Uva Wellassa University of Sri Lanka
Faculty of Science and Technology
Department of Science and Technology
300 level 1st Semester Examination – Sept. / Oct. 2015
SCT 341-3 Solid State Materials Science

Uva Wellassa University

Instructions to candidates
Duration: 03 hours
Number of questions: 06
Mark allocation: 150
Answer all questions
Answer question no 5 and 6 in a separate booklet.

1.

a. Solid state materials can mainly be classified as **crystalline** or **amorphous** according to the regularity of atoms or ions are arranged with respect to other.

i. Briefly describe differences between these two. (4 marks)
ii. Give two examples for each case. (2 marks)

b. What is the difference between single crystals and polycrystalline materials? (3 marks)

c. In crystallography, we use atomic hard sphere model. What is this model? (3 marks)

d. Give definitions of following two terms.
i. Unit cell (3 marks)
ii. Primitive unit cell (2 marks)

e. i. There are seven crystal systems into which all crystals are classified. Give relationship between lattice parameters (a, b, c and α, β, γ) of any four (04) systems amoung those seven systems. (8 marks)

2.

a. Define the two terms: Coordination Number and Atomic Packing Factor. (4 marks)

b. Following table is listed the atomic weight, density, and atomic radius for three hypothetical metals. For each determine whether its crystal structure is face centerd cubic (FCC), body centerd cubic (BCC), or smple cubic (SC) and then justify your determination. (9 marks)

Metal	Atomic Weight (g/mol)	Density (g/cm^3)	Atomic Radius (nm)
A	77.4	8.22	0.125
B	107.6	13.42	0.133
C	127.3	9.23	0.142

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c. i. Show the following planes in cubic unit cells: (210), $(\bar{1}10)$, and $(10\bar{2})$. (6 marks)

ii. Show the following directions in cubic unit cells: (111), $(\bar{1}\bar{2}1)$, and $(0\bar{1}2)$. (6 marks)

3.

a. Aluminum has FCC structure at 300K and its atomic radius is 0.1431 nm, calculate the planar packing fraction of the (110) plane and the linear packing density (atoms/cm) of the [100] direction. (5 marks)

b. Find the miller indices of the first three reflections in a powder diffreaction pattern taken from a simple cubic crystal. [Hint: the lowest sum square value of *(hkl)* would have the highest inter planer spacing (*d*)]. (5 marks)

c. Calculate the equibrium number of vacancies per cubic meter for copper at 1000 °C. The energy for vacancy formation is 0.9 eV/atom. The atomic weight and density (at 1000 °C) for copper are 63.5 g/mol and 8.40 g/cm^3, respectively. (5 marks)
[Boltzmann constant=8.617 × 10^{-5} eV/atom K]

d. Briefly explain Schottky and Frenkel types of defects in ionic crystals. Provide schematic representations for each case. (6 marks)

e. Suppose that Li_2O is added as a an impurity to CaO. If the Li^+ substitutes for Ca^{2+}, what kind of vacancies would you expect? Howmany of these vacancies are created for every Li^+ added? (4 marks)

4.

a. If the Orthogonal vectors of unit length are set to e_x, e_y, and e_z, the primitive translation vectors of the body centerd cubic (BCC) structure is given as follows. Obtain the unit vectors, b_1, b_2, and b_3 of reciprocal lattice of this system. (6 marks)

$$a_1 = \frac{\sqrt{3}a}{2}e_x - \frac{a}{2}e_y \qquad a_2 = ae_y \qquad a_3 = ce_z$$

Hint: The unit vector of b_1 of reciprocal lattice can be represented as $b_1 = \frac{(a_2 \times a_3)}{a_1.(a_2 \times a_3)}$

b. Solid solutions can be obtained when two metals are completely soluble in liquid state and also completely soluble in solid state. There are two main types of soild solutions named as **substitutional solid solutions** and **interstitial solid solutions**. Very briefly describe these two cases. (6 marks)

c. i. Why X-rays are so imporant for crystal structure determination? (3 marks)

ii. What are the methods or sources used for X-ray generation? (2 marks)

d. i. Briefly describe the sample preparation procedure for powder diffraction experiment. (5 marks)

ii. What are difficulties and limitations of powder diffraction? (3 marks)

5.

a. Define the term *dislocation density.* (3 marks)

b. Very briefly explain how the work hardening enhance the strength of materials. (4 marks)

c. A cylindrical specimen of work hardened metal has a ductility of 21.73%. If its strain hardened radius is 1.78 cm, what was its radius before deformation? (5 marks)

d. With the help of rough sketch, show how to impose compressive strains by adding a larger substitutional impurity atom to a host matrix having an edge dislocation. (5 marks)

e. A single crystal of a metallic Ni is oriented for a tensile test with its normal to slip plane making an angle of 45^0 with the tensile axis and slip direction make an angle of 45^0 with the same tensile axis. If plastic deformation begins at a tensile stress of 2.75 MPa, determine the critical resolved shear stress for this metallic Ni. (8 marks)

6.

a. State the Hall-Petch equation related to strengthening of crystalline materials by grain size reduction. (2 marks)

b. The lower yield point for a metal that has a grain diameter of 43 microns is 279 MPa. When the grain diameter is decreased to 21 microns the lower yield point increases to 571 MPa. At what grain diameter was the lower yield point be 400 MPa? (10 marks)

c. Explain the difference between *recrystallization* and *grain growth* processes. (5 marks)

d. What is the driving force for these *recrystallization* and *grain growth* processes? (3 marks)

e. Make a rough sketch to show the expected variation of recrystallization temperature with percent cold work (% CW) for a metal. (5 marks)