VE320 Homework Four

Due: 2021/6/14 23:59

1. (a) The required conductivity of an n-type silicon sample at $T = 300\ K$ is to be $\sigma = 10(\Omega \cdot cm)^{-1}$. What donor impurity concentration is required? What is the electron mobility corresponding to this impurity concentration?
   (b) A p-type silicon material is required to have a resistivity of $\rho = 0.20(\Omega \cdot cm)$. What acceptor impurity concentration is required and what is the corresponding hole mobility?

2. A perfectly compensated semiconductor is one in which the donor and acceptor impurity concentrations are exactly equal. Assuming complete ionization, determine the resistivity of silicon at $T = 300\ K$ in which the impurity concentrations are
   (a)$N_a = N_d = 10^{14} cm^{-3}$
   (b)$N_a = N_d = 10^{16} cm^{-3}$
   (c)$N_a = N_d = 10^{18} cm^{-3}$

3. Consider a semiconductor that is uniformly doped with $N_d = 10^{14} cm^{-3}$ and $N_a = 0$, with an applied electric field of $E = 100V/cm$. Assume that $\mu_n = 1000cm^2/V \cdot s$ and $\mu_p = 0$. Also assume the following parameters:
   $N_c = 2 \times 10^{19} \left(\frac{T}{300}\right)^{\frac{3}{2}} cm^{-3},\ N_v = 1 \times 10^{19} \left(\frac{T}{300}\right)^{\frac{3}{2}} cm^{-3},\ E_g = 1.10eV$
   (a) Calculate the electric-current density at $T = 300\ K$.
   (b) At what temperature will this current increase by 5 percent? (Assume the mobilities are independent of temperature.)

4. The effective density of states functions in silicon can be written in the form
   $$N_c = 2.8 \times 10^{19} \left(\frac{T}{300}\right)^{\frac{3}{2}}, N_v = 1.04 \times 10^{19} \left(\frac{T}{300}\right)^{\frac{3}{2}}$$
   Assume the mobilities are given by
   $$\mu_n = 1350 \left(\frac{T}{300}\right)^{-\frac{3}{2}}, \mu_p = 480 \left(\frac{T}{300}\right)^{-\frac{3}{2}}$$
   Assume the bandgap energy is $E_g = 1.12\ eV$ and independent of temperature. **Plot** the intrinsic conductivity as a function of T over the range $200 \leq T \leq 600\ K$.

5. The steady-state electron distribution in silicon can be approximated by a linear function of x. The maximum electron concentration occurs at $x = 0$ and is $n(0) = 2 \times 10^{16}\ cm^3$. At $x = 0.012\ cm$, the electron concentration is 5×10^{15}. If the electron diffusion coefficient is $D_n = 27cm^2/s$, determine the electron diffusion current density.

6. Consider an n-type semiconductor at $T = 300\ K$ in thermal equilibrium (no current). Assume that the donor concentration varies as $N_d(x) = N_{d0}e^{-\frac{x}{L}}$ over the range $0 \leq x \leq L$ where $N_{d0} = 10^{16}cm^{-3}$ and $L = 10\mu m$.
   (a) Determine the electric field as a function of x for $0 \leq x \leq L$.
   (b) Calculate the potential difference between $x = 0$ and $x = L$ (with the potential at $x = 0$ being positive with respect to that at $x = L$).