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ECE3040 : Homework # 1

1/23/2026

1) Diamond Lattice

↳ a) Ge lattice const (room temp) : $a = 5.65\,\mathring{A}$ → Ge atoms / cm^3 = ?

$\mathring{A} = 10^{-10}\,m \rightarrow 0.1\,nm$

$$\frac{8\text{ atom}}{\text{unit cell}} \times \frac{\text{unit cell}}{(\text{lattice const})^3} \times \frac{(1\,\mathring{A})^3}{(1\times10^{-8}\,cm)^3} = \boxed{4.6544\text{ atoms}/cm^3}$$

↳ diamond cubic struct.

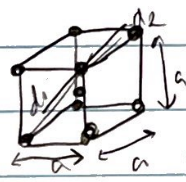
b) Si lattice const (room temp) : $a = 5.43\,\mathring{A}$, $m = 28.09\,g/mol$

$$\frac{8\text{ atoms}}{1\text{ unit cell}} \times \frac{1\text{ unit cell}}{(\text{lattice const})^3} \times \frac{(1\mathring{A})^3}{(1\times10^{-8}cm)^3} \times \frac{1\text{ mol}}{6.02\times10^{23}\text{ atoms}}$$

$$= 0.083\,\text{mol}/cm^3 \times \frac{28.09\,g}{1\text{ mol Si}} \approx \boxed{2.332\,g/cm^3}$$

2) Cubic Crystal Structure : in terms of lattice constant a, dist. between nearby neighbor atoms

a) BCC lattice → 8 nearest neighbors per atom

↳ 

diagonal$_1$ $= (a)^2 + (a)^2 = \sqrt{2}\,a$

diagonal$_2$ $= (\sqrt{2}a)^2 + (a)^2 = a\sqrt{3}$

(body diag)

∴ body centre → nearest neighbor : $\dfrac{\text{body diagonal}}{2}$

$$\boxed{\frac{a\sqrt{3}}{2}}$$

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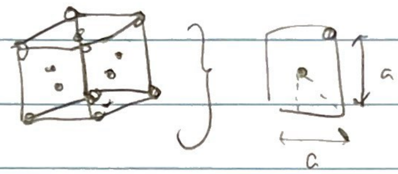
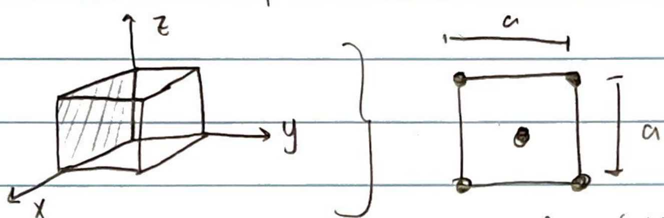
b) FCC lattice → 12 nearest neighbors

↳ 

$\therefore \left(\frac{a}{2}\right)^2 + \left(\frac{a}{2}\right)^2 = \frac{2a^2}{4} = \frac{\sqrt{2}\,a}{2} = \boxed{\frac{a}{\sqrt{2}}}$

3) Pierret – 1.5 (a) → (d) : Surface of Si wafer is a (100) plane

a) Sketch the placement of Si atoms on wafer surface



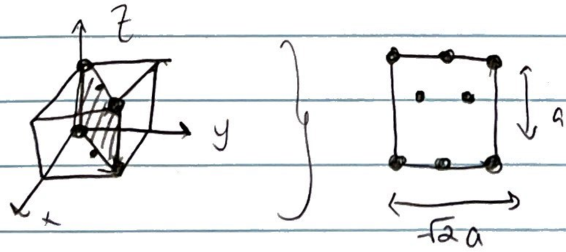
view from (100) plane

b) # of atoms / cm² at surface

↳ $a = 5.43\,\text{Å}$ $\left\{ \frac{2 \text{ atoms}}{1 \text{ unitcell}} \cdot \frac{1 \text{ unit cell}}{(5.43\,\text{Å})^2} \cdot \frac{(1\,\text{Å})^2}{(10^{-8}\,\text{cm})^2} = \boxed{6.78 \times 10^{14} \frac{\text{atoms}}{\text{cm}^2}} \right.$

$4 \times \frac{1}{4}$ atoms + 1 body atom = 2 atoms

c) Surface is a (110) plane



d) $a = 5.43\,\text{Å}$ $\left\{ \frac{4 \text{ atoms}}{1 \text{ unitcell}} \cdot \frac{1 \text{ unit cell}}{(\sqrt{2}a \cdot a)} \cdot \frac{(1\,\text{Å})^2}{(10^{-8}\,\text{cm})^2} = \boxed{9.59 \times 10^{14} \frac{\text{atoms}}{\text{cm}^2}} \right.$

↳ $4 \times (\frac{1}{4})$ atoms + $2 \times \frac{1}{2}$ atoms + 2 body atoms = 4 atoms

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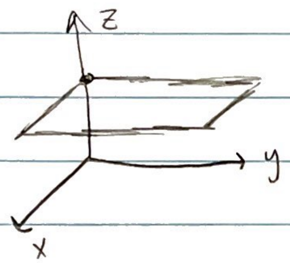
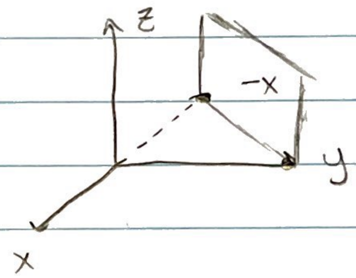
4) Assuming Cubic Crystal System → Sketch following planes

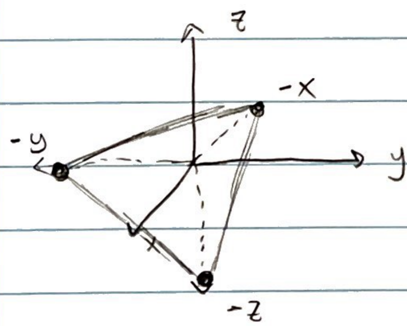
a) (001)



d) $(\bar{1}10)$

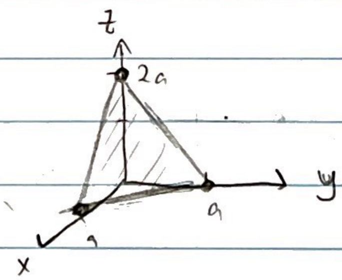


f) $(\bar{1},\bar{1},\bar{1})$



g) $(221) \rightarrow \left(\frac{1}{2}, \frac{1}{2}, 1\right) \rightarrow (1, 1, 2)$

Miller indices



5) Spheres w/ radii = 1/2 (dist (nearest neighbors))

↳ $V = 4/3 \pi r^3$

a) Simple cubic lattice : $\pi/6$ or 52%.

↳ volume $= a^3$ of cube

1 atom/unit cell → where $r = a/2$ ∴ $V_{atoms} = 4/3 \, \pi (a/2)^3$

$= \pi \, a^3/6$

ratio : $\frac{\text{atom Vol.}}{\text{total vol.}} = \frac{\pi a^3/6}{a^3} = \boxed{\frac{\pi}{6}}$

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b) BCC lattice : $\sqrt{3}\pi/8$ or 68%.

↳ total volume : a^3

diagonal : $(\sqrt{2}a)^2 + (a)^2 = \sqrt{3a^2}$ ∴ dist to necr : $\frac{\sqrt{3}a}{2}$

$V_{atoms} = \frac{4}{3}\pi\left(\frac{\sqrt{3}a}{4}\right)^3 = \frac{4}{3}\pi\left(\frac{3\sqrt{3}a^3}{64}\right) = \frac{\pi}{16} \cdot \sqrt{3}a^3$

×2 b/c 2 atoms ∴ $V_{atoms} = 2 \times \left(\frac{\pi}{16} \cdot \sqrt{3}a^3\right) = \frac{\sqrt{3}\pi a^3}{8}$

ratio : $\frac{\left(\frac{\sqrt{3}\pi a^3}{8}\right)}{a^3} = \boxed{\frac{\sqrt{3}\pi}{8}}$

c) FCC lattice : $\sqrt{2}\pi/6$ or 74%.

↳ total Vol : a^3

dist to necrest : $\left(\frac{a}{2}\right)^2 + \left(\frac{a}{2}\right)^2 = \sqrt{\frac{2a^2}{4}} = \frac{\sqrt{2}}{2}a$

↳ $r = \frac{\sqrt{2}a}{4}$

$V_{atoms} = 4 \text{ atoms} \times \left[\frac{4}{3}\pi\left(\frac{\sqrt{2}a}{4}\right)^3\right] = 4\left[\frac{4\pi}{3}\left(\frac{2\sqrt{2}a^3}{64}\right)\right]$

$= \frac{\sqrt{2}\pi a^3}{6}$ } ratio : $\frac{\left(\frac{\sqrt{2}\pi}{6}a^3\right)}{a^3} = \boxed{\frac{\sqrt{2}\pi}{6}}$

d) Diamond Structure : $\frac{\sqrt{3}\pi}{16}$ or

↳ total Vol : a^3

diagonal : based on figure 1.4c & part b

$\sqrt{3} \cdot (a/2)$ & dist between necrest : $\sqrt{3}a/4$

↳ $r = \sqrt{3}a/8$ } $V_{atoms} = 8 \text{ atom} \times \left[\frac{4}{3}\pi\left(\frac{\sqrt{3}a}{8}\right)^3\right]$

$\boxed{\therefore \text{ratio} = \sqrt{3}\pi/16}$ $= \frac{\sqrt{3}}{16}\pi a^3$