ME254: Materials Engineering

1st Midterm Exam

1st semester 1435-1436

October 29, 2014

Problem 1: *(21 points)*

Assume that you find the following three materials in the laboratory: 1. Copper (metal), 2. Magnesium oxide, MgO (ceramic), and 3. Polyethylene $(C_2H_4)_n$ (polymer).

a. What is the expected main type of primary atomic bonding in each of these materials? *(9 points)*

b. Briefly explain how each of these bonding form? *(12 points)*

Problem 2: *(24 points)*

Sketch the following planes and directions within cubic (part a) and HCP (part b) unit cells:

a. $[1\bar{2}0], [\bar{1}01], (\bar{2}01), and\ (31\bar{2}).$ *(12 points)*

b. $[1\bar{2}10], [11\bar{2}0], (0001), and\ (0\bar{1}10).$ *(12 points)*

Problem 3: *(26 points)*

a. Vacancy is one of the point defects in crystalline solids. Explain the effect of temperature on the number of equilibrium vacancy? *(7 points)*

b. Briefly explain the difference between substitutional and interstitial solution solutions? *(7 points)*

c. Determine the concentrations, in both weight percent and atom percent, of zinc and lead elements in an alloy that contains 25.3 kg copper, 37.8 kg zinc, and 10.5 kg lead. The atomic weights are as follow: 63.546 g/mol for copper, 65.38 g/mole for zinc, and 207.2 g/mol for lead. Avogadro number =6.023 X 10^{23} *(12 points)*

<u>Problem 4 :</u> *(29 points)*

For a <u>cubic</u> crystalline material, if the ratio of the (110) planar density to the (100) planar density is $\sqrt{2}\left(i.e.\ \frac{\mathrm{PD}_{(110)}}{\mathrm{PD}_{(100)}} = \sqrt{2}\right)$, answer the following:

c. Determine the crystal structure for this material? *(19 points)*

d. Calculate the linear density along [111] given that the radius of the atom is 0.127 nm? *(10 points)*

<u>Problem 5: Choose the correct answer:</u> *(5 points)*

<u>1. The chemical bond of rubber material is:</u>

a) Ionic b) Covalent c) Secondary bond

<u>2. Atomic mass is the sum of masses of:</u>

a) Proton+ neutron b) Neutron +electron c) Electron + protons

<u>3. The manner in which atoms are specially arranged is:</u>

a) Atomic structures b) Crystal structure c)amorphous structure

<u>4. There are -------- types of crystal systems.</u>

a) Four b) Five c) Seven

<u>5. Atomic Packing Factor (APF) must be:</u>

a) Equal to one b) less than one c) more than one

Solutions

Problem 1: *(21 points)*

Assume that you find the following three materials in the laboratory: 1. Copper (metal), 2. Magnesium oxide, MgO (ceramic), and 3. Polyethylene $(C_2H_4)_n$ (polymer).

a. What is the expected main type of primary atomic bonding in each of these materials? *(6 points)*
b. Briefly explain how each of these bonding form? *(9 points)*

Solutions:

a. The main types of primary bonding are:
    - Copper (metal): Metalling bonding. *(3 points)*
    - MgO (ceramic): Mainly ionic bonding. *(3 points)*
    - Polyethylene (polymer): Mainly covalent bonding. *(3 points)*

b. The above types of bonding are formed as follow:
    - The bonding arises as a result of the attraction between a sea of valence electrons (negative charge) and ions cores (positive charge). *(4 points)*
    - The ionic bonding forms as a result of a columbic attraction between two oppositely charged ions; it requires electron transfer where usually a metallic element donates its valence electron to a nonmetallic element. *(4 points)*
    - The covalent bonding occurs when pairs of electrons are shared between two atoms. *(4 points)*

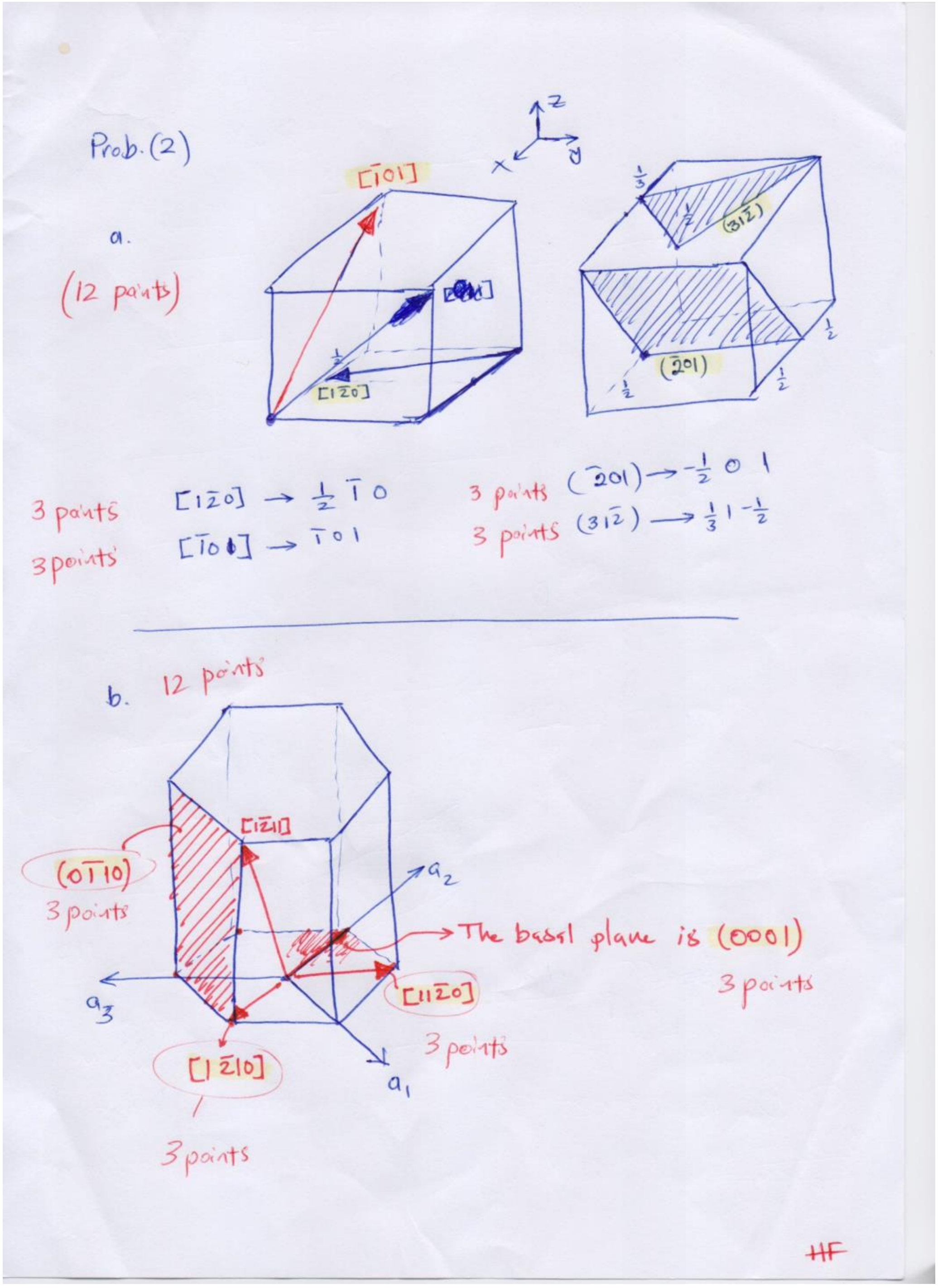
Problem 2: *(24 points)*

Sketch the following planes and directions within cubic (part a) and HCP (part b) unit cells:

a. $[1\bar{2}0], [\bar{1}01], (\bar{2}01), and\ (31\bar{2})$. *(12 points)*

b. $[1\bar{2}10], [11\bar{2}0], (0001), and\ (0\bar{1}10)$. *(12 points)*

Solutions:



Problem 3: *(26 points)*

a. Vacancy is one of the point defects in crystalline solids. Explain the effect of temperature on the number of equilibrium vacancy? *(7 points)*

b. Briefly explain the difference between substitutional and interstitial solution solutions? *(7 points)*

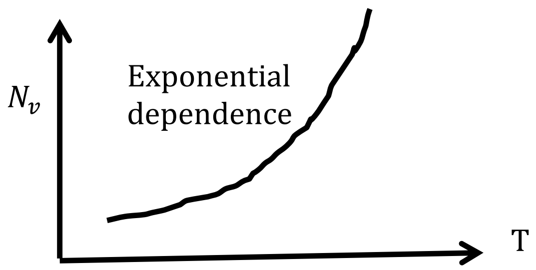
c. Determine the concentrations, in both weight percent and atom percent, of zinc and lead elements in an alloy that contains 25.3 kg copper, 37.8 kg zinc, and 10.5 kg lead. The atomic weights are as follow: 63.546 g/mol for copper, 65.38 g/mole for zinc, and 207.2 g/mol for lead. Avogadro number =6.023 X 10^{23} *(12 points)*

Solutions:

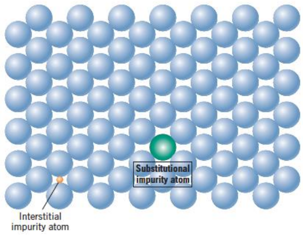
a. As the temperature increases, the number of equilibrium vacancy increases exponentially according to the following thermodynamic relation:

$$N_v = N\, e^{-Q/KT}$$

where N_v is the number of equilibrium vacancy and T is the temperature. The following graph shows the relation between N_v vs T is:



b. In substitutional solid solutions, the impurity atoms replace the host atoms. However, in interstitial solution solutions, the impurity atoms occupy interstitial positions between the solvent atoms.



c.

Cont'd

Prob. 3 (C)

* The concentrations in weight percent:

$$C_{Zinc} = \frac{m_{Zinc}}{\text{Total mass}} \times 100 = \frac{37.8}{73.6} \times 100 = 51.36 \text{ wt\%} \quad \text{(Ans.)}$$

$$\text{Total mass} = 25.3 + 37.8 + 10.5 = 73.6 \text{ Kg}$$

$$C_{lead} = \frac{m_{lead}}{\text{Total mass}} \times 100 = \frac{10.5}{73.6} \times 100 = 14.27 \text{ wt\%} \quad \text{Ans.}$$

* The concentrations in atom percent:

$$C'_{Zinc} = \frac{N_{moles\ Zinc}}{\text{Total moles}}$$

$$N_{mole\ Zinc} = \frac{m_{Zinc}}{A_{Zinc}} = \frac{37.8 \times 10^3}{65.38} = 578.15 \text{ moles}$$

$$N_{mole\ lead} = \frac{m_{lead}}{A_{lead}} = \frac{10.5 \times 10^3}{207.2} = 50.67 \text{ moles}$$

$$N_{mole\ Copper} = \frac{m_{Copper}}{A_{Copper}} = \frac{25.3 \times 10^3}{63.546} = 398.134 \text{ moles}$$

Total no. of moles $= 578.15 + 50.67 + 398.13 = 1027$

$$\therefore C'_{Zinc} = \frac{578.16}{1027} \times 100 = 56.297 \text{ at\%} \quad \text{(Ans.)}$$

$$C'_{lead} = \frac{50.67}{1027} \times 100 = 4.93 \text{ at\%} \quad \text{(Ans.)}$$

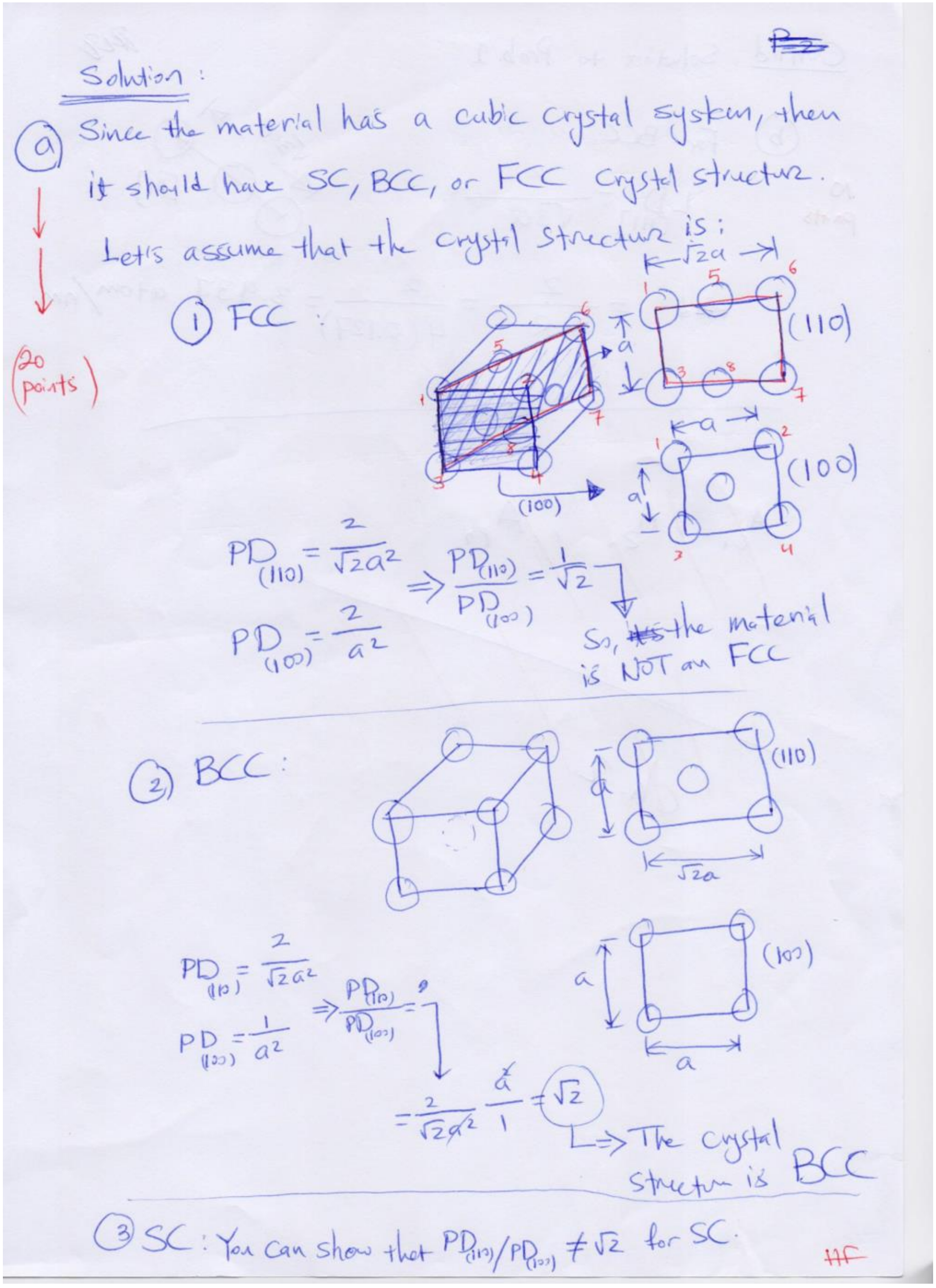
Problem 4 : *(29 points)*

For a cubic crystalline material, if the ratio of the (110) planar density to the (100) planar density is $\sqrt{2}$ $\left(i.e.\ \frac{\mathrm{PD}_{(110)}}{\mathrm{PD}_{(100)}} = \sqrt{2}\right)$, answer the following:

a. Determine the crystal structure for this material? *(19 points)*

b. Calculate the linear density along [111] given that the radius of the atom is 0.127 nm? *(10 points)*

Solutions:


Solution:

(a) Since the material has a cubic crystal system, then it should have SC, BCC, or FCC crystal structure.

Let's assume that the crystal structure is:

(20 points)

(1) FCC:

$$PD_{(110)} = \frac{2}{\sqrt{2}a^2} \quad PD_{(100)} = \frac{2}{a^2} \Rightarrow \frac{PD_{(110)}}{PD_{(100)}} = \frac{1}{\sqrt{2}}$$

So, the material is NOT an FCC

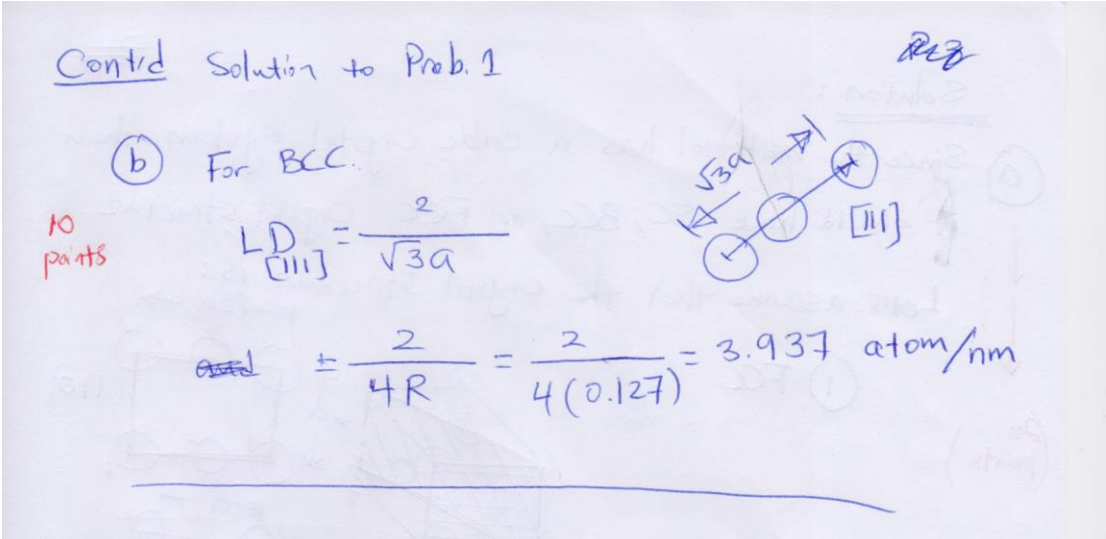
(2) BCC:

$$PD_{(110)} = \frac{2}{\sqrt{2}a^2} \quad PD_{(100)} = \frac{1}{a^2} \Rightarrow \frac{PD_{(110)}}{PD_{(100)}} = \frac{2}{\sqrt{2}a^2}\cdot\frac{a^2}{1} = \sqrt{2}$$

⟹ The crystal structure is BCC

(3) SC: You can show that $PD_{(110)}/PD_{(100)} \neq \sqrt{2}$ for SC.

HF



Cont'd Solution to Prob. 1

(b) For BCC

10 points

$$LD_{[111]} = \frac{2}{\sqrt{3}a}$$

$$= \frac{2}{4R} = \frac{2}{4(0.127)} = 3.937 \text{ atom/nm}$$

Problem 5: Choose the correct answer: *(5 points)*

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