3.091 Fall Term 2009

Homework #6

October 13 (to be tested Tuesday, October 20)

0. Iron (ρ= 7.86 g/cm^3) crystallizes in a BCC unit cell at room temperature. Calculate the radius of an iron atom in this crystal. At temperatures above 910ºC iron prefers to be FCC. If we neglect the temperature dependence of the radius of the iron atom on the grounds that it is negligible, we can calculate the density of FCC iron. Use this to determine whether iron expands or contracts when it undergoes transformation from the BCC to the FCC structure.

1. Determine the total void volume (cm^3/mole) for Au (at 27°C); make the hard-sphere approximation in your calculation; use data provided in the periodic table.

2. For the element copper (Cu) determine:

(a) the distance of second nearest neighbors;

(b) the interplanar spacing of {110} planes.

3. Consider a (111) plane in an FCC structure. How many different [110]-type directions lie in this (111) plane? Write out the indices for ***each*** such direction.

4. Determine for barium (Ba) the linear density of atoms along the <110> directions.

5. For aluminum at 300K, calculate the planar packing fraction (fractional area occupied by atoms) of the (110) plane and the linear packing density (atoms/cm) of the [100] direction.

6. Sketch a cubic unit cell and in it show the following planes: (111), (210), and (003).

7. Braquium, chemical symbol Bq, is simple cubic. Calculate the atomic density (atoms/cm^2) in the (011) plane of Bq. The molar volume of Bq is 22.22 cm^3.

8. Chemical analysis of a germanium crystal reveals indium at a level of 0.0003 atomic percent.

(a) Assuming that the concentration of thermally excited charge carriers from the Ge matrix is negligible, calculate the density of free charge carriers (carriers/cm^3) in this Ge crystal.

(b) Draw a schematic energy band diagram for this material and label all critical features.

9. Show that green light ($\lambda = 5 \times 10^{-7}$ m) can excite electrons across the band gap of silicon.

10. Determine the amount (in grams) of arsenic required to be substitutionally incorporated into a mole of silicon in order to achieve in it a free-electron density of 5×10^{17}/cm^3.

11. (a) Electromagnetic radiation of frequency 3.091×10^{14} Hz illuminates a crystal of germanium. Calculate the wavelength photoemission generated by this interaction. Germanium is an elemental semiconductor with a band gap, E_g, of 0.7 eV.

(b) Sketch the absorption spectrum of germanium, i.e., plot % absorption *vs* wavelength, λ.

12. (a) Chemical analysis of a silicon crystal reveals arsenic at a level of 0.0002 atomic percent. Assuming that the concentration of thermally excited charge carriers from the Si matrix is negligible, calculate the density of free charge carriers (carriers/cm^3) in this Si crystal.

(b) Draw a schematic energy band diagram for this material, and label all critical features.

13. (a) Determine the amount (in grams) of boron that substitutionally incorporated into 1 kg of germanium will establish a charge carrier density of $3.091 \times 10^{17}/cm^3$.

(b) Draw a schematic energy band diagram for this material, and label all critical features.

14. (a) An electron beam strikes a crystal of cadmium sulfide (CdS). Electrons scattered by the crystal move at a velocity of 4.4×10^5 m/s. Calculate the energy of the incident beam. Express your result in eV. CdS is a semiconductor with a band gap, E_g, of 2.45 eV.

(b) Cadmium telluride (CdTe) is also a semiconductor. Do you expect the band gap of this material to be greater or less than the band gap of CdS? Explain.

15. (a) Aluminum phosphide (AlP) is a semiconductor with a band gap, E_g, of 3.0 eV. Sketch the absorption spectrum of this material, *i.e.*, plot % **absorption** *versus* **wavelength**, λ.

(b) Aluminum antimonide (AlSb) is also a semiconductor. Do you expect the band gap of this material to be greater than or less than the band gap of AlP? Explain.

16. You wish to make n-type germanium.

(i) Name a suitable dopant.

(ii) Name the majority charge carrier in the doped material.

(iii) Draw a schematic energy band diagram of the doped material. Label the valence band, conduction band, and any energy levels associated with the presence of the dopant.