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Internal Assesment Test – 1

Sub: Material Science				Code: 18ME34
Date:16/12/2021	Duration: 90 mins	Max Marks: 50	Sem: 3	Branch (sections): ME (A)

Answer ALL FOUR questions

		Marks	OBE	
			CO	RBT
1	Calculate APF of HCP crystal structure.	[10]	CO1	L2
2	To produce a p-type semiconductor, boron is doped in pure silicon. Doping is done by B_2O_2 vapour. The atmosphere is equivalent to a surface concentration of $3X10^{26}$ boron atoms per cubic meter. Calculate the time required to get a boron content of 10^{23} atoms per cubic meter at a depth of 2.5μm. The doping temperature is 1100˚C and D at this temperature is $4X10^{-17} m^2/s$.	[15]	CO1	L2
3	With neat sketches explain the three modes of fracture.	[10]	CO2	L1
4	Explain plastic deformation by slip and twinning with the help of neat diagrams	[15]	CO1	L1

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Scheme Of Evaluation

Internal Assessment Test 1 – December 2021

Sub:	Material Science							**Code:**	18ME34
Date:	16/12/2021	Duration:	90mins	Max Marks:	50	**Sem:**	III	**Branch:**	ME

Note: Answer Any FIVE full questions

Question #	Description	Marks Distribution	Max Marks
1	**Calculating the Number of Atoms** **Diagram** **Calculating the APF** **Answer**	**2** **2** **5** **1**	10
2	**Given data** **Steps** **Answer**	**2** **10** **3**	15
3	**Diagrams** **Explanation**	**6** **4**	**10**
4	**Diagrams** **Explanation**	**8** **7**	**15**

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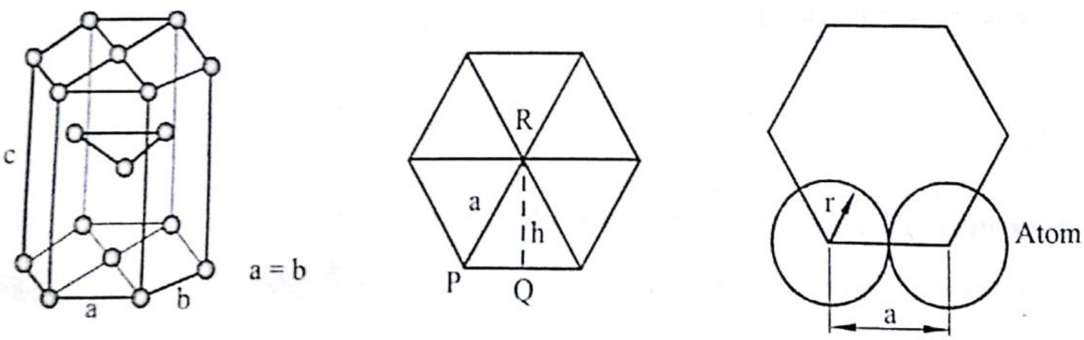
Internal Assesment Test – 1
Solutions

Sub:	Material Science							Code:	18ME34
Date:	16/12/2021	Duration:	90mins	Max Marks:	50	Sem:	III	Branch:	ME

1.

1.6.4 APF For Hexagonal Closed Packed (HCP) structure

Figure 1.16 shows the details of the HCP structure. Let 'r' be the radius of atom, 'a' be the side length of hexagonal face, and 'C' be the height of the hexagonal prism.



(a) HCP unit cell (b) Hexagonal plane surface (c) To express a in terms r

Figure 1.16 APF for HCP structure

w.k.t., atomic packing factor is given by, $APF = \dfrac{volume\ of\ atoms\ per\ unit\ cell}{volume\ of\ unit\ cell}$

$$= \frac{(volume\ of\ each\ atom)\times(number\ of\ atoms\ per\ unit\ cell)}{volume\ of\ unit\ cell} \quad \text{- - - - - (1)}$$

w.k.t. Volume of each atom (sphere) $= \dfrac{4}{3}\pi r^3$ - - - - - (2)

To find the number of atoms per unit cell

In the HCP structure, there are totally 12 atoms at the corners of the top and bottom hexagonal face. However, only $\frac{1}{6}$ of each corner atom is actually inside the hexagonal unit cell. Also, $\frac{1}{2}$ of the volume of each atom at the center of both the top and bottom hexagonal faces are inside the unit cell. In addition, there are also 3 full atoms within the volume of each unit cell.

$\therefore$ number of atoms in unit cell $= \left(12\times\frac{1}{6}\right)+\left(\frac{1}{2}\times 2\right)+3 = 2+1+3 = 6$ atoms. - - - - - (3)

Substituting equation (3) and (2) in (1), we have $APF = \dfrac{\left(\frac{4}{3}\pi r^3\right)\times 6}{Volume\ of\ unit\ cell}$ ----- (4)

To find volume of each unit cell

Volume of hexagonal unit cell = (cross-sectional area of hexagon) × (height of hexagon)

$= $ *(cross-sectional area of hexagon) × (C)* ----- (5)

To find cross-sectional area of hexagon

Consider the hexagonal plane surface as shown in figure 1.16 (b) Let the hexagonal plane be divided into 6 triangular parts as shown in the figure. Let 'h' be the height (altitude) of the triangle.

Area of hexagonal face = (area of each triangle) × (Number of triangles)

$$= \left(\frac{1}{2}\times base\times height\right)\times(6) = \left(\frac{1}{2}a\,h\right)\times 6$$

Area of hexagonal face $= 3ah$ ----- (6)

But $h = ?$

From right angle triangle PQR, we have, $PR^2 = QR^2 + PQ^2$

$$a^2 = h^2 + \left(\frac{a}{2}\right)^2$$

$$h^2 = a^2 - \frac{a^2}{4} \quad or \quad h^2 = \frac{3a^2}{4}$$

$$\therefore\ h = \frac{a\sqrt{3}}{2}$$ ----- (7)

Equation (7) in (6) gives, *area of hexagonal face* $= 3\times a\times\left(\frac{a\times\sqrt{3}}{2}\right) = \frac{3a^2\sqrt{3}}{2}$ ----- (8)

Now, equation (8) in (5), gives *Volume of hexagonal unit cell* $= \left(\frac{3a^2\sqrt{3}}{2}\right)\times C$ ----- (9)

In general, the ratio of height of the hexagonal prism (C) to the side of the hexagonal face (a) is expressed as $\frac{C}{a} = 1.633$, or $C = 1.633\,a$ ----- (10)

Equation (10) in (9) gives *Volume of hexagonal unit cell* $= \left(\frac{3.a^2\sqrt{3}}{2}\right) \times (1.633\ a)$

$\therefore$ *Volume of hexagonal unit cell* $= 4.242\ a^3$ ----- (11)

Substituting equation (11) in (4), we have, $APF = \frac{\left(\frac{4}{3}\pi r^3\right)}{4.242\ a^3} \times 6$

$$\therefore\ APF = \frac{(8\pi r^3)}{4.242\ a^3} \qquad \text{----- (12)}$$

To express '*a*' in terms of '*r*'

From figure 1.16(c). $a = 2.r$

$\therefore$ Equation (12) reduces to, $APF = \frac{(8\pi r^3)}{4.242\ (2r)^3} = \frac{(8\pi r^3)}{(4.242)\times(8r^3)} = 0.74$

$$\therefore\ APF = 0.74 \text{ or } 74\ \%.$$

2.

(2) Given :-

$C_s = 3 \times 10^{26}$ atoms/m^3

$C_x = 10^{23}$ atoms/m^3

$C_0 = 0$ atoms/m^3

$x = 2.5\ \mu m = 2.5 \times 10^{-6}\ m$

$T = 1100^\circ C = 1373 K.$

$D = 4 \times 10^{-17}\ m^2/s$

$t = ?$

$t = ?$

$$\frac{C_x - C_0}{C_s - C_0} = 1 - \text{erf}\left(\frac{x}{2\sqrt{Dt}}\right)$$

$$\frac{10^{23} - 0}{3\times10^{26} - 0} = 1 - \text{erf}\left(\frac{2.5\times10^{-6}}{2\sqrt{4\times10^{-17}\times t}}\right)$$

$$3.333\times10^{-4} = 1 - \text{erf}\left(\frac{197.64}{\sqrt{t}}\right)$$

$$\Rightarrow \text{erf}\left(\frac{197.64}{\sqrt{t}}\right) = 0.9996$$

z	$\text{erf}(z)$
2.4	0.9993
z	0.9996
2.6	0.9998

By interpolation,

$$\frac{z - 2.4}{2.6 - 2.4} = \frac{0.9996 - 0.9993}{0.9998 - 0.9993}$$

$$\Rightarrow z = 2.52.$$

$$\Rightarrow \frac{197.64}{\sqrt{t}} = 2.52.$$

$$\Rightarrow \sqrt{t} = \frac{197.64}{2.52}$$

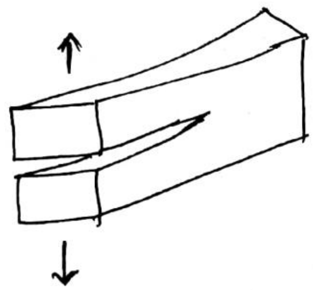
$$\Rightarrow \boxed{t = 6151.04 \text{ seconds}}$$

3.

MODES OF FRACTURE

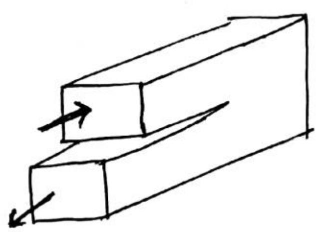
There are three ways of applying a force to enable a crack to propagate.

Mode I or Type I fracture Opening mode (a tensile stress normal to the plane of the crack).



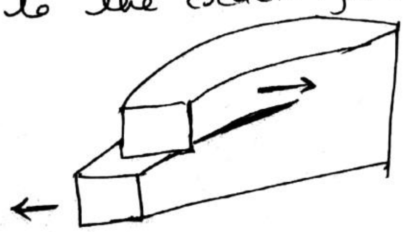
Mode I: Opening mode

Mode II or Type II fracture Sliding mode (a shear stress acting parallel to the plane of the crack and perpendicular to the crack front.



Mode II: In-plane shear

Mode III or Type III fracture Tearing mode (a shear stress acting parallel to the plane of the crack and parallel to the crack front.



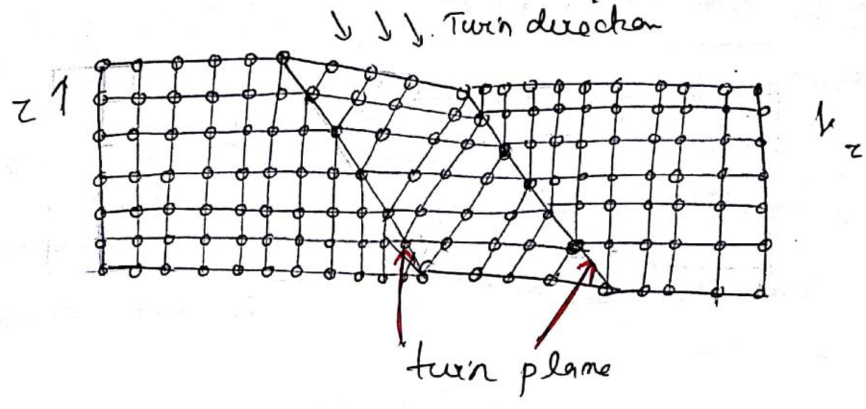
Mode III: Out of plane shear

4.

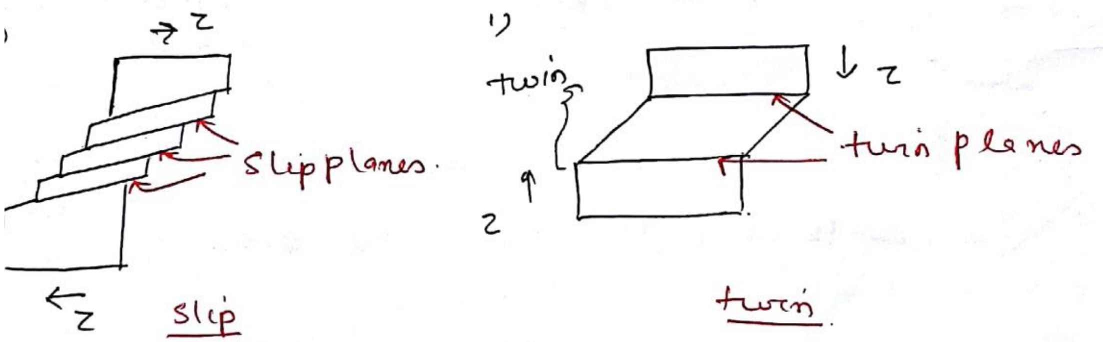
2) Twinning

Plastic deformation in metallic materials can also take place by formation of twins.
A shear force can produce atomic displacement. Such that on one side of a plane, atoms are located in mirror image positions of atoms on the other

side. The displacement magnitude within the twin region is proportional to the distance from the twin plane.
Like slip, twinning also occurs in definite crystallographic plane and in specific directions.



Difference between slip and twinning in single crystal



Slip	Twin
2) Crystallographic orientation above and below the slip plane is same before and after deformation.	2) The atoms are reoriented across the twin plane.
3) Slip occurs in distinct atomic spacing multiples	3) Displacement for twinning is less than interatomic distance. Displacement is proportional to distance from twin plane.
4) Bulk plastic deformation is ~~les~~ more	4) is less.