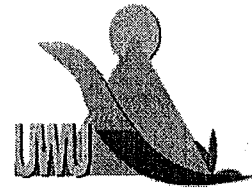


Uva Wellassa University, Sri Lanka
End Semester Examination - March 2012
SCT 341-3 Solid State Materials Science



Time: Three (03) hours

Total 07 questions
Answer 06 questions only

- 01). i. Describe how the ten Bravais Lattices (space lattices) are constructed by translation of the five 2d nets (plane lattices) along a non-coplanar stacking vector in an x,y,z reference frame. Indicate the unit cell in each lattice.
- ii. Explain grouping of the shapes of the above unit cells in the six crystal systems.
- iii. Describe symmetry elements and operations with examples.
- iv. Graphically illustrate,
(a). (110) (001) and (111) planes
(b). [120] direction

(25 Marks)

- 02). i. "Increasing ionic radius ratio in crystalline structures increases the coordination number". Illustrate this.
- ii. Distinguish between Cubic Closest Packing and Hexagonal Closest Packing structures.
- iii. Most of the common metals have Face Centred Cubic Closest Packing (FCC) or Body Centred Cubic Closest Packing (BCC) structures. Show that metals with FCC structure have a more densely packed atomic arrangement than those with BCC structure.
- iv. Planar density is defined as the number of atoms per unit area. Derive an expression for the planar density of an FCC crystal in terms of atomic radius.

(25 Marks)

- 03). i. Make a list of all possible *point defects* occurring in crystals.
- ii. Explain the terms *Schottky defects* and *Frenkel defects* with the help of schematic representations.
- iii. Express the relationship between the *equilibrium number of vacancies* (N_v) with the *temperature* for a given quantity of a crystalline material. The atomic weight and the density of a crystalline material are 106.4 g/mol and 8.9 g/cm³, respectively. If the energy for vacancy formation is 0.75 eV/atom, compute N_v at 800 °C for this material. The Boltzmann constant (K_B) and the Avogadro number (N_A) are 8.62×10^{-5} eV atom⁻¹ K⁻¹ and 6.02×10^{23} mol⁻¹, respectively.

- iv. Briefly explain the term *nonstoichiometry* found in the terminology of Materials Science.
- v. What are the two main mechanisms responsible for maintaining the charge balance in nonstoichiometric materials.

(25 Marks)

- 04). i. List the three most important characteristics of solid solutions.
- ii. What are the four main factors that decide the high solubility in a substitutional solid solution? Considering these factors, explain the possibility of obtaining total solubility of Cu in Ni.
- iii. Explain the term *interfacial defects*. Give three examples for the interfacial defects occurring in crystals.
- iv. With the help of schematic representation, briefly explain the terms *high angle grain boundary* and *low angle grain boundary*.
- v. What is the composition in wt% of an alloy that consists of 3.7 at% Aluminum and 96.3 at% Copper? The atomic weights of Aluminum and Copper are 26.98 g/mol and 63.55 g/mol, respectively.

(25 Marks)

- 05). i. Define the term *dislocation density*. What could be the approximate dislocation densities (in cm^{-2}) in a *carefully solidified metal crystal* and in a *heavily deformed metal*.
- ii. Explain the terms; *slip plane*, *slip direction* and *slip system*.
- iii. Why do the FCC and the BCC crystals are more ductile than the HCP crystals?
- iv. Give expressions for the *Resolved shear stress* and the *Critical resolved shear stress*. A Cu single crystal is tensile tested with its normal to slip plan making an angle of 59° with the tensile axis and slip direction making an angle of 42° with the same tensile axis. If the critical resolved shear stress is 12.8×10^6 Pa, what applied stress will be necessary to cause the single crystal to yield?
- v. Explain the reason for the polycrystalline metals to be stronger than the single crystal metals.

(25 Marks)

- 06). i. Briefly explain the mechanism behind the strengthening of crystalline materials by *grain size reduction*.
- ii. Why small-angle grain boundaries are not as effective in blocking dislocations as high-angle grain boundaries.
- iii. Write down the Hall-Petch equation related to strengthening of crystalline materials by grain size reduction. A novel super alloy showed a yield point of 2.53×10^9 Pa when its average grain diameter was 5.93×10^{-6} m. With the reduction of the average grain diameter to $2.87.0 \times 10^{-6}$ m, the yield point increased to 4.59×10^9 Pa. What will be the new yield point of this super alloy if the average grain diameter is further reduced to 1.01×10^{-6} m.
- iv. Explain how the addition of an impurity reduces the overall strain energy and anchor the dislocation in the *solid-solution strengthening* mechanism.
- v. With the help of schematic representation show how to impose compressive strain by adding *heavier* (larger) substitutional impurity atoms to a host matrix containing an edge dislocation.
- 07). i. What does it cause to improve the strength of crystalline materials in the *forging* process.
- iii. Make a rough 2-diamentional sketch to show the expected variation of the *ductility* of a crystalline material with the *percentage of cold-working*.
- iii. Write down the main steps of the *recovery* process.
- iv. What are the driving forces for *recrystallization* and *grain growth* processes?
- v. The variation of grain diameter with time was investigated for an alloy at 1250°C . The average grain diameters after 22 min and 46 min were 0.048 mm and 0.079 mm, respectively. What will be the average grain diameter if the heat treatment is continued upto one hour. Consider a value of 2 for the time independent constant n .

(25 Marks)

