Uva Wellassa University, Sri Lanka
Faculty of Science and Technology
Science and Technology Degree Programme
1st Semester Examination – March/April 2013

SCT 341-3 Solid State Materials Science

Uva Wellassa University

Number of questions: Six (06)
Answer **all** questions
Time allocation : Three (03) hours
Total marks : 150

1. a. Derive the Miller Index of a planar surface in a crystal that intersects +a axis at two unit lengths, +b axis and -c axis at a unit length each.

   b. Show that any plane parallel to the above will have the same Miller Index. The second plane should also intersect +a, +b and –c axes.

   c. Labeling three orthogonal *a, b,* and *c* axes with unit lengths, indicate $[1\,\bar{2}\,\bar{3}]$ and $[\bar{1}\,0\,3]$ directions in a cubic crystal.

   d. Illustrate the concepts of unit cell and lattice.

   e. Distinguish between the primitive unit cell and a non-primitive unit cell in a 2-D lattice.

   (25 Marks)

2. a. Briefly explain how the combination of 2-D motif symmetries (planar point groups) and plane lattices (2-D nets) generates plane groups.

   b. Describe the symmetry content of a cubic crystal.

   c. Illustrate how cubic close packing (CCP) structure is generated in a monoatomic crystal.

   d. Show that increasing atomic radius ratio increases the coordination number.

   e. Derive the atomic packing factor (APF) of a body centred cubic (BCC) structure.

   (25 Marks)

3. a. What causes crystals to be *imperfect*?

   b. With rough sketches, explain the existence of *Frenkel* and *Schottky* defects in ionic crystals.

   c. Can *Schottky defects* exist in Na_2O? Explain the answer.

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d. Determine the *equilibrium number of vacancies* for Ag at 900 ^{0}C, considering the energy needed for vacancy formation for this metal as 0.83 eV/atom at the given temperature. The atomic weight and the density of Ag at 900 ^{0}C, are 107.9 g/mol and 9.5 g/cm^3, respectively. The Avogadro's number and the Boltzmann constant are 6.023 x 10^{23} atoms/mol and 8.62 x 10^{-5} eV/K, respectively.

e. What are the two main mechanisms by which the *nonstoichiometric* solids maintain their charge balance?

(25 Marks)

4. a. Explain the four main factors that determine the high solubility in *substitutional solid solutions*.

b. Briefly explain the formation of *interstitial solid solutions* using the crystal structure of *steel* as an example.

c. Draw the two symbols used to denote *edge* and *screw* dislocations.

d. What does *grain boundary* mean?

e. List the four main categories of *bulk (volume) defects* occurring in crystalline solids.

(25 Marks)

5. a. Explain the term *slip system* in the crystallographic terminology.

b. State the expression for the *critical resolved shear stress* for a single crystal to yield. In tensile testing of a pure mineral, a single crystal is oriented for the test with its normal to slip plane making an angle of 51.7^0 with the tensile axis and slip direction making an angle of 43.9^0 with the same tensile axis. The critical resolved shear stress for this crystal is already known as 9.75x10^6 Pa. Calculate the *applied stress* needed for this crystal to start plastic deformation.

c. What is the basic principle behind the mechanism of *strengthening by grain-size reduction?*

d. What is the reason for *high-angle grain boundaries* to be more effective in blocking dislocations than *the low-angle grain boundaries*?

e. Make a rough sketch to explain the expected variation of the *tensile strength* with the increase of the *solute content* under the solid-solution strengthening mechanism.

(25 Marks)

6. a. What are the other two terms analogues to *strain hardening* used in materials terminology?

b. Ancient Sri Lankans had been world famous for producing strong and sharp metal tools by increasing the dislocation density (a process now called *forging*). Explain how this forging process strengthens metals.

c. A cylindrical specimen of strain hardened steel has a ductility of 23.5%. If its strain hardened radius is 47.9×10^{-3} m, what was its radius before deformation?

d. Write down the main steps of the *recovery* process.

e. Make a rough sketch to show the expected variation of recrystallization temperature with percent cold work (%CW) for a metal.

(25 Marks)