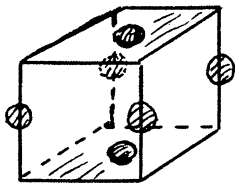
Contents

PROBLEM SOLUTIONS
CHAPTER 1

(1.1)

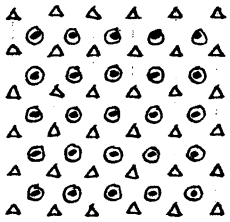
(a)



... $\frac{1}{2}$ atom inside cell on top and bottom faces
... $\frac{1}{4}$ atom along each vertical edge

TOTAL ATOMS = $2 \times \frac{1}{2} + 4 \times \frac{1}{4} = \underline{\underline{2}}$

(b)



⇐ TOP VIEW
• ... plane #1
△ ... plane #2
○ ... plane #3

(c) bcc

(1.2)

(a) The diamond lattice is composed of two interpenetrating fcc lattices. Each fcc lattice unit cell contains 4 atoms. ($\frac{1}{2}$ atom at each of 6 faces and $\frac{1}{8}$ atom at each of 8 corners.) Thus the Si lattice contains [8 ATOMS] per unit cell. Inspecting Fig. 1.5a leads to the same conclusion -- there are 4 atoms totally inside the cube and an fcc arrangement on the faces of the cube.

(b)

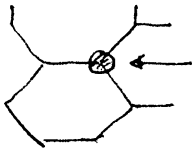
$$\frac{\text{Si ATOMS}}{\text{CM}^3} = \frac{\text{ATOMS/UNIT CELL}}{a^3} = \frac{8}{(5.431 \times 10^{-8})^3} = 4.994 \times 10^{22}$$

a from Table 1.5

(c) Looking at Fig. 1.5a we note that the upper front corner atom and the atom along the body diagonal through the upper front corner are nearest neighbors. These are separated by 1/4 × length of a body diagonal. Thus

$$d = \frac{1}{4}\sqrt{3}a = \frac{\sqrt{3}}{4}(5.431\times10^{-8}) = 2.352\times10^{-8}\ cm$$

(1.3) Looking at Fig. 1.6a we conclude (counting Cd ↔ N atoms in the figure)



each bottom/top face atom shared with 6 cells
... $\frac{1}{6}\times 6 = 1$ atom total inside cell on top and bottom faces AT corners
... $\frac{1}{2}$ atom also at center of top + bottom faces
... Total of 3 atoms on top + bottom faces
ALSO, there are 3 atoms inside cell near middle
6 atoms of N per unit cell

As stated in the text, the hexagonal unit cell volume is $\frac{3\sqrt{3}}{2}a^2c$
Thus

$$\frac{N\ atoms}{cm^3} = \frac{6}{\frac{3\sqrt{3}}{2}a^2c} = \frac{4}{\sqrt{3}a^2c} = \frac{4}{\sqrt{3}(3.1115\times10^{-8})^2(4.9798\times10^{-8})}$$

$$= 4.790\times10^{22}$$

(1.4)

(a) (i) 6, 3, 2 ... normalized intercepts
1/6, 1/3, 1/2 ... 1/[INTERCEPTS]
1, 2, 3 .... MULTIPLY X 6 to get whole numbers
(1 2 3) .... MILLER INDICES OF PLANE

(ii) [1 2 3] ... direction normal to plane has same indices as plane in cubic crystals

(b) 2, ∞, 3 ... normalized intercepts
1/2, 0, 1/3 ... 1/INTERCEPTS
3, 0, 2 ... multiply X 6
(3 0 2) ... MILLER INDICES

(c) 1, 1, -1/2, 1 ... intercepts
1, 1, -2, 1 .... 1/intercepts ... already whole numbers
(1 1 $\bar{2}$ 1) ... MILLER INDICES

NOTE: h+k+i = 0, thus the i index associated with the a_3 axis must be $\bar{2}$. There is really no need to work out the intermediate steps for this index.

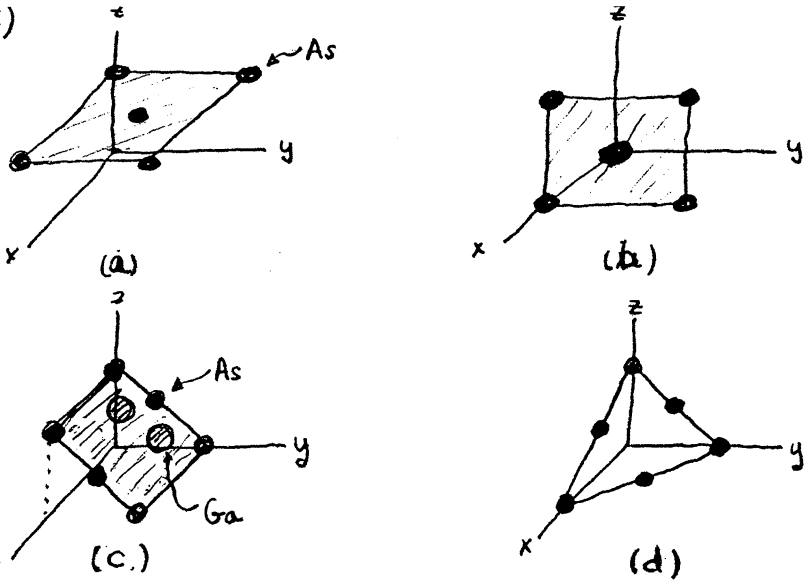
(1.5) (a) Intercepts ... 1, 1, ∞
1/Intercepts ... 1, 1, 0
Whole # set ... 1, 1, 0
Miller indices ... (1 1 0)

(b) Intercepts ... 1, 1, 1
1/Intercepts ... 1, 1, 1
Whole # set ... 1, 1, 1
Miller indices ... (1 1 1)

(c) Projections ... 0, 1/2, 1/2
Whole # set ... 0, 1, 1
Direction ... [0 1 1]

(d) Point E lies along the cube diagonal.
DIRECTION ... [1 1 1]

(1.6)



(1.7)

(a) To lie in the (100) surface plane a direction must be perpendicular to the [100] direction. Using Eq.(1.3) we must have

$$\cos\theta = \frac{h_2}{(h_2^2+k_2^2+l_2^2)^{1/2}} = 0 \qquad \ldots h_1=1, k_1=0, l_1=0$$

or $h_2 = 0$

Thus all directions $[0kl]$ lie in the (100) surface plane.

$[011]$, $[0\bar{1}1]$, $[01\bar{1}]$, $[0\bar{1}\bar{1}]$ ... <110> directions lying in the (100) surface plane

(b) For a direction to be perpendicular to the [111] direction we must have (using Eq.(1.3))

$$\cos\theta = \frac{h_2+k_2+l_2}{\sqrt{3}(h_2^2+k_2^2+l_2^2)^{1/2}} = 0 \qquad \ldots h_1=1, k_1=1, l_1=1$$

[Any direction $[hkl]$ where $h+k+l=0$] will be perpendicular to the [111] direction. Possible answers are

$[11\bar{2}]$, $[3\bar{1}\bar{2}]$ etc.

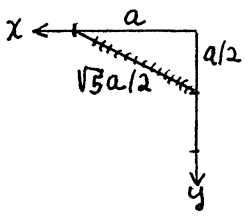
(1.8)

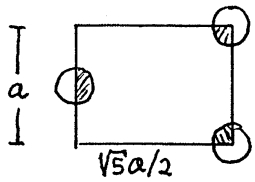
(a) Cubic

(b) Examining Fig. 1.6, we conclude that there are 4 atoms within the unit cell. (There are 1/4 of 12 atoms along the cube edges and 1 interior atom. Alternatively, one might note that the Pb and S atoms lie on interpenetrating fcc lattices. The fcc lattice has 4 atoms per unit cell.)

$$\text{Pb atoms/cm}^3 = \frac{4}{a^3} = \frac{4}{(5.9362\times10^{-8})^3} = 1.9122\times10^{22}/\text{cm}^3$$

(c) A (120) plane has intercepts of 1, $\frac{1}{2}$, and ∞ on the x, y and z axes, respectively.





⇐ atom arrangement on plane. Reduced from Fig. 1.6

$$\underset{\text{on (120) plane}}{\text{Pb atoms/cm}^2} = \frac{1\text{ atom}}{a\cdot\sqrt{5}a/2} = \frac{2}{\sqrt{5}(5.9362\times10^{-8})^2} = 2.5382\times10^{14}/\text{cm}^2$$

(1.9)

(a) If the cleavage plane is a (111), (1$\bar{1}$1), (11$\bar{1}$) or (1$\bar{1}\bar{1}$) plane

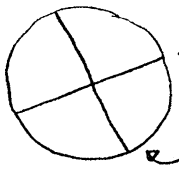
$$\cos\theta = \frac{1}{\sqrt{3}} \Rightarrow \left[\theta = 54.74^\circ\right]$$

If the cleavage plane is a ($\bar{1}$11), ($\bar{1}\bar{1}$1), ($\bar{1}$1$\bar{1}$) or ($\bar{1}\bar{1}\bar{1}$) plane

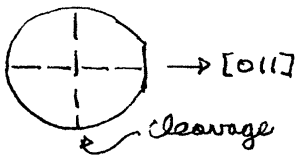
$$\cos\theta = -\frac{1}{\sqrt{3}} \Rightarrow \left[\theta = 125.26^\circ\right]$$

Actually, as inferred from Fig. P1.9, both of the above angles will be observed after a single break --- one piece has a normal pointing upward, one has a normal pointing downward.

(b) Four pieces (ideally).



(c) As discussed in the text, for a (100) plane, the primary flat along the edge of the wafer is a (011) plane. The intercept of a $\{111\}$ plane and the (100) plane is always a $\langle 110 \rangle$ direction. Thus



(1.10) To determine the positioning of the ingot for sawing, we must determine the angles between the [001] ↔ [112] and [110] ↔ [112] directions.

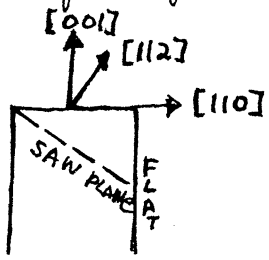
For [001] ↔ [112]

$$\cos\theta = \frac{2}{\sqrt{6}} \quad \Rightarrow \quad \theta = 35.26^\circ$$

For [110] ↔ [112]

$$\cos\theta = \frac{2}{\sqrt{12}} \quad \Rightarrow \quad \theta = 54.74^\circ$$

If  are conceptually drawn about the ingot and flat normals we see that the normal to the saw plane lies in the plane of the aforementioned normals



PROBLEM SOLUTIONS
CHAPTER 2

(2.1) We concluded from the Bohr atom analysis that

$$E_N = \frac{m_0 q^4}{2(4\pi\epsilon_0 N\hbar)^2} = -\frac{13.6}{N^2}\ eV \qquad [Eq.(2.7)]$$

Thus for an exciton in the $n=1$ state

$$E_{ex} = \frac{(m_0/2)q^4}{2(4\pi K_s \epsilon_0 \hbar)^2} = -\frac{1}{2K_s^2}(13.6)\ eV$$

$$= -0.0488\ eV$$

(2.2) We know

$$E = \tfrac{1}{2} m_0 v^2$$

$$p = m_0 v$$

$$\lambda = h/p = 2d\sin\theta \quad \text{or} \quad p = \frac{h}{2d\sin\theta}$$

Thus

$$E = \tfrac{1}{2} m_0 v^2 = \frac{p^2}{2m_0} = \frac{h^2}{2m_0(2d\sin\theta)^2}$$

$$= \left(\frac{6.63\times10^{-34}}{10^{-9}\sin 1^\circ}\right)^2 \frac{1}{2(9.11\times10^{-31})} \cdot \frac{1}{1.6\times10^{-19}}$$

(converts to eV)

$$E = 4.95\ KeV$$