

Introduction to crystal elasticity and crystal plasticity

WEEK 1 Assignment

Module 1: Structure and properties of materials

1. The close packed direction of a BCC crystal is **1 Mark**

- (a) $\langle 1\ 1\ 1 \rangle$ (b) $\langle 1\ 1\ 0 \rangle$ (c) $\langle 1\ 0\ 0 \rangle$ (d) $\langle 1\ 0\ 1 \rangle$

Ans :(a)

2. The stacking arrangement of FCC crystal structure is **1 Mark**

- (a) ABCABCABC... (b) ABABAB... (c) ABABCABA... (d) ABCABABC.....

Ans :(a)

3. Sufficient ductility is observed in which of the following type of atomic bond?**1 Mark**

- (a) metallic bond (b) covalent bond (c) ionic bond (d) van der Walls bond

Ans :(a)

4. What is the crystal system of Gypsum **1 Mark**

- (a) Cubic (b) Triclinic (c) Orthorhombic (d) Rhombohedral

Ans: (c)

5. What is the Miller indices of a plane whose intercepts are at $a/2$, b , $2c$ in a simple cubic unit cell.

- (a) $(4\ 2\ 1)$ (b) $(2\ 2\ 4)$ (c) $(1\ 2\ 1)$ (d) $(2\ 1\ 2)$ **1 Mark**

Ans: (a)

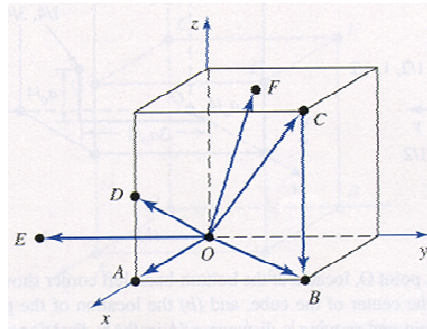
Detailed solution:

The given parameters are $a/2$, b , $2c$

Its numeral parameters are $\frac{1}{2}$, 1 , 2

Miller indices are $\left(\frac{1}{\frac{1}{2}}\ \frac{1}{1}\ \frac{1}{2}\right)$ OR **(421)**

6. Identify the miller indices for the corresponding directions OA, OC, OD and OF from Figure given below. **2 Mark**



- (a) $[1\ 1\ 0]$, $[2\ 0\ 1]$, $[1\ 2\ 2]$, $[1\ 0\ 1]$
- (b) $[1\ 1\ 1]$, $[2\ 2\ 1]$, $[1\ 1\ 2]$, $[1\ 0\ 1]$
- (c) $[1\ 0\ 0]$, $[1\ 1\ 1]$, $[2\ 0\ 1]$, $[1\ 1\ 2]$
- (d) $[1\ 2\ 1]$, $[2\ 0\ 1]$, $[1\ 1\ 2]$, $[1\ 1\ 0]$

Ans.(c)

7. The angle between $[111]$ and $[11\bar{2}]$ directions in cubic unit cell is

- (a) 0° (b) 45° (c) 90° (d) 180°

2 Mark

Ans. (c)

8. An FCC structure has a lattice parameter of 0.396 nm. Determine the planar density for the (111) plane of FCC structure. **2 Mark**

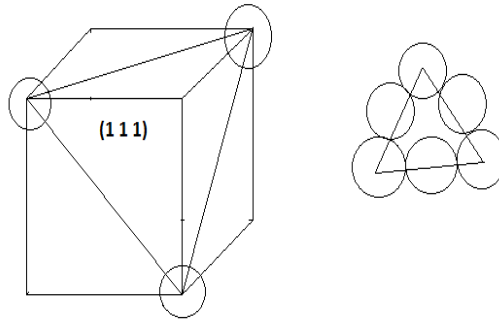
- (a) 0.1743×10^{15} points/cm²
- (b) 0.1473×10^{16} points/cm²
- (c) 0.1473×10^{12} points/cm²
- (d) 0.2473×10^{16} points/cm²

Ans :(b)

Detailed solution:

For plane (1 1 1)

$$\text{Planer density} = \frac{\text{Noof atom in plane}}{\text{area of that plane}} = \frac{2}{\left(\frac{\sqrt{3}}{2}\right) \times a^2}$$



9. Rhenium has an HCP crystal structure with atomic radius of 0.137 nm and c/a ratio as 1.615. Compute the volume of the unit cell for Rhenium. **2 Marks**

- (a) 0.0863 nm^3 (b) 0.043 nm^3 (c) 0.863 nm^3 (d) 0.317 nm^3

Ans: (a)

Detailed solution:

The volume of unit cell for HCP $V_C = c \times \text{base area}$

The base area for HCP structure is $6R^2\sqrt{3}$

Given that, $c = 1.615a$

And $a = 2R$

$\therefore c = 3.23R$

Again, given that $R = 0.137 \text{ nm}$

$\therefore V_C = 3.23 \times 0.137 \text{ nm} \times 6 \times (0.137 \text{ nm})^2 \times \sqrt{3} = \mathbf{0.0863 \text{ nm}^3}$

10. Find the Interplanar spacing for a (1 2 1) plane in a simple cubic lattice whose lattice constant is 0.412 nm. **2 Marks**

- (a) 0.01 nm (b) 0.11 nm (c) 0.14 nm (d) 0.16 nm

Ans: (d)

Detailed solution:

For a cubic lattice the interplanar distance is $d = \frac{a}{\sqrt{h^2+l^2+k^2}}$

where, d = Interplanar distance

a = lattice parameter

(hkl) is the Miller indices of the plane

$$\therefore d = \frac{0.412 \text{ nm}}{\sqrt{1^2 + 2^2 + 1^2}} = \mathbf{0.168 \text{ nm}}$$

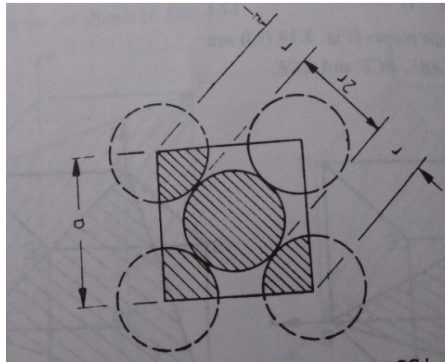
11. How many atoms per square millimeter are there on (010) plane of lead? Assume the interatomic distance to be $3.499 \times 10^{-10} \text{ m}$. **2 Marks**

- (a) $2.04 \times 10^{12} \text{ atoms/mm}^2$ (b) $8.16 \times 10^{12} \text{ atoms/mm}^2$ (c) $16.32 \times 10^{12} \text{ atoms/mm}^2$

Ans: (b)

Detailed Solution:

Lead has FCC structure



The given interatomic distance = $3.499 \times 10^{-10} \text{ m}$

$$\therefore 2r = 3.499 \times 10^{-10} \text{ m}$$

If 'a' is the side of the square

$$\therefore \sqrt{2a^2} = 4r$$

$$\therefore a = 4.95 \times 10^{-10} \text{ m}$$

Now, area of (010) plane = $a^2 = (4.95 \times 10^{-10})^2 \text{ m}^2$

For FCC, Number of atoms in (010) plane = 2

$$\therefore \text{number of atoms per millimeter square} = \frac{2}{(4.95 \times 10^{-10})^2 \text{ m}^2} = \mathbf{8.16 \times 10^{12} \text{ atoms/mm}^2}$$

12. Molybdenum has a density of $10.2 \times 10^3 \text{ kg/m}^3$ with atomic weight 95.94 g/mol. Calculate its atomic radius. **2 Marks**

- (a) 1.36 Å (b) 13.6 Å (c) 0.136 Å (d) 2.42 Å

Ans: (a)

Detailed solution

$$\text{density} = \frac{n \times A}{N_A \times a^3}$$

$$a^3 = \frac{n \times A}{N_A \times \text{density}}$$

where, a = sides of unit cell

$$N_A = \text{Avogadro's number} = 6.023 \times 10^{23}$$

$n = \text{number of atoms in unit cell}$

$A = \text{atomic weight}$

Molybdenum has BCC structure

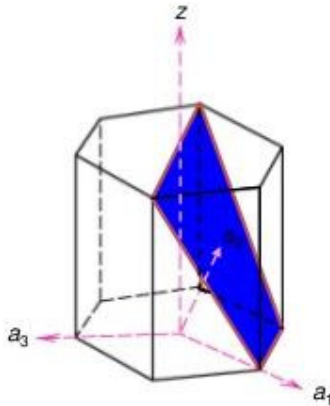
$$\therefore n = 2 \text{ and } a = \frac{4r}{\sqrt{3}}$$

$$\text{Thus, } \left(\frac{4r}{\sqrt{3}}\right)^3 = \frac{2 \times 95.94 \times 10^{-3} \text{ kg/mol}}{6.023 \times 10^{23} \times 10.2 \times 10^3 \text{ kg/m}^3}$$

$$\therefore r = 1.36 \text{ \AA}$$

13. What are the Miller indices of the plane in blue shade shown in figure below? 2

Marks



(a) $(1\ 0\ \bar{1}\ 1)$

(b) $(\bar{1}\ 0\ 1\ 1)$

(c) $(0\ \bar{1}\ 1\ 1)$

(d) $(0\ 1\ \bar{1}\ 1)$

Ans: (a)

Solution:

	a1	a2	a3	c
Intercepts	1	∞	-1	1
Reciprocals	1/1	1/ ∞	-1/1	1/1
Reduction	1	0	-1	1
Miller Indices	$(1\ 0\ \bar{1}\ 1)$			

What is the theoretical density (ρ_{TH}) and linear density (ρ_{LD}) along $[110]$ of Cr. Assume atomic weight of Cr to be 52 g/mol and atomic radius is 0.125 nm.

(a) $\rho_{TH} = 7.18 \frac{g}{cm^3}$; $\rho_{LD} = 11.28\ nm^{-1}$

(b) $\rho_{TH} = 3.59 \frac{g}{cm^3}$; $\rho_{LD} = 5.65\ nm^{-1}$

(c) $\rho_{TH} = 14.36 \frac{g}{cm^3}$; $\rho_{LD} = 8\ nm^{-1}$

(d) $\rho_{TH} = 8.17 \frac{g}{cm^3}$; $\rho_{LD} = 16\ nm^{-1}$

Ans: (a)

Detailed solution:

$$\text{Theoretical density } \rho_{TH} = \frac{\text{Mass of atoms in unit cell}}{\text{Total volume of unit cell}} = \frac{nA}{V_C N_A}$$

where. n = number of atoms/unit cell

A = atomic weight

V_C = Volume of unit cell = a^3 for cubic

N_A = Avogadro's number = 6.023×10^{23} atoms/mol

Cr is having BCC, thus n = 2

R = 0.125 nm

$$\therefore a = \frac{4R}{\sqrt{3}} = 0.2887 \text{ nm}$$

Given, A = 52 g/mol;

$$\therefore \rho_{TH} = \frac{2 \times 52 \text{ g/mol}}{(0.2887)^3 \text{ nm}^3 \times 6.023 \times 10^{23} \text{ atoms/mol}} = 7.18 \text{ g/cm}^3$$

$$\text{Linear density } \rho_{LD} = \frac{\text{Number of atoms}}{\text{Unit length of direction vector}}$$

$$\rho_{LD} = \frac{2}{\sqrt{2} \times 0.125 \text{ nm}} = 11.28 \text{ nm}^{-1}$$

15. Calculate the theoretical volume change in percentage accompanying a polymorphic transformation in a pure metal from the FCC to BCC crystal structure. Assume the hard-sphere atomic model and that there is no change in atomic volume before and after the transformation. **2 Marks**

(a) +8.8%

(b) -0.88%

(c) +4.42%

(d) -0.44%

Ans: (a)

Detailed solution:

$$\text{In FCC crystal structure unit cell } a = \frac{4R}{\sqrt{2}}$$

In BCC crystal structure unit cell $a = \frac{4R}{\sqrt{3}}$

The volume per atom of FCC crystal lattice

$$V_{FCC} = \frac{a^3}{4} = 5.66 R^3$$

The volume per atom of BCC crystal lattice

$$V_{BCC} = \frac{a^3}{2} = 6.16 R^3$$

The change in volume associated with the transformation from the FCC to BCC crystal structure, assuming no change in atomic radius, is

$$\frac{\Delta V}{V_{FCC}} = \left(\frac{V_{BCC} - V_{FCC}}{V_{FCC}} \right) \times 100\% = \left(\frac{6.16R^3 - 5.66R^3}{5.66 R^3} \right) \times 100\% = +\mathbf{8.8\%}$$