3.091 Fall Term 2004

Homework #5 with Solutions

October 5 (for weekly quiz on Tuesday, October 12)

1. 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.

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

3. 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 $5 \times 10^{17}/cm^3$.

4. (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.

5. (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.

6. (a) Determine the amount (in grams) of boron required to be substitutionally incorporated into 1 kg of germanium in order to 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.

7. (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 electron 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.

8. (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.

9. 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.