H3-2022: Extra Practice Question Set 2

1. A semiconductor sample is doped with donor impurity such that the thermal equilibrium electron concentration is 1.04×10^{13} cm^{-3}. The intrinsic carrier concentration is n_i = 5 × 10^{12} cm^{-3} and the semiconductor has a bandgap energy of 0.8 eV. Assume that T = 300 K.
   (a) What is the thermal equilibrium hole concentration?

   (b) Determine the donor doping concentration.

   (c) Calculate the position of the Fermi level E_F relative to the valance band edge E_v and sketch the corresponding energy band diagram.

   (d) Find the effective masses of electrons and holes in this semiconductor.

   [Ans: (a) 2.404×10^{12} cm^{-3}, (b) 8×10^{12} cm^{-3}, (c) 0.419 eV, (d) 1.0113 m_0]

2. The Fermi level of a non-degenerate Si semiconductor at 300 K is 0.2 eV above the valance band edge, E_v. What doping type and concentration are needed to shift the Fermi level upwards by 0.7 eV? Assume that the semiconductor has $N_C = 2.8\times10^{19}$ cm^{-3}, $N_V = 1.04\times10^{19}$ cm^{-3} and E_g = 1.12 eV.

   [Ans: 1.0337×10^{16} cm^{-3}]

3. A constant electric field of $\xi = 500$ V/cm exists in a p-type semiconductor sample at 310 K. The hole concentration at position x = 0 in the sample is 5.44×10^{11} cm^{-3}. The electron and hole diffusion coefficients are 35 cm^2/s and 15 cm^2/s, respectively.

   (a) Calculate the hole mobility in the semiconductor.

   (b) Determine the hole concentration as a function of x in the semiconductor if a constant total hole current density of 2 mA/cm^2 flows through the sample.

   [Ans: (a) 561.7 cm^2/V-s, (b) $p = 5\times10^{11}\exp(18750x) + 4.444\times10^{10}$ cm^{-3}]

4. The hole concentration in a p-type Ge semiconductor sample is

$$p = 10^{16}\left(x^2 + b^2\right) \quad \text{cm}^{-3}$$

   where b = 1 μm and $0 \le x \le 20$ μm. The total hole current density is zero throughout the sample. Assume that the hole mobility is $\mu_p = 700$ cm^2/V.s and T = 300 K.

   (a) Determine the electric field ξ as a function of x in the sample.

   (b) Calculate the hole drift and diffusion current densities at $x = 5$ μm.

   [Ans: (a) $\dfrac{0.0517x}{\left(x^2+b^2\right)}$ V/cm, (b) -28.95 μA/cm^2]

5. Figure 1 shows the energy band diagram of a uniformly doped *n*-type semiconductor sample of length 20 μm. The doping concentration is $5\times10^{17}\ \text{cm}^{-3}$ and the electron and hole mobilities are $200\ \text{cm}^2/\text{V}\cdot\text{s}$ and $100\ \text{cm}^2/\text{V}\cdot\text{s}$, respectively.

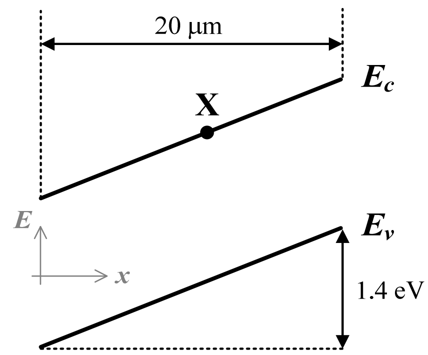

Figure 1

(a) What is the conduction mechanism (i.e. drift or diffusion) in the sample? Justify your answer.

(b) Determine the magnitude and direction of the electric current at point X in the sample.

[Ans: (a) *drift*, (b) 11,200 A/cm^2]

6. The energy band diagram of a wide bandgap semiconductor with $n_i = 250\ \text{cm}^{-3}$ is shown in Figure 2. The semiconductor is at a temperature of $T = 350$ K.

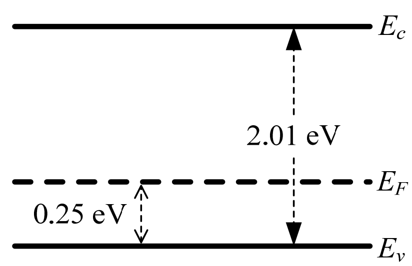

Figure 2

(a) Is this a non-degenerate semiconductor? Explain your answer.

(b) Determine the thermal equilibrium electron and hole concentrations.

(c) What is the maximum wavelength of light that you can use to create excess electron-hole pairs in the semiconductor?

[Ans: (b) $1.8766\times10^{13}\ \text{cm}^{-3}$, $3.33\times10^{-9}\ \text{cm}^{-3}$, (c) 617.4 nm]

7. The resistance of an intrinsic semiconductor increases by a factor of 10 when its temperature changes from 420 K to 350 K. What is the bandgap energy of the semiconductor? Assume that the bandgap energy, the carrier mobilities and the effective density of states do not vary with temperature.

[Ans: 0.833 eV]