EL 212 : Solid State Devices

Problem Set No. 4

Due*: 10-Feb-2006

Note

In the following problems, if necessary, assume at \( T = 300K \)
\( n_i = 1 \times 10^{10} \text{ cm}^{-3}, \mu_n = 1500 \text{ cm}^2\text{V}^{-1}\text{s}^{-1} \)
and \( \mu_p = 450 \text{ cm}^2\text{V}^{-1}\text{s}^{-1} \).

1. Assume that a silicon sample is doped with \( N_d = 1 \times 10^{13} \text{ cm}^{-3} \) and \( N_a = 2.5 \times 10^{13} \text{ cm}^{-3} \) at \( T = 300K \)
Find
   a) if this material is n-type or p-type.
   b) Calculate the equilibrium electron and hole concentration i.e., \( n_0 \) and \( p_0 \).

2. A sample of silicon is doped with \( 10^{14} \) donor atoms/cm\(^{-3} \) and \( 7 \times 10^{13} \) acceptor atoms/cm\(^{-3} \). If the applied electric field is 2 V/cm , find the total conduction current density.

3. A silicon region doped with acceptors at \( N_a = 10^{15} \text{ cm}^{-3} \) and donors \( N_d = 8 \times 10^{14} \text{ cm}^{-3} \)
   a) What electric field must be applied for the magnitude of drift velocity of the majority carriers to be \( 4 \times 10^6 \text{ cm/s} \)?
   b) What is the drift current density of majority carriers for the case of electric field in part a)?

4. To design a semiconductor resistor with a specified resistance to handle a given current density on an integrated circuit. A silicon at \( T = 300K \) is initially doped with donors at a concentration of \( N_d = 5 \times 10^{15} \text{ cm}^{-3} \). Acceptors are to be added to form a compensated p-type material. The resistor is to have a resistance of 10 k\( \Omega \) and handle a current density of 50 A/cm\(^2 \) when a voltage of 5V is applied. Find the dimensions of the resistor (length and cross section area).

5. The electron concentration in silicon at \( T = 300K \) is given by
   \[
   n(x) = 10^{16} \exp\left(\frac{-x}{18}\right) \text{ cm}^{-3}
   \]
   where \( x \) is measured in \( \mu m \) and is limited \( 0 \leq x \leq 25 \mu m \) The electron diffusion coefficient is \( D_n = 25 \text{ cm}^2/\text{s} \) and the electron mobility is \( \mu_n = 960 \text{ cm}^2\text{V}^{-1}\text{s}^{-1} \). The total electron current density through semiconductor is constant and equal to \( J_n = 40 \text{ A/cm}^2 \). The electron current has both drift and diffusion components. Determine the electric field as a function of \( x \) which must exist in the semiconductor.

6. A sample of silicon is doped with the \( N_d = 5 \times 10^{15} \text{ cm}^{-3} \). At a temperature of 400K, find the energy difference, in eV, between the Fermi level \( E_F \) and intrinsic Fermi-level \( E_i \).

*All assignments are to be handed in on Fridays in the boxes provided in the Lab105 for Group 1 and 2 and in Lab208 for Group 3 and 4. Late submissions are not permitted. If Friday is a holiday, 9:00 am the following working day including Saturday is the submission time.