Engineering 45
The Structure and Properties of Materials
Midterm Examination
February 23, 2007

1a: 8pts	
1b: 7pts	
2a: 10pts	
2b: 5 pts	
2c: 5pts	
3: 20pts	
4a: 10pts	
4b: 5pts	
4c: 10pts	
4d: 5pts	
5a: 5pts	
5b: 5pts	
5c: 5pts	

Name:

Student ID number:

Show all work!
No partial credit if you do not show your work.
Good Luck!

Problem 1:

(a) Give a brief, 1-2 sentence description of each of the four basic types of chemical bonding.

(b) How might you increase the electrical conductivity of an ionically bonded material (e.g. NaCl) without changing its basic crystal structure?

1a) i) Ionic: nondirectional, electron transfer

ii) Covalent: directional, electron sharing

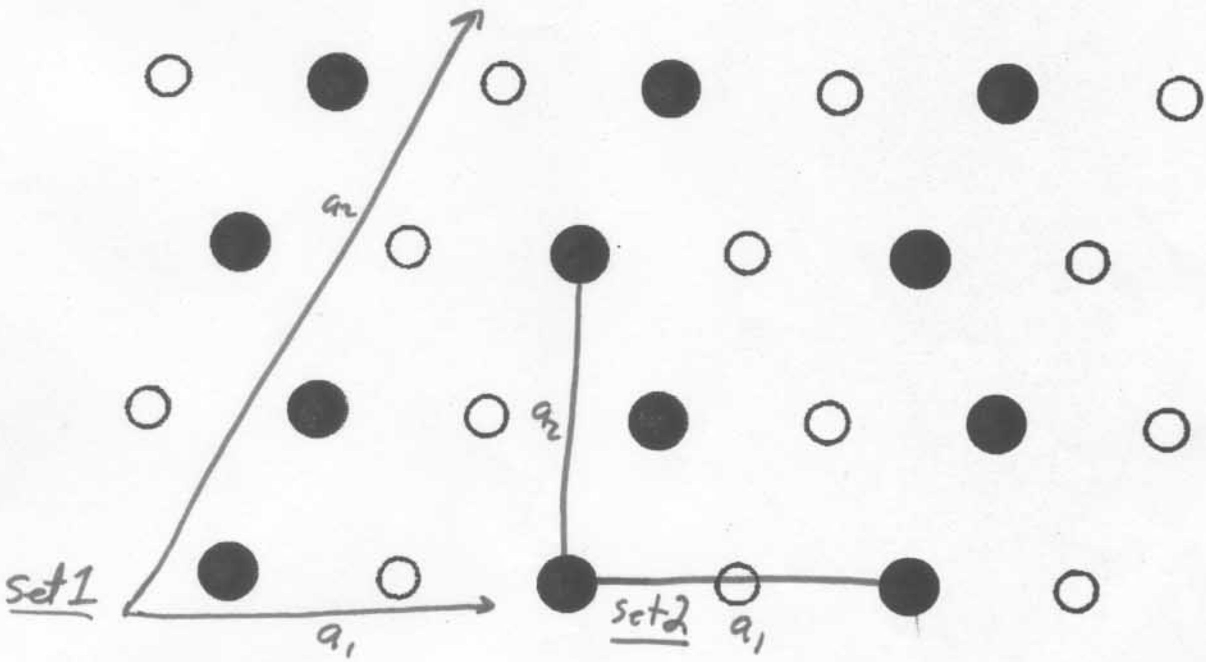
iii) Metallic: nondirectional, The valence electrons form an electron gas or sea of electrons.

iv) Vander Waals: Polar moments lead to this type of bonding.

1b) Introduce a substitutional defect to the lattice. If the valence of the substitutional atom is different then the original atom then the conductivity will change, increase. The best results occur if the number of valence electrons are increased.

Problem 2:

(a) Draw in the lattice vectors for the two-dimensional structure below and indicate the number of atoms of each element in the cell. The open circles and solid circles represent atoms of different elements.



Several different options are:

Set 1: 4 atoms ○
4 atoms ●

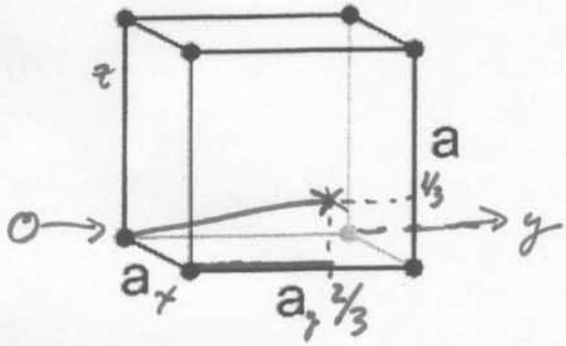
Set 2:
2 atoms ○
2 atoms ●

Each of these could be shifted to have the origin on the different type of atom.

(b) In the cubic unit cell below draw the [321] direction. Label as needed.

- You could draw out the # of cubes you need in the directions and write/draw in the full vector.

or scale the vector back into the unit cube by dividing by the largest number to yield the vector.



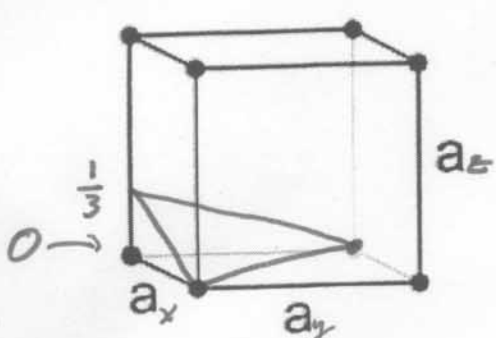
$$\frac{3}{3} \quad \frac{2}{3} \quad \frac{1}{3}$$

$$\left[1 \ \frac{2}{3} \ \frac{1}{3}\right]$$

Then select a right handed coordinate system

(c) In the cubic unit cell below draw the plane and give the Miller indices if the intercepts are 1,1,1/3 . If the lattice parameter is 1nm what is the distance to a parallel plane?

Select a right handed coordinate system



miller indices

$$\frac{1}{a} \quad \frac{1}{b} \quad \frac{1}{c}$$

$$\frac{1}{1} \quad \frac{1}{1} \quad \frac{1}{1/3}$$

$$(1 \ 1 \ 3)$$

$$d_{hkl} = \frac{a}{\sqrt{h^2+k^2+l^2}}$$

$$= \frac{1nm}{\sqrt{1+1+9}} = \frac{1nm}{\sqrt{11}}$$

Problem 3:

Iron changes from bcc to the fcc metal structure at 912 degrees C (1673 F). At this temperature, the atomic radii of the iron atoms in the two structures are 0.126nm (bcc) and 0.129nm (fcc), respectively,

(a) What is the percent volume change as the structure changes?

$$a_{bcc}\sqrt{3} = 4R_{bcc} \quad , \quad a_{fcc}\sqrt{2} = 4R_{fcc}$$

A common basis for the two structures is needed. Select fcc as the reference which gives us a 4 atom basis. To have a 4 atom two unit cells of bcc iron are needed.

$$V_{fcc} = a_{fcc}^3 = \left[4(0.129\,nm)/\sqrt{2}\right]^3 = 0.0486\,nm^3$$

$$2V_{bcc} = 2a_{bcc}^3 = 2\left[4(0.126\,nm)/\sqrt{3}\right]^3 = 0.0493\,nm^3$$

$$\frac{\Delta V}{V} = \frac{0.0486 - 0.0493}{0.0493} = -0.014$$

$\Rightarrow -1.4\%$ volume change

Problem 4:

(a) Draw an edge dislocation in a simple cubic crystal. Indicate its "Burgers vector" and its "glide plane".

(b) Rank the following bonds in decreasing order of the expected energy necessary to create a vacancy: Metallic, Ionic and Covalent.

(c) Calculate the equilibrium concentration of vacancies in copper (FCC, lattice parameter $a = 0.3615$nm) at room temperature (25 C). Assume that 10,000 cal are required to produce a mole of vacancies. R = 1.987 (cal/mole*K)

(d) Is it possible to calculate the equilibrium concentration of dislocations at the above temperature? If it is possible, how would you perform this calculation; if it is not possible why is it not possible? (This is a short answer question.)

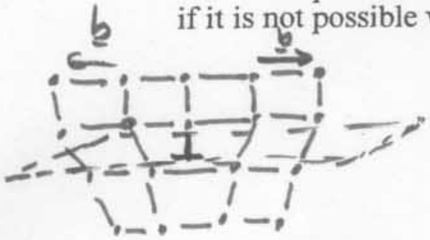
a) 

fig 4.10 - 4.11 from book.

b) Ionic
Covalent
Metallic

c) 1st calculate atomic density: $n = \frac{4 \text{ atoms}}{a^3} = 8.47 \times 10^{22} \frac{\text{cu atoms}}{\text{cm}^3}$

$$n_v = n \exp(-E_v/RT)$$

$$T = 25 + 273 = 298 \text{ k}$$

$$n_v = 3.92 \times 10^{15}$$

d) No, dislocations are non-equilibrium defects.

Problem 5:

(a) What type of polymer would you use to make a surgeon's glove and why?
Elastomer

(b) What type of polymer would you use to make a beverage container and why?

(c) What type of polymer would you use to make a pulley (structural element) and why?

5a) Elastomer; The glove must stretch a great deal to fit the surgeon's hand and have it remain tight.

5b) Thermoplastic: This use requires the polymer to be formable and have ductility. Also to be formable many time for recycling. ~~It~~ This type of polymer is meltable.

5c) Thermosetting: The pulley will be subject to some stress and wear as a belt passes over it. A relatively strong, ridged, hard material is required to prevent wear.