Uva Wellassa University, Sri Lanka
End Semester Examination – January 2010
SCT 341-3 Solid State Materials Science

Time: Three (03) hours

Total 08 questions
Six (06) questions to be answered from **Part A and Part B**

Part A : Answer <u>two (02)</u> questions only

01) i. Derive the Miller Index of a planar surface in a crystal that intersects $+a$ axis at a unit length, $+b$ axis at two units and is parallel to c axis.

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

iii. Labeling three orthogonal axes a, b, and c with unit lengths, indicate the [211] direction in a crystal.

iv. Define *unit cell* and *space lattice.*

v. Mark the primitive unit cell and a non-primitive unit cell in a 2D lattice.

(25 marks)

02) i. Describe three basic symmetry operations and symmetry elements.

ii. List out the seven crystal systems with their essential/characteristic symmetry.

iii. Draw the three types of unit cells in cubic system.

iv. Discuss the relationship between atomic radius ratio and coordination number.

v. Using the atomic hard sphere model, show that the atomic packing factor (APF) of a face centred cubic (FCC) structure is 0.74.

(25 Marks)

03) i. Explain the stacking sequence of hexagonal close packing (HCP) structure.

ii. Derive a relationship between the unit cell edge length (a) and the atomic radius (R) of a body centred cubic (BCC) structure assuming the atomic hard sphere model.

iii. Calculate the number of atoms in the face centred cubic (FCC) unit cell of copper. Given the atomic weight of copper 63.5g/mol, atomic radius 0.128nm and Avagadro's number 6.023×10^{23} atoms/mol compute the theoretical density of copper.

iv. Illustrate Bragg's Law in X-ray diffraction technique in crystal studies.

v. Given that the inter-planar spacing of (220) planes in BCC iron is 0.1013nm calculate the 1st order diffraction angle of X-rays having wavelength of 0.1790nm.

(25 Marks)

Part B : Answer **four (04)** questions only

04) i. List the four main categories of defects in crystals that are classified according to their dimensions.

ii. A lighter atom is added as an impurity to a crystal. Give schematic representations for the (a) interstitial impurity and (b) substitutional impurity point defects in this crystal.

iii. Define the term *nonstoichiometric materials*.

iv. Name two possible mechanisms that can help to maintain the charge balance in nonstoichiometric solids.

v. If Fe^{3+} substitutes for Ni^{2+}, when Fe_2O_3 is added as an impurity to NiO, what kind of vacancy can be expected to form? Explain your answer. How many of these vacancies are created for every Fe^{3+} added?

(25 Marks)

05) i. Define the terms *solvent* and *solute*, which are in the terminology of alloys.

ii. Name two main important characteristics of a solid solution.

iii. Cu and Ni are completely soluble in one another at all proportions. Make a schematic representation to explain the formation of the Cu-Ni solid solution.

iv. There are four main factors that decide the high solubility in formation of a solid solution. Explain how the relevant parameters of Cu and Ni are fulfilling these conditions (four main factors) to form a complete solid solution.

vi. The surface energy of a single crystal depends on crystallographic orientation. Briefly explain why this surface energy decreases with an increase in planar density?

(25 Marks)

06) i. Dislocations have strain fields arising from distortions at their cores. Give schematic representations to show the strain field around an edge dislocation in a crystalline solid.

ii. Define the term *dislocation density*.

iii. Our ancient people knew how to improve the strength and the sharpness of metal tools by increasing the dislocation density (a process called now as *forging*). Briefly explain how this forging process strengthens metals.

iv. Two previously undeformed cylindrical steel rods are to be strain hardened by reducing their cross-sectional areas (while maintaining their circular cross sections). For the first rod, the initial and deformed radii are 18 cm and 15 cm, respectively. The second rod, with an initial radius of 14 cm, must have the same deformed hardness (same %CW) as the first specimen. Calculate the radius of the second rod after deformation.

v. What will be the major changes taking place in the grain structure of a cold worked metal when it is recrystallized.

(25 Marks)

07) i. Briefly explain why small-angle grain boundaries are not as effective in blocking dislocations as high-angle grain boundaries.

ii. The yield point for an alloy that has an average grain diameter of 0.05 mm was 150 MPa. The yield point increased to 250 MPa when the average grain diameter was decreased to 0.008 mm. What can be the yield point of the alloy when average grain diameter is 0.01 mm.

iii. List two common techniques that are used to control grain size under the strengthening mechanism by grain size reduction.

iv. Define the term *recrystallization temperature*.

v. Make a rough sketch to show the variation of recrystallization temperature with percent cold work (%CW) for metallic iron.

(25 Marks)

08) i. What does *solid-solution strengthening* mean?

ii. With the help of schematic representations, show how to impose compressive strains by adding larger substitutional impurity atoms to a host matrix having an edge dislocation.

iii. What is the driving force for grain growth?

iv. The grain diameter varies with time for most of the polycrystalline materials. Write down the typical formula showing the variation of grain diameter with time.

v. The variation of grain diameter with time was investigated for a metal at 1000 ^{0}C. The average grain diameters after 30 min and 75 min were 0.06 mm and 0.09 mm, respectively. For how long the metal should be heated treated at 1000 ^{0}C in order to grow grains to the average size of 0.1 mm? Consider a value of 2 for the time independent constant *n* in the formula of above iv.

(25 Marks)

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