**II Semester 2013-14**                                                                    **Mid Sem (Closed Book)**
**Max Time: 90 min**              **Total Max Marks:105**                  **Date 9th March, 2014**

- ✓ The Question paper has two parts: Part A and Part B
- ✓ Answer Part A in question paper itself in the space provided.
- ✓ Answer Part B in the answer book.
- ✓ Return part A with the answer book

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**SECTION A (42 marks)**

**Q 1: True or false? Write only 'T' or 'F' clearly at the right side of the question.**          **[0.5 x 10]**

A. (222) plane is practically possible for a BCC unit cell but not for a FCC unit cell.
B. At room temperature polycarbonate shows brittle facture but polyethylene shows ductile facture under a constant force and reasonably small strain rate.
C. Wavelength of the electron accelerating under 200 keV should be half of that for 100keV.
D. For edge dislocation, Burger vector moves perpendicular to the motion of dislocation line, but for screw dislocation , Burger vector moves parallel to the motion of dislocation line.
E. For a FCC crystal structure unit, the distance between two face centered atoms and between one face centered atom and one corner atom is different.
F. for cubic systems, all parallel direction vectors have the same direction indices, but all parallel planes don't have same plane indices.
G. The shear stress required to move a dislocation from one equilibrium location to another equilibrium location is proportional to magnitude of Burger vector.
H. Linear density of BCC [111] and FCC [110] is not same.
I. Considering the annealing of a heavily cold worked brass sample, maximum recovery of the mechanical properties happened in recrystallization stage compared to other two stages.
J. For polymer increase in cross linking/networking decrease  crystallinity and strength.

**Q 2: Multiple choice: Cross the right one only. Multiple cross will reward no marks.**          **[1 x 10]**

A. The FCC crystal unit can't be consider as a primitive cell, because
   a. It has 1/2 lattice point on each face
   b. It contains 1/8 lattice point per corner
   c. It contains more than one lattice point per unit cell
   d. Total number of lattice point per unit cell is 4
   e. All of the above

B. In spinel structure, $AB_2O_4$
   a. $O^{2-}$ occupy FCC sites, A and B ions occupy tetrahedral and octahedral interstitials, respectively.
   b. $O^{2-}$ occupy FCC sites, B and A ions occupy tetrahedral and octahedral interstitials, respectively.
   c. $O^{2-}$ occupy FCC sites, A and B ions occupy tetrahedral and octahedral interstitials randomly.
   d. $O^{2-}$ occupy BCC sites, A and B ions occupy tetrahedral and octahedral interstitials, respectively.
   e. None of the above

C. In polymer, spherulite structure represents
   a. Alternating brittle and ductile polymer regions
   b. Alternating cross-linked and linear chain regions
   c. Alternating chain-folder crystallites and amorphous regions
   d. Alternating regions of different steriochemical configurations

e. None of the above

D. For polymeric materials both $T_m$ and $T_g$ increase with increasing
   a. Polar group and irregularity in structure
   b. Polar group and/or bulky side group in structure
   c. Aromatic chain group and impurity in structure
   d. Polar group and bulky side group in structure
   e. All of the above

E. In thermoplastic polymers increase in strain rate and/or decrease in temperature during deformation lead to
   a. Increases in elastic modulus, decrease in tensile strength and ductility
   b. Increases in elastic modulus and tensile strength, and decrease in ductility.
   c. Decrease in elastic modulus, increase in tensile strength and ductility.
   d. Increases in elastic modulus, tensile strength, and ductility.
   e. Increases in elastic modulus and ductility, and decrease in tensile strength.

F. In X-ray diffraction technique atoms of a parallel plane family (hkl) in a crystal
   a. Produce destructive interference of the scattered rays at specific angles.
   b. Produce destructive interference with the rays reflected from perpendicular planes.
   c. Produce destructive or constructive interference of the scattered rays at any angles.
   d. Produce constructive interference with the rays reflected from perpendicular planes.
   e. Produce constructive interference of the scattered rays at specific angles.

G. For SEM, magnification can obtain by
   a. Decreasing scanning area and image screen area
   b. Increasing scanning area image screen area
   c. Keeping scanning area constant and decreasing image screen area
   d. Decreasing scanning area and increasing image screen area.
   e. None of the above

H. Relationship between $\sigma_y$ and $\tau_{CRSS}$ can express as
   a. $\sigma_y = \tau_{CRSS}/(\cos\phi\cos\lambda)^{1/2}$
   b. $\sigma_y = \tau_{CRSS}/(\cos\phi\cos\lambda)^2$
   c. $\sigma_y = \tau_{CRSS}.(\cos\phi\cos\lambda)$
   d. $\sigma_y = \tau_{CRSS}$
   e. $\sigma_y = \tau_{CRSS}/(\cos\phi\cos\lambda)$
   where $\phi$=angle between slip plane normal and stress axis and $\lambda$= angle between slip direction and stress axis

I. The term strain hardening refers to a phenomenon in which
   a. Ductile metal becomes harder and stronger during plastic deformation.
   b. Ductile polymer becomes harder and stronger during plastic deformation.
   c. Ductile ceramic becomes harder and stronger during plastic deformation.
   d. Ductile metal becomes more ductile during plastic deformation.
   e. All of the above is true

J. In stainless steel, which is a Fe-C system
   a. C substitutes Fe atom up to ~725 °C
   b. C occupies interstitial of FCC Fe only at room temperature
   c. C occupies interstitial of FCC Fe up to ~725 °C
   d. C occupies interstitial of BCC Fe at room temperature
   e. C occupies interstitial of BCC Fe up to ~725 °C

**Q 3: Answer following questions in the space provided below only. Be to the point.** **[20]**

A. Consider a material showing two XRD peaks at 30 and 60 °, respectively. Which one would be preferable slip plane? Justify. **[2]**

B. What kind of vacancy will be formed if 10 wt% sodium chloride is replaced by calcium chloride? Calculate the fraction of vacancy formed with respect to the ideal lattice. **[4]**

C. Consider $BaTiO_3$ structure, where $O^{2-}$ is in a FCC arrangement.
   a. What kind of interstitial sites would be occupied by $Ba^{2+}$?
   b. What kind of interstitial sites would be occupied by $Ti^{4+}$?
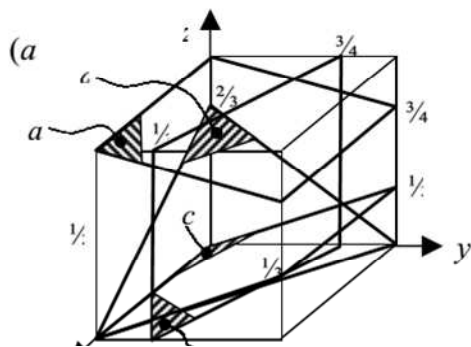   c. What % of total sites ($O_h + T_d$) remain unoccupied? **[4]**

D. Derive the following relations between true stress ($\sigma_T$) and engineering stress ($\sigma$), and between true strain($\varepsilon_T$) and engineering strain ($\varepsilon$) **[3+3]**

$$\sigma_T = \sigma(1 + \varepsilon); \text{ and } \varepsilon_T = \ln(1 + \varepsilon)$$

E. What maximum and minimum values of critical free energy could be achieved for heterogeneous nucleation compared to homogeneous nucleation? Show the trend of 'rate of nucleation' during cooling from melting temperature for both cases. **[4]**

**Q 4:** Draw the directions $[2\bar{3}3]$, $[1\bar{1}\bar{2}]$, and $[\bar{2}\bar{2}3]$ in simple cubic unit cell. Mark the origin clearly.     **[3]**

**Q 5:** Determine the Miller indices of the planes shown in the unit cell below.     **[4]**

Periodic Table

| hydrogen 1 H 1.0079 | | | | | | | | | | | | | | | | | | helium 2 He 4.0026 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| lithium 3 Li 6.941 | beryllium 4 Be 9.0122 | | | | | | | | | | | boron 5 B 10.811 | carbon 6 C 12.011 | nitrogen 7 N 14.007 | oxygen 8 O 15.999 | fluorine 9 F 18.998 | neon 10 Ne 20.180 |
| sodium 11 Na 22.990 | magnesium 12 Mg 24.305 | | | | | | | | | | | aluminium 13 Al 26.982 | silicon 14 Si 28.086 | phosphorus 15 P 30.974 | sulfur 16 S 32.065 | chlorine 17 Cl 35.453 | argon 18 Ar 39.948 |
| potassium 19 K 39.098 | calcium 20 Ca 40.078 | scandium 21 Sc 44.956 | titanium 22 Ti 47.867 | vanadium 23 V 50.942 | chromium 24 Cr 51.996 | manganese 25 Mn 54.938 | iron 26 Fe 55.845 | cobalt 27 Co 58.933 | nickel 28 Ni 58.693 | copper 29 Cu 63.546 | zinc 30 Zn 65.39 | gallium 31 Ga 69.723 | germanium 32 Ge 72.61 | arsenic 33 As 74.922 | selenium 34 Se 78.96 | bromine 35 Br 79.904 | krypton 36 Kr 83.80 |
| rubidium 37 Rb 85.468 | strontium 38 Sr 87.62 | yttrium 39 Y 88.906 | zirconium 40 Zr 91.224 | niobium 41 Nb 92.906 | molybdenum 42 Mo 95.94 | technetium 43 Tc [98] | ruthenium 44 Ru 101.07 | rhodium 45 Rh 102.91 | palladium 46 Pd 106.42 | silver 47 Ag 107.87 | cadmium 48 Cd 112.41 | indium 49 In 114.82 | tin 50 Sn 118.71 | antimony 51 Sb 121.76 | tellurium 52 Te 127.60 | iodine 53 I 126.90 | xenon 54 Xe 131.29 |
| caesium 55 Cs 132.91 | barium 56 Ba 137.33 | 57-70 ✶ | lutetium 71 Lu 174.97 | hafnium 72 Hf 178.49 | tantalum 73 Ta 180.95 | tungsten 74 W 183.84 | rhenium 75 Re 186.21 | osmium 76 Os 190.23 | iridium 77 Ir 192.22 | platinum 78 Pt 195.08 | gold 79 Au 196.97 | mercury 80 Hg 200.59 | thallium 81 Tl 204.38 | lead 82 Pb 207.2 | bismuth 83 Bi 208.98 | polonium 84 Po [209] | astatine 85 At [210] | radon 86 Rn [222] |
| francium 87 Fr [223] | radium 88 Ra [226] | 89-102 ✶✶ | lawrencium 103 Lr [262] | rutherfordium 104 Rf [261] | dubnium 105 Db [262] | seaborgium 106 Sg [266] | bohrium 107 Bh [264] | hassium 108 Hs [269] | meitnerium 109 Mt [268] | ununnilium 110 Uun [271] | unununium 111 Uuu [272] | ununbium 112 Uub [277] | | ununquadium 114 Uuq [289] | | | | |

*Lanthanide series

| lanthanum 57 La | cerium 58 Ce | praseodymium 59 Pr | neodymium 60 Nd | promethium 61 Pm | samarium 62 Sm | europium 63 Eu | gadolinium 64 Gd | terbium 65 Tb | dysprosium 66 Dy | holmium 67 Ho | erbium 68 Er | thulium 69 Tm | ytterbium 70 Yb 173.04 |

nobelium 102 No [259]

| Cation | Ionic Radius (nm) | Anion | Ionic Radius (nm) |
|---|---|---|---|
| $Al^{3+}$ | 0.053 | $Br^-$ | 0.196 |
| $Ba^{2+}$ | 0.136 | $Cl^-$ | 0.181 |
| $Ca^{2+}$ | 0.100 | $F^-$ | 0.133 |
| $Cs^+$ | 0.170 | $I^-$ | 0.220 |
| $Fe^{2+}$ | 0.077 | $O^{2-}$ | 0.140 |
| $Fe^{3+}$ | 0.069 | $S^{2-}$ | 0.184 |
| $K^+$ | 0.138 | | |
| $Mg^{2+}$ | 0.072 | | |
| $Mn^{2+}$ | 0.067 | | |
| $Na^+$ | 0.102 | | |
| $Ni^{2+}$ | 0.069 | | |
| $Si^{4+}$ | 0.040 | | |
| $Ti^{4+}$ | 0.061 | | |

### SECTION B (63 marks)

**Q1:** What kind of structure would you expect for zinc sulphide; sodium chloride, cesium chloride, zinc blend, perovskite, fluoride? Why? Ionic radius of $O^{2-}$ is 0.140 nm and $Zn^{2+}$ is 0.174 nm. Based on your answer determine the followings for the structure.                    **[1+3+4+4]**
        A.  The lattice parameter
        B.  The density
        C.  X-Ray diffraction (θ-2θ scan) peak position of the (231) plane

**Q2:** Calculate the size of the critical radius and the number of atoms in the critical nucleus when solid Cu forms by homogeneous nucleation. Calculate the critical free energy also.                    **[12]**

**Q3:** We wish to produce a 0.1 cm thick, 6 cm wide Cu strip having at least 414 MPa yield strength and at least 5% elongation. We are able to purchase 6-cm wide strip only in a thickness of 5 cm. Design a process to produce the product we need.                    **[11]**

**Q4:** A new grade flexible impact resistant polyethylene for use as a this film requires a density of 0.88 to 0.915 g/cm$^2$. Design the polyethylene required to produce this properties. The density of amorphous polyethylene is about 0.87 g/cm$^3$. Lattice parameters for polyethylene unit cell are 0.741 nm, 0.494 nm, and 0.255 nm.                    **[10]**

**Q5: A:** Derive the packing factor of diamond.                    **[8]**

**B:** Calculate the theoretical volume change accompanying a polymorphic transformation in a pure metal from BCT to end centered monoclinic. Consider the hard-sphere atomic model and there is no change of atomic volume before and after transformation. The lattice constants for the monoclinic unit cells are a = 5.156 Å, b = 5.191 Å, and c = 5.304 Å, and angle β is 98.9 °. The lattice constants for the tetragonal unit cell are a = 5.094Å and c = 5.304 Å.                    **[10]**

TABLE 7-1 ■ Values for freezing temperature, latent heat of fusion, surface energy, and maximum undercooling for selected materials

| Material | Freezing Temperature ($T_m$) (°C) | Heat of Fusion ($\Delta H_f$) (J/cm³) | Solid-Liquid Interfacial Energy ($\sigma_{sl}$) (J/cm²) | Typical Undercooling for Homogeneous Nucleation ($\Delta T$) (°C) |
|---|---|---|---|---|
| Ga | 30 | 488 | $56 \times 10^{-7}$ | 76 |
| Bi | 271 | 543 | $54 \times 10^{-7}$ | 90 |
| Pb | 327 | 237 | $33 \times 10^{-7}$ | 80 |
| Ag | 962 | 965 | $126 \times 10^{-7}$ | 250 |
| Cu | 1085 | 1628 | $177 \times 10^{-7}$ | 236 |
| Ni | 1453 | 2756 | $255 \times 10^{-7}$ | 480 |
| Fe | 1538 | 1737 | $204 \times 10^{-7}$ | 420 |
| NaCl | 801 | | | 169 |
| CsCl | 645 | | | 152 |
| H₂O | 0 | | | 40 |

Table 4.1   Atomic Radii and Crystal Structures for 16 Metals

| Metal | Crystal Structure[a] | Atomic Radius[b] (nm) | Metal | Crystal Structure | Atomic Radius (nm) |
|---|---|---|---|---|---|
| Aluminum | FCC | 0.1431 | Molybdenum | BCC | 0.1363 |
| Cadmium | HCP | 0.1490 | Nickel | FCC | 0.1246 |
| Chromium | BCC | 0.1249 | Platinum | FCC | 0.1387 |
| Cobalt | HCP | 0.1253 | Silver | FCC | 0.1445 |
| Copper | FCC | 0.1278 | Tantalum | BCC | 0.1430 |
| Gold | FCC | 0.1442 | Titanium ($\alpha$) | HCP | 0.1445 |
| Iron ($\alpha$) | BCC | 0.1241 | Tungsten | BCC | 0.1371 |
| Lead | FCC | 0.1750 | Zinc | HCP | 0.1332 |

[a] FCC = face-centered cubic; HCP = hexagonal close-packed; BCC = body-centered cubic.
[b] A nanometer (nm) equals $10^{-9}$ m; to convert from nanometers to angstrom units (Å), multiply the nanometer value by 10.