VE320 Intro to Semiconductor Devices
Summer 2022 — Problem Set 2

May 27, 2022

Exercise 2.1

Two possible valence bands are shown in the E versus k diagram given in Figure 1. State which band will result in the heavier hole effective mass; state why.

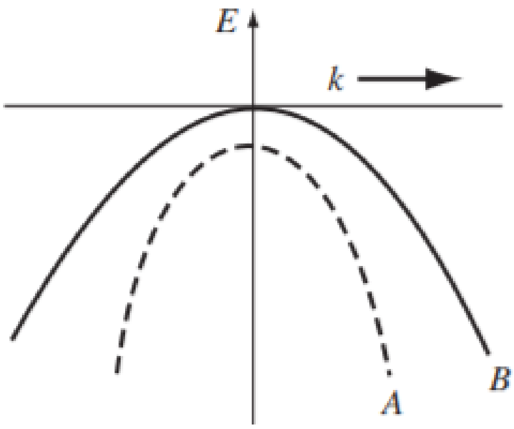

Figure 1: Valence bands for Problem 2.1.

Exercise 2.2

(a) The forbidden bandgap energy in GaAs is 1.42eV. (i) Determine the minimum frequency of an incident photon that can interact with a valence electron and elevate the electron to the conduction band. (ii) What is the corresponding wavelength?

(b) Repeat part (a) for silicon with a bandgap energy of 1.12eV.

Exercise 2.3

The energy-band diagram for silicon is shown in Figure 2. The minimum energy in the conduction band is in the [100] direction. The energy in this one-dimensional direction near the minimum value can be approximated by

$$E = E_0 - E_1 \cos \alpha (k - k_0)$$

where k_0 is the value of k at the minimum energy. Determine the effective mass of the particle at $k = k_0$ in terms of the equation parameters.

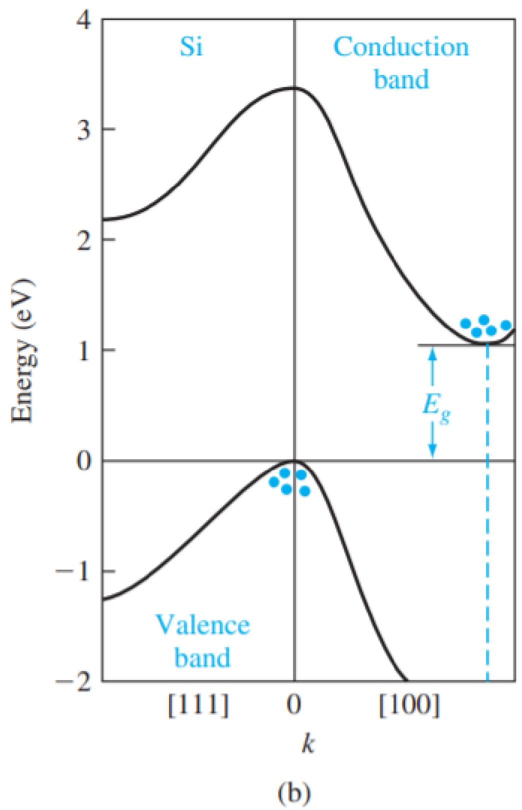

Figure 2: Energy-band structures of Si

Exercise 2.4

(a) Determine the total number (#/cm^3) of energy states in silicon between E_v and $E_v - 3kT$ at (i) $T = 300$ K and (ii) $T = 400$ K.

(b) Repeat part (a) for GaAs.

Exercise 2.5

(a) For silicon, find the ratio of the density of states in the conduction band at $E = E_c + kT$ to the density of states in the valence band at $E = E_v - kT$.

(b) Repeat part (a) for GaAs.

Exercise 2.6

Consider the energy levels shown in Figure 3. Let $T = 300$ K.

(a) If $E_1 - E_F = 0.30$eV, determine the probability that an energy state at $E = E_1$ is occupied by an electron and the probability that an energy state at $E = E_2$ is empty.

(b) Repeat part (a) if $E_F - E_2 = 0.40$eV.

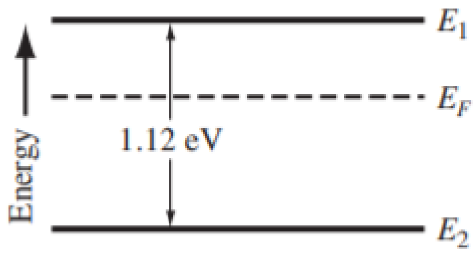

Figure 3: Energy levels for Problem 2.6

Exercise 2.7

(a) The carrier effective masses in a semiconductor are $m_n^* = 1.21m_0$ and $m_p^* = 0.70m_0$. Determine the position of the intrinsic Fermi level with respect to the center of the bandgap at $T = 300$ K.

(b) Repeat part (a) if $m_n^* = 0.080m_0$ and $m_p^* = 0.75m_0$.

Exercise 2.8

Silicon at $T = 300$ K is doped with boron atoms such that the concentration of holes is $p_0 = 5 \times 10^{15}$ cm^{-3}.

(a) Find $E_F - E_v$.

(b) Determine $E_c - E_F$.

(c) Determine n_0.

(d) Which carrier is the majority carrier?

(e) Determine $E_{Fi} - E_F$.

Reference

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