

iii. How do you distinguish between primitive and non-primitive unit cells? Explain using a 2-D lattice.

iv. With an appropriate example, show how you would derive the Miller Index of a planar surface within a crystal.

v. Prove that parallel planes within a crystal have the same Miller Index.

(25 marks)

02). i. What are the assumptions of the atomic hard sphere model used in crystal studies.

ii. Describe how cubic close packing (CCP) and hexagonal close packing (HCP) structures are generated by different stacking sequences of atoms.

iii. Chromium has a Body Centered Cubic (BCC) crystal structure. Draw a schematic diagram to show the unit cell of chromium using atomic hard sphere model.

iv. Show that the Atomic Packing Factor of a BCC crystal structure is smaller than that of a Face Centered Cubic (FCC) crystal structure.

v. Derive expressions for the atomic linear density along [110] direction and planar density on (110) plane in FCC crystal structure in terms of atomic radius (R).

(25 Marks)

03). i. Defects in crystals can be classified into four categories depending on their dimensions. Name these four main categories of defects, giving two examples for each category.

ii. A heavier atom is added as a substitutional impurity to a crystal. Give schematic representations for this point defect in the crystal, using arrows to indicate the directions of the local stresses introduced by this point defect.

iii. Calculate the energy for vacancy formation in silver, given that the equilibrium number of vacancies at 1073 K is 3.6×10^{23} m^{-3}. The atomic weight and density of silver at 1073 K are 107.9 g/mol and 9.5 g/cm^3, respectively.

iv. Taking Wüstite *(ferrous oxide)* as an example, explain the term *nonstoichiometric materials.*

v. What point defects are possible for CaO as an impurity in Al_2O_3? How many Ca^{2+} ions must be added to form each of these defects? Explain your answer.

(25 Marks)

04). i. What are the two major components of a *solid solution*? Explain the term *secondary phase,* which is in the terminology of alloys.

ii. Name three factors that determine the formation of solid solution with the addition of impurities.

iii. With a schematic representation explain the formation of the interstitial solid solution of *steel* by adding C to α-Fe. For this highly packed structure of α-Fe, the voids (or interstices) between the Fe atoms are relatively small and it is a major limitation in the formation of any interstitial solid solution with α-Fe. Explain how C fulfills this condition to form the interstitial solid solution of steel.

iv. A slip system is a set of two components. Briefly explain these two components.

v. A single crystal of a metal is oriented for a tensile test with its normal to slip plane making an angle of 71^0 with the tensile axis and slip direction making an angle of 29^0 with the same tensile axis. If the critical resolved shear stress is 7.3 MPa, what applied stress will be necessary to cause the single crystal to yield?

(25 Marks)

05). i. What is the basic principle behind the mechanism for *strengthening polycrystalline materials* by *grain size reduction.*

ii. The lower yield point for a polycrystalline material that has a grain diameter of 87 μm is 151 MPa. When the grain diameter is decreased to 39 μm the lower yield point increases to 307 MPa. At what grain diameter will the lower yield point be 250 MPa?

iii. Define the term *dislocation density.*

iv. Ancient Sri Lankans were world famous as manufacturers of strong and sharp metal tools. The secret behind this success was their expertise in a process now called as *forging.* Briefly explain how this forging process strengthens metals.

v. Make a rough 3-diamentional sketch, to show the decreasing of ductility with the increasing of percent cold work in a metal that underwent work hardening.

(25 Marks)

06). i. Very briefly explain how the addition of substitutional impurity atoms to a host matrix reduces the overall strain energy of the matrix, under the solid-solution strengthening mechanism.

ii. With the help of schematic representation, show how to impose tensile strain by adding *lighter* (small) substitutional impurity atoms to a host matrix having an edge dislocation.

iii. What are the driving forces for recrystallization and grain growth processes?

iv. Name the two main factors that determine the extent of recrystallization.

v. Compare the differences in grain structure for a metal that has been cold worked and then recrystallized.

(25 Marks)