ECE 340

Homework Assignment #2

Fall 2015

DUE: FRIDAY, SEPTEMBER 11, 2015

Print your **name** and **NetID** legibly. Follow the guidelines and format given in the syllabus. Staple multiple pages. Show all units. Homework must be turned in at the **beginning** of class and any late homework assignments will not be accepted. Please contact the course director, Professor Dallesasse, should any issues with late homework arise.

1. CHARGE CARRIERS IN SEMICONDUCTORS

Using Fig. 1.1, given below, answer the following questions. The red circles labeled (1), (2), (3), and (4) represent holes in the valence band. Holes (1) and (2) are both located at energy level E_1.

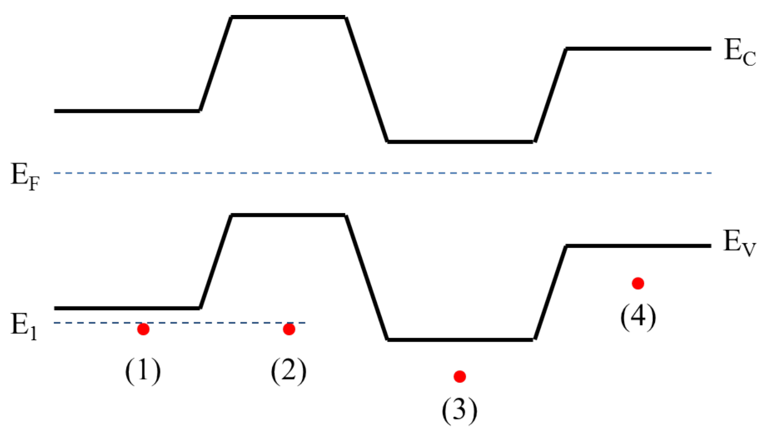

Figure 1.1: Energy band diagram. The red circles labeled (1), (2), (3), and (4) represent holes in the valence band.

(A). What is the doping type in the regions where holes (1), (2), (3), and (4) are located?

(B). Which hole has the highest potential energy? Which hole has the lowest potential energy? Explain why for both answers.

(C). Which hole has the highest kinetic energy? Which hole has the lowest kinetic energy? Draw a diagram to support your answers.

(D). Which hole has the highest occupation probability at equilibrium? Which hole has the lowest occupation probability at equilibrium? Explain why for both answers.

2. DOPING IN A SEMICONDUCTOR

A piece of **GaAs** is doped with **Si** atoms. If the **Si** atoms replace only **As** atoms is the semiconductor *n*- or *p*-type doped? Why? Now supposed that only $\frac{3}{5}$ of the **Si** atoms replace **As** atoms while the other $\frac{2}{5}$ replace **Ga** atoms. Is the material *n*- or *p*-type doped? How does the doping level compare to the situation where **Si** only replaces **As**?

3. The Fermi Distribution and Doping

The following problem should be done assuming room temperature (T = 300K) equilibrium conditions. Please show your work for all calculations. A piece of **GaAs** has a hole concentration of 8×10^{-2} cm^{-3}. Knowing that **GaAs** has an intrinsic carrier concentration of $n_i = 2\times10^{6}$ cm^{-3} at room temperature:

(A). What is the electron concentration? Is the **GaAs** *n*- or *p*-type doped?

(B). Where is the Fermi level, E_F, positioned relative to the intrinsic energy level E_i? Your answer should be a difference between two energy levels.

(C). What is the electron occupation probability of an energy state located at the Fermi level?

(D). Assuming E_i is located at the center of the band gap, what is the electron occupation probability of an energy state located exactly at the conduction band, E_C?

(E). Draw the real-space energy band diagram of this piece of **GaAs** labeling the conduction band, valence band, the Fermi level, and the intrinsic energy level. Also label the quantity calculated in part (b).

(F). Find the electron and hole concentrations assuming the difference between E_F and E_i is a third of your calculated value in part (b).

4. The Intrinsic Energy Level

In the previous problem you were told to assume that the intrinsic energy level, E_i was located at exactly the center of the band gap. While this is usually a safe assumption and will be used for most of this course it is still not exact. In semiconductors with large differences in the effective masses of electrons and holes, the error in this assumption can become large.

For the following problem, assume you have an unknown semiconductor with a band gap of E_g = 0.75 eV at T = 500K. The effective density of states at the conduction band edge is $N_c = 4.37\times10^{17}$ cm^{-3} and the effective density of states at the valence band edge is $N_v = 8.68\times10^{18}$ cm^{-3}. The electron concentration is 5×10^{11} cm^{-3}.

(A). Calculate the intrinsic carrier concentration and hole concentration.

(B). Calculate the difference between E_F and E_i. Is the semiconductor *n*- or *p*-type doped?

(C). Calculate the difference between E_i and the center of the band gap. Be sure to show your work.