Tutorial Sheet 8-9

1 → Pb- FCC structure

lattice parameter $a = 0.4949$ nm

There is one vacancy per 500 Pb atoms.

No. of atoms per unit cell = 4 (FCC structure)

Ideal density = $\dfrac{4 \times \text{Atomic wgt. of Pb}}{a^3 \times N_a}$

$\rho = \dfrac{n \times A}{a^3\, N}$

$= \dfrac{4 \times 207.2\ g}{(4.949 \times 10^{-8} cm)^3 \times 6.022 \times 10^{23}}$

$= 11.35\ g/cm^3$

a) density with defect :-

500 atoms → 1 vac

1 atom

1 atoms cells 4 atoms

No. of vacancy per unit cell = $\dfrac{4}{500}$

No. of atoms in unit cell = $4 - \dfrac{4}{500}$

Density = $\dfrac{\left(4 - \frac{4}{500}\right) \times 207.2}{(4.947 \times 10^{-8})^3 \times 6.022 \times 10^{23}}$

$= 11.32\ g/cm^3$.

gle

$\dfrac{11\,gm}{cell}$ 2

11gm $\dfrac{1}{cell}$ 2

b) No. of vacancies per gram,

cell volume = $(4.949 \times 10^{-8})^3$

density = $11.32\ g/cm^3$

2) 11.32 gm → 1 cm³ of Pb = $\dfrac{1}{(4.949 \times 10^{-8})^3}$ no. of cells

1 gm → $\dfrac{1}{(4.949 \times 10^{-8})^3 \times 11.32}$ No. of cell

No. of vacancy per cell = $\dfrac{4}{500}$

2) No. of vacancy in 1 gm of Pb = $\dfrac{4}{500} \times \dfrac{1}{(4.949 \times 10^{-8})^3 \times 11.3}$

$= 5.83 \times 10^{18}$

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No. of vacancies

$$n = N \exp\left(-\frac{Q_v}{k_B T}\right)$$

$$\boxed{\frac{n}{N} = \frac{\rho}{V}}$$

$$N = \frac{N_A \rho}{A}$$

~~bcc~~

$A_{\text{gold}} = 197$

$k_B = 8.62 \times 10^{-5} \frac{eV}{K}$

$T = 900°C = 900 + 273$

$N_A = 6.022 \times 10^{23}$

$Q_V = 0.98$ eV/atom

$= 0.98 \times 1.6 \times 10^{-19}$

$\rho = 19.32$ g/cm³

$$n = \frac{6.022 \times 10^{23} \times 19.32 \text{ g/cm}^3}{\cancel{19.32 \text{ g/cm}^3} \; 197} \exp\left(\frac{-0.98}{8.62 \times 10^{-5}} \times \frac{1}{1173}\right)$$

$$= \frac{6.022 \times 10^{23} \times 19.32}{197} \times \frac{1}{1.1087}$$

$= \cancel{5.4058 \times 10^{22} \text{ cm}^{-3}}$

$= 5.3268 \times 10^{22}$ cm³

3.

Aluminium given

$T = 500^\circ C$

$= 500 + 273$

$= 773\ K$

$N_v = 7.57 \times 10^{23}\ m^{-3}$

$W = 26.98\ g/mol$

$\rho = 2.62\ g/cm^3$

$N = \dfrac{N_A\ \rho}{A}$

$= \dfrac{6.022 \times 10^{23} \times 2.62}{26.98}$

$= 5.85 \times 10^{22}$ atoms/cm³

$= 5.85 \times 10^{28}$ atoms/m³

Now $N_v = N \exp\left(-\dfrac{Q_v}{KT}\right)$

$\dfrac{N_v}{\cancel{\rho}} = N \exp\left(-\dfrac{Q_v}{KT}\right)$

Taking Natural log on both sides

$\ln N_v = \ln N - \dfrac{Q_v}{KT}$

$Q_v = -KT \ln\left(\dfrac{N_v}{N}\right)$

$= -(8.62 \times 10^{-5}\ eV/atoms) \times 773 \ln\left(\dfrac{7.57 \times 10^{23}\ m^{-3}}{5.85 \times 10^{28}\ m^{-3}}\right)$

$\cancel{= -8.62 \times 10^{-5} \times 773 \times 2.303 \times \log(1.294 \times 10^{-5})}$

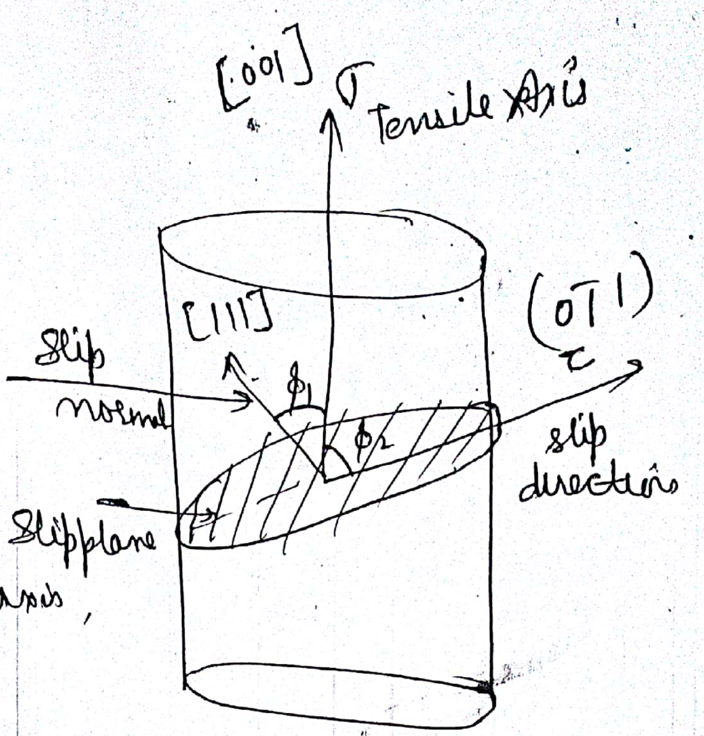
$= \cancel{-8.62 \times 10^{-5} \times 773 \times 2.303 \times} -4.888$

$= 0.75\ eV/atoms$

Q. $\tau = \sigma \cos\phi_1 \cos\phi_2$

$\tau \rightarrow$ shear stress

$\sigma \uparrow$ tensile stress



$\tau \rightarrow$ resolved on a slip plane whose normal makes an angle ϕ_1 with the stress axis, along a slip direction inclined at an angle ϕ_2 to the stress axis, is given by

$$\tau = \sigma_0 \cos\lambda \cos\phi$$

Y. $\cos\phi_1 = \dfrac{1.0 + 1.0 + 1.1}{\sqrt{1+1+1}\ \sqrt{0+0+1}} = \dfrac{1}{\sqrt{3}} \Rightarrow \underline{\phi_1 = 54.73°}$

$\cos\phi_2 = \dfrac{0.0 + 0.-1 + 1\times1}{\sqrt{0+0+1}\ \sqrt{1+1+1}} = \dfrac{1}{\sqrt{2}} \Rightarrow \underline{\phi_2 = 45°}$

$\sigma = 3000$ psi

$\tau = \cancel{3000 \times \cos\phi_1 \cos\phi_2}$

C.T.M. $\boxed{1000 \text{ psi} = 6.895 \text{ MPa}}$

Angle ϕ b/w two planes having miller indices $(h_1 k_1 l_1)$ $(h_2 k_2 l_2)$ is given by:-

$$\cos\phi = \frac{h_1 h_2 + k_1 k_2 + l_1 l_2}{\sqrt{h_1^2 + k_1^2 + l_1^2} \cdot \sqrt{h_2^2 + k_2^2 + l_2^2}}$$

5

Hall Petch Equation

$$\sigma_y = \sigma_0 + \frac{k}{\sqrt{d}}$$

For 20,000 psi $\Rightarrow$ $\sigma_y = 20 \times \underline{1000} \cancel{\times 10}$ psi

$= 20 \times 6.895$ MPa

$= 137.9$ MPa

$\Rightarrow 137.9 = \sigma_0 + \frac{k}{\sqrt{0.05}}$ — (1)

Illy for 40,000, we have $\sigma_y = 40 \times 6.895$

$= 275.8$ MPa

$275.8 = \sigma_0 + \frac{k}{\sqrt{0.007}}$ — (2)

Solving (1) and (2)

$k = 18.43$ MPa mm$^{1/2}$

$\sigma_0 = 55.5$ MPa

$\Rightarrow \sigma_y = 55.5 + \frac{18.43}{d^{1/2}}$

For 30,000 psi, $\Rightarrow$ $30 \times 6.895 = 206.9$ MPa

$206.9 = 55.5 + \frac{18.43}{d^{1/2}}$

$\Rightarrow d = 0.0148$ mm

$= 14.8$ μm.

6.

$\phi_1 = 43.18$

$\phi_2 = 47.98$

Critical stress = 20.7 MPa

Applied stress = 45 MPa

c) $\tau = 45 \cos(43.18) \cos(47.98)$

$= 22.0$ MPa

Since the resolved shear stress (22. MPa) is greater than the critical resolved shear stress (20.7 MPa), the single crystal will yield.

7. We have to find out the critical resolved stress for aluminium,

and given $\phi_1 = 28.1°$

and possible values of λ are

$\phi_2 = 62.4°, 72.0°, 81.1°$

(a) Slip will occur along that direction for which $\cos\phi \cos\lambda$ is maximum, in the case for the largest $\cos\lambda$.

So $\cos(62.4°) = 0.46$

$\cos(72.0°) = 0.31$

$\cos(81.1°) = 0.15$

Thus, the slip direction is at angle of $62.4°$ with the tensile axis

(b) critical Resolved shear stress is thus

$\tau_{crss} = \sigma_0 (\cos\phi_1 \cos\phi_2)_{max}$

$= (1.95) \cos 28.1^\circ \cos 62.4$

$= 0.80$ MPa | (114 psi)

8. True stress is defined as the stress ~~as the~~ in which the area is taken as the fracture Area A_f ~~fracture stre~~

$F = \sigma_f A_0$

$= 460 \times 10^6 \times \frac{\pi}{4}\left(\left(\frac{12.8}{\cancel{4}}\times 10^{-3}\right)\right)^2$ $\frac{\pi d^2}{4}$

original diameter

~~$= 2147290.656$ N~~

~~$= 59466.624$ N~~

259216.457 N

$\sigma_T = \frac{F}{A_f} = \frac{59216.457}{\frac{\pi}{4}(10.7\times 10^{-3})^2}$

$= 658$ MPa.

9.
$d_0 = 10\,mm$

$\Delta d = 2.5\,\mu m$

ν = Poisson ratio = 0.34

E = Young's Modulus = 97 G Pa

$$\nu = -\frac{\epsilon_x \text{ transverse}}{\epsilon_z \text{ axial strain}} = \frac{\Delta d / d_0}{\sigma / E} = \frac{\Delta d}{d_0} \times \frac{E}{\sigma}$$

$$\nu = \frac{\Delta d}{d_0} \times \frac{E}{\frac{F}{\pi\left(\frac{d}{2}\right)^2}} = \frac{\Delta d}{d_0} \times \frac{E}{4F} \times \pi d^2$$

$$F = \frac{\Delta d\, \pi\, d_0\, E}{4\nu}$$

$$= \frac{2.5 \times 10^{-6} \times 3.142 \times 10 \times 10^{-3} \times 97 \times 10^9}{4 \times 0.34}$$

$$\boxed{F = 560.246\ N}$$

10. σ_y = yield strength = 275 MPa

E = Young's modulus = 115 GPa

cross-sectional area = 325 mm^2

a.) $\sigma_y = \frac{F_{max}}{A} \Rightarrow F_{max} = \sigma_y \cdot A$

$= 275 \times 10^6 \times 325 \times 10^{-6}$

$= \cancel{76800}\ N.$
89375

b. $l_0 = 115\,mm$

$$\epsilon = \frac{\sigma}{E} = \frac{\sigma_y}{dl / d_0} = \sigma_y \frac{d_0}{dl}$$

$$dl = \frac{\sigma_y l_0}{E}$$

maximum length $= l_0 + dl$

$$= l_0 + \frac{\sigma_y l_0}{E}$$

$$= 115.275\,mm$$

11. Young's modulus $= 110\,GPa$

$\sigma = 240\,MPa$

$F = 6660\,N$.

$l_0 = 380\,mm$

$\Delta l = 0.50\,mm$

$$\sigma = \frac{F}{A_0} = \frac{F}{\pi\left(\frac{d_0^2}{4}\right)} = E\frac{\Delta l}{l_0}$$

$E \rightarrow$ young's modulus

$$d_0 = \sqrt{\frac{4 l_0 F}{\pi E \Delta l}}$$

$$= \sqrt{\frac{4 \times 380 \times 10^{-3} \times 6660}{\pi \times 110 \times 10^{9} \times 0.50 \times 10^{-3}}}$$

$$= 7.65 \times 10^{-3}$$

$$= 7.65\,mm$$

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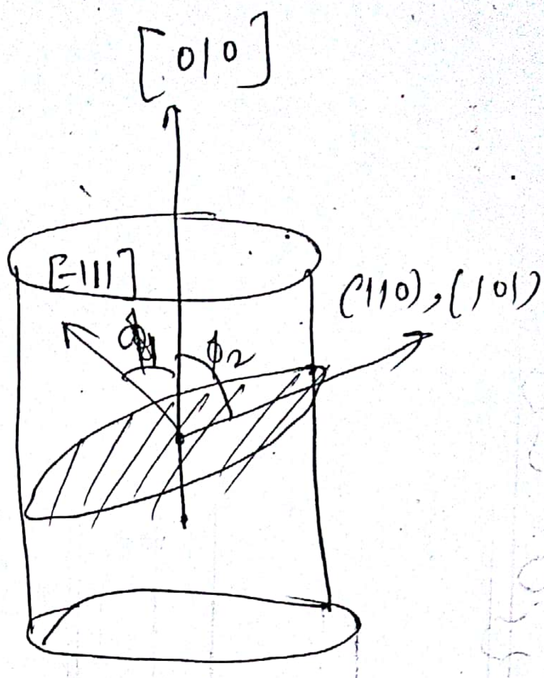
$$\cos\phi_1 = \frac{0\cdot -1 + 1\cdot 1 + 0\cdot 1}{\sqrt{0+1+0}\ \sqrt{1+1+1}}$$

$$= \frac{1}{\sqrt{3}}$$

$$\phi_1 = 54.7^\circ$$



a

ϵ_{axial} = (+ve axial tension
−ve compression)

ϵ_{trans} = transverse strain
(−ve for axial tension (stretching))
= +ve for axial compression

Poisson's ratio $\nu = -\frac{\epsilon_t}{\epsilon_l}$ → elongation is transverse and in longitudinal directions

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