Roll No:

NATIONAL INSTITUTE OF TECHNOLOGY, HAMIRPUR, H.P

Department of Materials Science and Engineering

Mid -Term Examination

Materials Science and Engineering (MS-101)

Duration: 1.5 hrs (90 min) ***Maximum Marks***: 30

Attempt all the following questions. Useful data is given at the end of the question paper.

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1. For an Hexagonal Closed Packed (HCP) crystal structure, show that the ideal c/a ratio is 1.633 and the atomic packing factor is 0.74. Molybdenum has a BCC crystal structure, an atomic radius of 0.1363 nm, and an atomic weight of 95.94 g/mol. Compute its theoretical density. *(2 + 2 + 1)*
2. Derive liner density expression for BCC [111] direction and planer density expression for FCC (100) plane in terms of atomic radius (R). The metal niobium has a BCC crystal structure. If the angle of diffraction for the (211) set of planes occurs at 75.99°(first-order reflection) when monochromatic x-radiation having a wavelength of 0.1659 nm is used, compute (a) the interplaner spacing for this set of planes and (b) the atomic radius for the niobium atom. *(2 + 3)*
3. Discuss the various imperfections in crystalline materials. *(5)*
4. State and explain the Fick's laws of diffusion. Determine the carburizing time necessary to achieve a carbon concentration of 0.30 wt% at a position 4 mm into an iron–carbon alloy that initially contains 0.10 wt% C. The surface concentration is to be maintained at 0.90 wt% C, and the treatment is to be conducted at 1100°C. *(5)*
5. Briefly explain, with suitable examples, wherever required, ***any five*** of the following:
   - *i.* Classification of Materials
   - *ii.* Diffusion Mechanisms
   - *iii.* Hume-Rothery Rules
   - *iv.* Tetrahedral and Octahedral Voids in FCC Crystal Structures
   - *v.* Diamond Cubic Structure
   - *vi.* Various Interatomic Bonds
   - *vii.* Perovskite (ABO_3 Type) Structure

(2×5)

Useful Data:

1. For the diffusion of C in FCC iron: Q_d (activation energy for diffusion) = 148, 000 J/mol and $D_0 = 2.3\times 10^{-5}$ m^2/s

2. R = 8.314J/mol-K, N_A (Avogadro's number) = 6.023×10^{23} mol^{-1}

3. Table of Error Function:

Z	*erf (Z)*	*Z*	*erf (Z)*	*Z*	*erf (Z)*	*Z*	*erf (Z)*
0	0	0.40	0.4284	0.85	0.7707	1.6	0.9763
0.025	0.0282	0.45	0.4755	0.90	0.7970	1.7	0.9838
0.05	0.0564	0.50	0.5205	0.95	0.8209	1.8	0.9891
0.10	0.1125	0.55	0.5633	1.0	0.8427	1.9	0.9928
0.15	0.1680	0.60	0.6039	1.1	0.8802	2.0	0.9953
0.20	0.2227	0.65	0.6420	1.2	0.9103	2.2	0.9981
0.25	0.2763	0.70	0.6778	1.3	0.9340	2.4	0.9993
0.30	0.3286	0.75	0.7112	1.4	0.9523	2.6	0.9998
0.35	0.3794	0.80	0.7421	1.5	0.9661	2.8	0.9999

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1. Using schematic diagram(s) show that for Hexagonal Closed Packed (HCP) crystal structure, the ideal c/a ratio is 1.633 and the atomic packing fraction is 0.74.

2 + 2

2. Determine the planer density and packing fraction for FCC nickel in the (111) planes, given that the lattice constant of nickel is 3.5167 Å.

2

3. Why do crystals diffract X-Rays? Discuss the Bragg's law of X-Ray diffraction. An X-Ray Diffractometer recorder chart for an element that has either the BCC or the FCC crystal structure shows diffraction peaks at the following 2θ angles: 40, 58, 73, 86.8, 100.4 and 114.7. The wavelength of the incoming X-ray used was 0.154 nm. Determine (a) the cubic structure of the element and (b) the lattice constant of the element.

1 + 1 + 4

4. Briefly discuss the various factors that influence solid state diffusion. Consider the impurity diffusion of gallium into a silicon wafer. If gallium is diffused into a silicon wafer with no previous gallium in it at a temperature of 1100°C for 3 hours, what is the depth below the surface at which the concentration is 10^{22} atoms/m^3 if the surface concentration is 10^{24} atoms/m^3?

2 + 4

5. Briefly explain, with suitable examples, wherever required, ***any six*** of the following:
   - *i.* Unit Cell and Space Lattice
   - *ii.* Fluorite and Anti-Fluorite Crystal Structures
   - *iii.* Frenkel and Schottky Defects
   - *iv.* Octahedral Voids in FCC Crystal Structures
   - *v.* Dislocations in Metallic Crystals
   - *vi.* Ionic, Covalent and Metallic Bonds
   - *vii.* Hume-Rothery Rules

(2×6)

Useful Data:

1. For the diffusion of gallium in silicon, $D_{1100^{\circ}C} = 7.0\times10^{-17}$ m^2/s
2. R = 8.314J/mol-K, N_A (Avogadro's number) = 6.023×10^{23} mol^{-1}
3. Table of Error Function:

Z	***erf (Z)***	***Z***	***erf (Z)***	***Z***	***erf (Z)***	***Z***	***erf (Z)***
0	0	0.40	0.4284	0.85	0.7707	1.6	0.9763
0.025	0.0282	0.45	0.4755	0.90	0.7970	1.7	0.9838
0.05	0.0564	0.50	0.5205	0.95	0.8209	1.8	0.9891
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0.25	0.2763	0.70	0.6778	1.3	0.9340	2.4	0.9993
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0.35	0.3794	0.80	0.7421	1.5	0.9661	2.8	0.9999