VE320 Intro to Semiconductor Devices
Summer 2022 — Problem Set 3

June 2, 2022

Exercise 3.1

The thermal equilibrium hole concentration in silicon at $T = 300$ K is $p_0 = 2\times10^5$ cm^{-3}. Determine the thermal-equilibrium electron concentration. Is the material n type or p type?

Exercise 3.2

In silicon at $T = 300$ K, it is found that $N_a = 7 \times 10^{15}$ cm^{-3} and $p_0 = 2 \times 10^4$ cm^{-3}.
(a) Is the material n type or p type?
(b) What are the majority and minority carrier concentrations?
(c) What must be the concentration of donor impurities?

Exercise 3.3

A silicon device is doped with donor impurity atoms at a concentration of 10^{15} cm^{-3}. For the device to operate properly, the intrinsic carriers must contribute no more than 5 percent to the total electron concentration.

(a) What is the maximum temperature that the device may operate?

(b) What is the change in $E_c - E_F$ from the $T = 300$ K value to the maximum temperature value determined in part (a).

(c) Is the Fermi level closer or further from the intrinsic value at the higher temperature?

Exercise 3.4

Silicon is doped at $N_d = 10^{15}$ cm^{-3} and $N_a = 0$.

(a) Plot the concentration of electrons versus temperature over the range $300 \leq T \leq 600$ K.

(b) Calculate the temperature at which the electron concentration is equal to 1.1×10^{15} cm^{-3}.

Exercise 3.5

GaAs at $T = 300$ K is doped with donor impurity atoms at a concentration of 7×10^{15} cm^{-3}. Additional impurity atoms are to be added such that the Fermi level is 0.55eV above the intrinsic Fermi level. Determine the type (donor or acceptor) and concentration of impurity atoms to be added.

Exercise 3.6

A compensated p-type silicon material at $T = 300$ K has impurity doping concentrations of $N_a = 2.8 \times 10^{17}$ cm^{-3} and $N_d = 8 \times 10^{16}$ cm^{-3}. Determine the

(a) hole mobility
(b) conductivity
(c) resistivity

Exercise 3.7

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 $= 100$ V/cm. Assume that $\mu_n = 1000$ cm^2/V $\cdot$ 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.)

Reference

1. Neamen, Donald A. Semiconductor physics and devices: basic principles. McGraw-hill, 2003.