VE320 Homework 4

Due: 12/06/2019 10:00 am

1.

Consider a semiconductor that is uniformly doped with $N_d = 10^{14}\ \text{cm}^{-3}$ and $N_a = 0$, with an applied electric field of E = 100 V/cm. Assume that $\mu_n = 1000\ \text{cm}^2/\text{V-s}$ and $\mu_p = 0$. Also assume the following parameters:

$$N_c = 2 \times 10^{19}\ (T/300)^{3/2}\ \text{cm}^{-3}$$
$$N_v = 1 \times 10^{19}\ (T/300)^{3/2}\ \text{cm}^{-3}$$
$$E_g = 1.10\ \text{eV}$$

(*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.)

2.

The effective density of states functions in silicon can be written in the form

$$N_c = 2.8 \times 10^{19}\left(\frac{T}{300}\right)^{3/2} \qquad N_v = 1.04 \times 10^{19}\left(\frac{T}{300}\right)^{3/2}$$

Assume the mobilities are given by

$$\mu_n = 1350\left(\frac{T}{300}\right)^{-3/2} \qquad \mu_p = 480\left(\frac{T}{300}\right)^{-3/2}$$

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 $200 \le T \le 600$ K.

3.

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 $n(0) = 2 \times 10^{16}\ \text{cm}^{-3}$. At $x = 0.012$ cm, the electron concentration is $5 \times 10^{15}\ \text{cm}^{-3}$. If the electron diffusion coefficient is $D_n = 27\ \text{cm}^2/\text{s}$, determine the electron diffusion current density.

4.

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

5.

GaAs, at $T = 300$ K, is uniformly doped with acceptor impurity atoms to a concentration of $N_a = 2 \times 10^{16}\ \text{cm}^{-3}$. Assume an excess carrier lifetime of 5×10^{-7}s. (*a*) Determine the electron–hole recombination rate if the excess electron concentration is $\delta n = 5 \times 10^{14}\ \text{cm}^{-3}$. (*b*) Using the results of part (*a*), what is the lifetime of holes?

6.

(a) A sample of semiconductor has a cross-sectional area of 1 cm^2 and a thickness of 0.1 cm. Determine the number of electron–hole pairs that are generated per unit volume per unit time by the uniform absorption of 1 watt of light at a wavelength of 6300 Å. Assume each photon creates one electron–hole pair. (b) If the excess minority carrier lifetime is 10 μs, what is the steady-state excess carrier concentration?

7.

Consider a one-dimensional hole flux as shown in Figure 6.4. If the generation rate of holes in this differential volume is $g_p = 10^{20}$ cm^{-3}-s^{-1} and the recombination rate is 2×10^{19} cm^{-3}-s^{-1}, what must be the gradient in the particle current density to maintain a steady-state hole concentration?

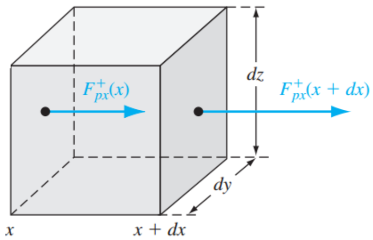

Figure 6.4 | Differential volume showing x component of the hole-particle flux.

8.

Consider an n-type semiconductor as shown in Figure P6.41, doped at $N_d = 10^{16}$ cm^{-3} and with a uniform excess carrier generation rate equal to $g' = 10^{21}$ cm^{-3}-s^{-1}. Assume that $D_p = 10$ cm ^{2}/s and $\tau_{p0} = 10^{-7}$ s. The electric field is zero. (a) Determine the steady-state excess minority carrier concentration versus x if the surface recombination velocity at $x = 0$ is (i) $s = 0$, (ii) $s = 2000$ cm/s, and (iii) $s = \infty$. (b) Calculate the excess minority carrier concentration at $x = 0$ for (i) $s = 0$, (ii) $s = 2000$ cm/s, and (iii) $s = \infty$.

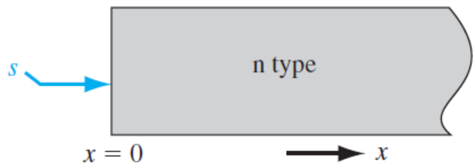

Figure P6.41 | Figure for Problem 6.41.

9.

Consider a p-type silicon semiconductor at $T = 300$ K doped at $N_a = 5 \times 10^{15}$ cm^{-3}. (a) Determine the position of the Fermi level with respect to the intrinsic Fermi level. (b) Excess carriers are generated such that the excess carrier concentration is 10 percent of the thermal-equilibrium majority carrier concentration. Determine the quasi-Fermi levels with respect to the intrinsic Fermi level. (c) Plot the Fermi level and quasi-Fermi levels with respect to the intrinsic level.

10.

In a n-type Ge semiconductor, the excess hole concentration is 10^{13} cm^{-3}, the hole lifetime is 100μs. Calculate the hole recombination rate at 300K.

11.

In the following conditions, please make a judgment whether there is net recombination or generation.

(a) Inside a semiconductor in which the charge carriers are all completely depleted.

(b) Inside a semiconductor in which only minority carriers are depleted (e.g. $p_n \ll p_{n0}$ and $p_n = p_{n0}$)

(c) Inside a semiconductor in which n=p ($n \gg n_i$)