Tutorial

Carrier Concentartion

1. Calculate the intrinsic carrier concentration in GaAs at T = 400 K and at T = 250 K. Assume that E_g = 1.42 eV is constant over this temperature range.
2. What is the ratio of n_i at T = 400 K to that at T = 250 K?
3. Determine the position of the intrinsic Fermi level at T = 300 K with respect to the center of the bandgap for (a) GaAs and (b) Ge
4. Calculate the ionization energy and the radius (normalized to the Bohr radius) of a donor electron in its lowest energy state in GaAs
5. Calculate the thermal equilibrium concentrations of electrons and holes for a given Fermi energy. Consider silicon at T = 300 K so that N_c 2.8 x 1019(1/cm3)and N_v = 1.04 x 1019 (1/cm3).Assume that the Fermi energy is 0.25 eV below the conduction band. If we assume that the bandgap energy of silicon is 1.12 eV, then the Fermi energy will be 0.87 eV above the valence band.
6. The hole concentration in p-type GaAs is given by $p(x) = 10^{16}(1 + x/L)^2 cm^{-3}$ for $–L \leq x \leq 0$ where L = 12 µm. The hole diffusion coefficient is $D_p = 10\ cm^2/s$. Calculate the hole diffusion current density at (a) x = 0, (b) x = -6 µm, and (c) x = -12 µm.
7. Germanium is doped with 5×10^{15} donor atoms per cm^3 at T = 300 K. The dimensions of the Hall device are $d = 5 \times 10^{-3}$ cm, $W = 2 \times 10^{-2}$ cm, and $L = 10^{-1}$ cm. The current is I_x = 250 µA, the applied voltage is V_x = 100 mV, and the magnetic flux density is B_z = 500 gauss = 5×10^{-2} tesla. Calculate: (a) the Hall voltage (b) Hall field and (c) the carrier mobility.
8. In GaAs, the donor impurity concentration varies as N_{d0} exp (-x/L) for $0 \leq x \leq L$, where L = 0.1 µm and $N_{d0} = 5 \times 10^{16}\ cm^{-3}$. Assume µn = 6000 cm^2/V-s and T = 300 K. (a) Derive the expression for the electron diffusion current density versus distance over the given range of x. (b) Determine the induced electric field that generates a drift current density that compensates the diffusion current density.
9. A drift current density of J_{drf} 75 A/cm2 is required in a device using p-type silicon when an electric field of E 120 V/cm is applied. Determine the required impurity doping concentration to achieve this specifi cation. Assume that electron and hole mobilities from below table.

	un (cm^2/V-s)	Mp (cm ^{2}/V-s)
Silicon	1350	480
Gallium arsenide	8500	400
Germanium	3900	1900

10. An n-type silicon sample contains a donor concentration of Nd = 1016 cm-3. The minority carrier hole lifetime is found to be τp0 = 20 µs. (a) What is the lifetime of the majority carrier electrons? (b) Determine the thermal-equilibrium generation rate for electrons and holes in

this material. (c) Determine the thermal-equilibrium recombination rate for electrons and holes in this material.

11. Consider silicon at T=300K doped at concentrations of N_d=1015 cm−3 and N_a=0. Assume that $n' = p' = n_i$ in the excess carrier recombination rate equation and assume parameter values of τ_{n0}= τ_{p0}=5×10−7 s. Calculate the recombination rate of excess carriers if δ_n=δ_p=1014 cm−3.