59

Department of Materials Science and Engineering
Henri Samueli School of Engineering and Applied Science
University of California, Los Angeles

MSE 104, QUIZ No. 1 ver 1 (1hr)
Winter 2017
Show all work and include units for full credit

NAME: Owen Hemmerger

UCLA

Problem 1 (15 pts) Short answer

1 (15 pts)	10
2 (30 pts)	19
3 (25 pts)	14
4 (30 pts)	30
Total points	73

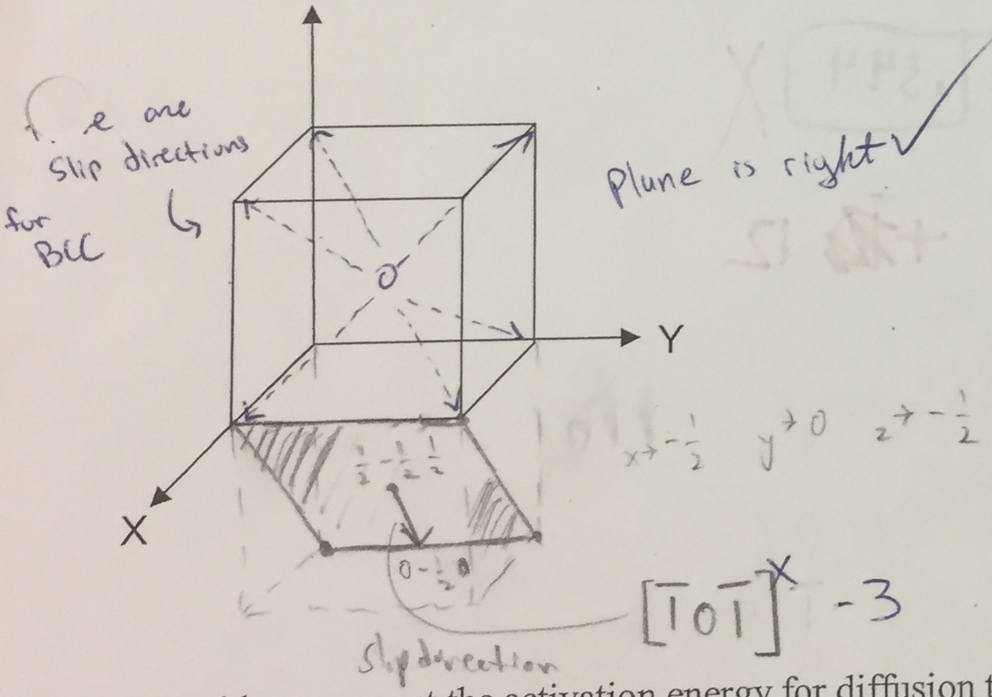
a. State for each type of bonding whether it is directional or non-directional. (6 pts)

i. Covalent Directional ✓

ii. Ionic Directional ✗ -2

iii. Metallic Nondirectional ✓

b. Draw the $(10\bar{1})$ plane, and within that plane, draw one slip direction that would be possible for a BCC metal and state the indices for the direction you have drawn.



c. Would you expect the activation energy for diffusion to be higher in self-diffusion via vacancies or impurity atom diffusion via interstitials (no explanation necessary)? (3 pts)

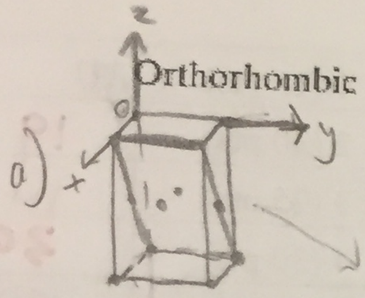
self-diffusion via vacancies ✓

Problem 2 (30 pts) Crystal structure

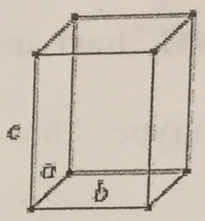
The orthorhombic crystal structure is shown below, and a = 0.35 nm, b = 0.38 nm, and c = 0.30 nm. Assume that a is in the x-direction, b is in the y-direction, and c is in the z-direction. Solve the following problems:

(a) For a face-centered orthorhombic unit cell, draw the $(1\bar{1}0)$ plane and derive the planar density in number/nm^2 (number of atoms on plane based on their area divided by total planar area) for that plane.

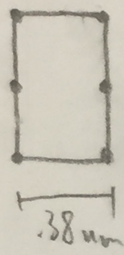
(b) What is the atomic packing factor for the face-centered orthorhombic unit cell if the atomic radius is 0.120 nm?



$a \neq b \neq c$ $\alpha = \beta = \gamma = 90°$



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



$\sqrt{.35^2 + .30^2}$ nm = .461 nm

.38 nm

X +2

$PD = \frac{\#\ atoms}{unit\ area} = \frac{\frac{1}{4}\cdot 4 + \frac{1}{2}\cdot 2}{.38\ nm \cdot .461\ nm} = 11.4\ \frac{number}{nm^2}$

X +5

b) # atoms per cell = $\frac{1}{8}\cdot 8 + \frac{1}{2}\cdot 4 = 3$ ~~3~~ 4

$APF = \frac{V_{atoms}}{V_c} = \frac{3 \cdot \frac{4}{3}\pi \cdot (.120\ nm)^3}{.35\ nm \cdot .38\ nm \cdot .30\ nm} = .544$ X

+~~10~~ 12

Problem 3 (25 pts) Crystal structure and Defects

A hypothetical pure FCC metal has an atomic radius of 0.140 nm. Assume the energy for vacancy formation is 0.85 eV/atom. (Hint: In the vacancy number density equation, N_o is the number density of atoms in a perfect crystal and it can be calculated based on crystal structure). What is the number density of vacancies (in units of m^{-3}) at 1200K?

atoms/cell in FCC: $\frac{1}{8} \cdot 8 + \frac{1}{2} \cdot 6 = 4$

$N_v = N_o e^{\frac{-Q_v}{kT}}$

$N_v = 8.88 \times 10^{28}\ m^{-3} \cdot e^{\frac{-.85\ eV/atom}{8.62 \times 10^{-5}\ eV/atom \cdot K \cdot 1200K}}$

$= 2.40 \times 10^{25}\ m^{-3}$

$V_{cell} = a^3$

$= (.323 \times 10^{-9}\ m)^3$

$= 3.38 \times 10^{-29}\ m^3$

$a = \frac{4R}{\sqrt{3}} = .323\ nm$

$N_o = \frac{3\ atoms}{3.38 \times 10^{-29}\ m^3} = 8.88 \times 10^{28}\ m^{-3}$

Problem 4 (30 pts) 30

In the preparation of a semiconducting device, gallium (Ga) atoms are to be diffused into pure silicon (Si) at 1200°C for 2 hours. If the required concentration of Ga at a position 1.5 μm below the surface is 5×10^{23} atoms/m^3, compute the required surface concentration assuming that the surface concentration remains constant and the diffusion pre-exponential and activation energy values are 3.74×10^{-5} m^2/s and 327.2 KJ/mol, respectively.

$T = 1200°C = 1473\ K$, $t = 2h = 7200\ s$, $x = 1.5 \times 10^{-6}\ m$, $C_x = 5 \times 10^{23}\ atoms/m^3$

$C_0 = 0$ (pure silicon)

$$D = 3.74 \times 10^{-5}\ m^2/s \cdot e^{-\frac{327.2\ kJ/mol}{8.314 \times 10^{-3}\ kJ/mol \cdot K \cdot 1473\ K}}$$

$$= 9.32 \times 10^{-17}\ m^2/s$$

$$\frac{x}{2\sqrt{Dt}} = \frac{1.5 \times 10^{-6}\ m}{2\sqrt{9.32 \times 10^{-17}\ m^2/s \cdot 7200\ s}} = .915$$

$$\frac{C_x - C_0}{C_s - C_0} = 1 - erf\left(\frac{x}{2\sqrt{Dt}}\right)$$

$$erf(.915) = .7970 + (.8209 - .7970)\left(\frac{.015}{.05}\right)$$

$$= .804$$

$$C_s = C_0 + \frac{C_x - C_0}{1 - erf\left(\frac{x}{2\sqrt{Dt}}\right)}$$

$$C_s = \frac{C_x}{1 - erf\left(\frac{x}{2\sqrt{Dt}}\right)}$$

$$C_s = \frac{5 \times 10^{23}\ atoms/m^3}{1 - .804}$$

$$C_s = 2.56 \times 10^{24}\ atoms/m^3$$