Module 2 Unit 1

SEMICONDUCTORS – NUMERICAL PROBLEMS

Fundamental constants:

1. Elementary charge q = 1.6 x 10^{-19} C
2. Avogadro's number N_0 = 6.023 x 10^{23}/mol
3. Boltzmann constant k = 1.38 x 10^{-23} J/K = 8.62 x 10^{-5} eV/K

Take kT = 0.025 eV and $\frac{kT}{q}$ = 0.025 volt at room temperature (RT)

1. Determine resistivity of intrinsic Si. Electron and hole mobility in Si are 0.13 and 0.05 m^2/V-s respectively. Intrinsic carrier concentration for Si = $10^{10}/cm^3$.
2. Calculate the majority and minority carrier concentrations and resistivity if we dope Si in previous example with $10^{16}/cm^3$ phosphorous atoms.
3. Density of Si is 2340 kg/m^3 and its atomic weight is 28 gm/mol. If a Si crystal is doped with 1 ppb boron atoms, what type of material would it become. Determine boron concentration in cm^{-3}.
4. An n-type impurity is added to a semiconductor at 0.01 ppm concentration. Calculate resistivity of this doped sample. Given density of the semiconductor material 5.3 gm/cm^3 and its molecular weight is 144.65 gm/mol. Given mobility of electrons in this material is 8.5 m^2/V-s.
5. Calculate intrinsic concentration for GaAs at RT. Given effective density of states in the CB and VB of GaAs to be 4.37 x 10^{17}/cc and 8.68 x 10^{18}/cc respectively. Energy band gap of GaAs = 1.42.
6. Estimate the drift velocity and drift current density if a Si sample doped with $10^{16}/cm^3$ donor impurity is subjected to an electric field of 50 V/cm. Given mobility of electrons in Si to be 0.13 m^2/V-s.
7. Estimate the diffusion current density in p-type Si, if hole concentration drops from 3 x $10^{18}/cm^3$ to 5 x $10^{14}/cm^3$ over a space of 10 µm. given diffusion coefficient for holes in Si to be 10 cm^2/s.
8. An electric field of intensity 2 x 10^4 V/m is required to compensate the hole diffusion current generated due to hole concentration gradient of 3 x $10^{21}/cm^4$. Calculate hole concentration at RT.
9. Determine the probability that an electron is present in CB in intrinsic Ge at RT. Given energy band gap of Ge = 0.66 eV.
10. Estimate the probability that a hole is present in the VB in intrinsic Si at RT. Given energy band gap of Si = 1.12 eV. What would be the probability of getting an electron in the VB?
11. If a Ge sample is doped with phosphorous atoms at a concentration of $10^{16}/cm^3$, determine the shift in Fermi level from its intrinsic position.
12. If Si is doped with indium atoms at a concentration of $10^{16}/cm^3$, determine the probabilities of getting an electron and a hole in its VB. Compare with the results of example 10.
13. A Si sample is doped with 10^{17}/cc donor impurity. Due to doping, a donor level is introduced at 0.05 eV below the CB. Calculate the probability that this donor has donated electrons (meaning it is ionized) at RT. Intrinsic concentration in Si at RT = 10^{10}/cc.
14. Intrinsic carrier concentration in Ge at RT is 2 x $10^{13}/cm^3$. Determine its resistivity. Given electron and hole mobility in Ge to be 0.39 and 0.19 m^2/V-s respectively. If this sample is doped with $10^{16}/cm^3$ Al atoms, what type of material would it become? determine resistivity of this doped sample. If the same sample is doped further by 5 x $10^{18}/cm^3$ Sb atoms, what type of material would it become? Re-estimate its resistivity.

15. Si is doped with 10^{15}/cm^3 boron atoms. Determine the temperature at which, intrinsic concentration of Si would match the doping concentration. Given energy band gap for Si = 1.1 eV (assume it is constant of temperature). Given effective density of states in the CB and VB of Si are 2.82 x 10^{19}/cc and 1.83 x 10^{19}/cc respectively.

HOME WORK

1. Calculate the proportion of electrons having energy E_C and E_C + 10kT in Si at RT.
2. Estimate the probability that an electron is present in the CB and VB in Si at RT for the Si sample of example 15.
3. Determine intrinsic carrier concentration in Si at (i) 100 K, (ii) 300 K (RT) and (iii) 500 K. Assume Si data as in example 15 of solved problems.
4. Conductivity of an intrinsic semiconductor changes from 2.88 x 10^{-3} S/cm to 1.1 x 10^{-2} S/cm when temperature increases from 27°C to 100°C. Calculate energy band gap of this material.
5. Mobility of electrons in Si is 1300 cm^2/V-s. These electrons possess average thermal energy given by E_{th} = kT at a given temperature. Let their mean thermal velocity be given by $v_{th} = \sqrt{\frac{2E_{th}}{m}}$, then estimate the electric field at which, the drift velocity of electrons would exceed their average thermal velocity at RT.

==========