ECE609 Spring09

HOMEWORK 3

Carrier Densities

1 Carrier Densities

1. For a 3D semiconductor, develop an expression for the total number of available states/cm^3 in the conduction band between energies E_c and $E_c + \gamma k_B T$, where γ is an arbitrary constant. Do the same for the valence band between energies $E_v - \gamma k_B T$ and E_v.

2. Evaluate the approximation errors if one uses the Maxwell-Boltzmann statistics instead of the Fermi-Dirac statistics, for the following energies: $E - E_F = 2.2k_BT$, $E - E_F = 2.9k_BT$, $E - E_F = 4.6k_BT$. Comment.

3. Determine the temperature at which the intrinsic carrier density in (i) Silicon and (ii) GaAs are equal to the room temperature ($300K$) intrinsic carrier density of Germanium (Ge) $n_i = 2 * 10^{13}/cm^3$ (here N_c, N_v, E_G and m^* are independent of the temperature).

4. Semiconductor A has a bang gap of $1eV$ and semiconductor B has a band gap of $2eV$. What is the ratio of the intrinsic carrier density in the two materials (n_i^A/n_i^B) at $300K$. We assume that all effective masses are equal (electrons and holes for both A and B). You will comment the result.

5. Determine the equilibrium electron and hole concentrations inside a uniformly doped sample of Silicon under the following conditions:

   a- T=300K, N-type Semiconductor, $N_D = 10^{15}/cm^3$
   b- T=300K, P-type Semiconductor, $N_A = 10^{16}/cm^3$
   c- T=300K, $N_A = 9 * 10^{15}/cm^3$, $N_D = 10^{16}/cm^3$
   d- T=450K, $N_A = 0$, $N_D = 10^{14}/cm^3$
   e- T=650K, $N_A = 0$, $N_D = 10^{14}/cm^3$

   Attention: You will consider that $n_i = 10^{10}/cm^3$ at $T = 300K$, $m_n^* = 1.18m_0$, $m_p^* = 0.81m_0$, and $E_g = 1.42eV$ at $T = 300K$, $E_g = 1.08eV$ at $T = 450K$ and $E_g = 1.015eV$ at $T = 650K$, every other material dependent quantities should be calculated.

6. For each of the conditions specified in the above question, determine the position of E_i, compute $E_F - E_i$, and draw a dimensioned energy band diagram for the Silicon sample.

7. Determine the concentration of donor atoms that must be added so that the Silicon is N-type and the Fermi energy is $0.2eV$ below the conduction band edge. Assume complete ionization, temperature $T = 300K$, $2.8 * 10^{19}/cm^3$ for the effective DOS for the electrons, and $n_i = 10^{10}/cm^3$.

8. A GaAs semiconductor is doped with $2.3 * 10^{17}$ donors per cm^3, assuming that this semiconductor is non-degenerate, calculate the electron and hole concentration at equilibrium. Calculate ($Ec - EF$). Comments about the obtained results and the assumption made to calculate these results.

9. In a nondegenerate Germanium at room temperature, we give $n_i = 10^{13}/cm^3$, $n = 2p$ and $N_a = 0$. Determine n, p, N_d and where is the Fermi level located from E_i ?