Engineering Materials (UES012)
School of Physics and Materials Science
Tutorial Sheet #6

1. In an FCC lattice, the largest interstitial voids occur at positions like (½, 0, 0), (0, ½, 0), (0, 0, ½) etc. γ-iron crystallizes in FCC structure. Find atomic radius of the largest interstitial void in γ-iron.

2. An optical microscope can resolve a step of aluminum width 300 nm. A slip band was observed in a simple cubic crystal (a = 3 Å). How many (minimum) dislocations must have slipped out of the crystal?

3. Does the burger vector change with the size of the burger circuit? Explain.

4. Distinguish between the direction of the dislocation line, the burgers vector and the direction of motion for both the edge and screw dislocations. Differentiating between positive and negative types.

5. An aluminum crystal has a dislocation density of $10^{10}\ m^{-2}$. The sheer modulus of aluminum is GNm^{-2}. Calculate the elastic energy of line imperfections stored in the crystal.

6. Average energy required to create Frenkel defect in an ionic crystal is 1.4 eV. Calculate the ratio of Frenkel defects at 20°C and 300°C in 1 gram of crystal.

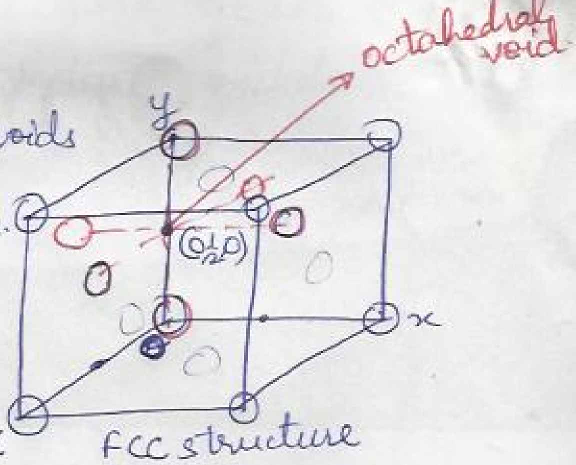
7. The small angle boundary in FCC copper is due to extra (100) planes of atoms as edge dislocations. If the angle of disorientation is 1°, what is the distance between two neighboring edge dislocations? Given lattice parameter for Cu = 3.62 Å.

8. Calculate the spacing between dislocation in a low angle tilt boundary in Iridium (FCC) when the angles of tilts are 1° and 3°. Lattice constant of Ir is 3.84 Å.

9. A positive edge dislocation 1mm long climbs down by 2μm in a Polonium crystal whose radius is 1.7 Å, Calculate the number of vacancies created or lost.

Tutorial Sheet No.-6.

Quest In an FCC lattice, two types of voids are
- tetrahedral voids
- octahedral voids.



FCC structure

$(\frac{1}{2},0,0)$, $(0,\frac{1}{2},0)$ & $(0,0,\frac{1}{2})$ positions correspords to an octahedral void, with coordination no. 6.

The radius of an atom that can fit an octahedral void has radius $=(0.414r)$

where, $r \rightarrow$ radius of parent atom.

Radius of Iron $R_{BCC} = 1.258 A^\circ$

$R_{FCC} = 1.292 A^\circ$.

$\therefore$ Atomic radius of largest interstitial void in γ-iron.(FCC)

$= 0.414 \times (1.292)\ A^\circ$

$= 0.534\ A^\circ$

Ques 2 According to the resolution power of the optical microscope, a step of Aluminium is 300nm wide, and a slip band is observed.

i.e. width of slip band $= 300\text{nm} = 3000\ A^\circ$

The lattice parameter for SC Aluminium, $a = 3A^\circ$.

For Simple cubic crystal, burger vector, $b = a = 3A^\circ$

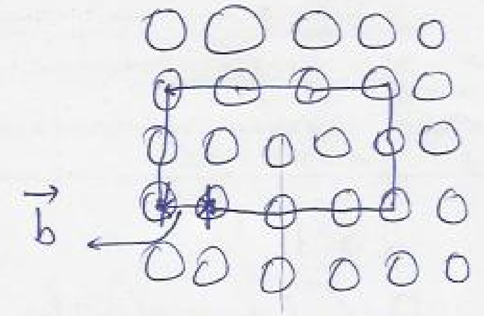
where $b \rightarrow$ size of one dislocation.

$\therefore$ No. of dislocations slipping out of the crystal

$= \dfrac{\text{width of slip band}}{\text{No. of dislocations}} - 1$

$= \dfrac{3000A^\circ}{3A^\circ} - 1 = 1000 - 1 = 999$ dislocations

Ques3 No, the Burger vector does not change with the size of the Burger circuit. Burger vector is about the magnitude and direction of lattice distortion resulting from a dislocation in a crystal lattice.



Ques5

dislocation density, $\rho = 10^{10}\,m^{-2}$

Sheer modulus, $\mu = 25.94\ GNm^{-2}$

$\rho = \frac{1}{l^2}$, $l \rightarrow$ length of dislocation line.

$$l = \frac{1}{\sqrt{\rho}} = \frac{1}{\sqrt{10^{10}}} = \frac{1}{10^5} = 10^{-5}\,m$$

Sheer stress, $\tau = \frac{\mu b}{l}$

For perfect crystal, $\tau = \frac{\mu}{6}$ $\left[\frac{b}{l} = \frac{1}{6}\right]$

$$b = \frac{l}{6} = 1.67 \times 10^{-6}\,m = 1.67\,\mu m.$$

$$E = \frac{\mu b^2}{2} = \frac{25.94 \times 10^9 \times (1.67 \times 10^{-6})^2}{2} = 36.17 \times 10^{-3}\ J.$$

Ques6 for ionic crystals, no. of point imperfections,

$$n = N \exp\left(-\frac{\Delta H_f}{2RT}\right)$$

where, $\Delta H_f \rightarrow$ enthalpy of formation of one mole each of cation + anion.

$R = 8.62 \times 10^{-5}\ eVK^{-1}$

$N \rightarrow$ Avogadro's number.

Given, $\Delta H_f = 1.4\,eV$.

$$\frac{n_1}{n_2} = \frac{\exp\left(-\frac{\Delta H_f}{2RT_1}\right)}{\exp\left(-\frac{\Delta H_f}{2RT_2}\right)} = \exp\left[-\frac{\Delta H_f}{2R}\left(\frac{1}{T_1} - \frac{1}{T_2}\right)\right]$$

$$\frac{n_1}{n_2} = \exp\left[\frac{-1.4}{2\times 8.62\times 10^{-5}}\left(\frac{1}{293} - \frac{1}{573}\right)\right]$$

$$= \cancel{\exp(8.57)} = 1.65\times 10^{-4}$$

Ques 7 $\frac{b}{h} = \tan\theta$

$\theta = 1^\circ \approx 0.017$ radians $\qquad \sqrt{2}a = b.$

$a = 3.62\,Å$ (FCC) Cu.

$b = \frac{a}{\sqrt{2}} = 2.559\,Å$

$\therefore\ h = \frac{b}{\tan\theta} = \frac{2.559}{0.017} = 150.5\,Å$

Ques 8 for FCC Iridium,

$a = 3.84\,Å \quad , \quad b = \frac{a}{\sqrt{2}} = 2.715\,Å$

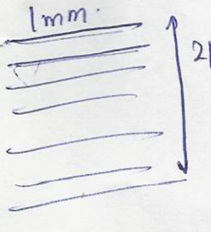
$\theta_1 = 1^\circ \approx 0.017\,\text{rad}, \quad \theta_2 = 3^\circ \approx 0.052\,\text{rad}.$

$h_1 = \frac{b}{\theta_1} = \frac{2.715}{0.017} = 159.70\,Å$

$h_2 = \frac{b}{\theta_2} = \frac{2.715}{0.052} = 52.21\,Å$

Spacing between dislocation, $h_1 - h_2 = 159.70 - 52.21 = 107.48\,Å$

Ques 9 A polonium crystal has a simple cubic structure.



radius, $r = 1.7\,Å$

$\Rightarrow$ lattice parameter, $a = 2r = 2\times 1.7 = 3.4\,Å$

Burger vector, $b = a = 3.4\,Å$

No. of vacancies along length '1mm' and height (2 μm)

$$= \frac{1\times 10^{-3}}{3.4\times 10^{-10}} \times \frac{2\times 10^{-6}}{3.4\times 10^{-10}}$$

$$= \underline{1.73\times 10^{10}}$$