VE320 Intro to Semiconductor Devices

Summer 2022 — Problem Set for Chapter 7

June 28, 2022

Homework description

This is an extra exercise for Chapter 7, and you don't need to hand in.

Exercise 5.1

(a) Consider a uniformly doped silicon pn junction at $T = 300$ K. At zero bias, 25 percent of the total space charge region is in the n-region. The built-in potential barrier is $V_{bi} = 0.710$ V. Determine $(i) N_a$, $(ii) N_d$, (iii) x_n, (iv) x_p, and $(v) |\mathrm{E}_{\max}|$.

(b) Repeat part (a) for a GaAs pn junction with $V_{bi} = 1.180$ V.

Exercise 5.2

An "isotype" step junction is one in which the same impurity type doping changes from one concentration value to another value. An n-n isotype doping profile is shown in Figure 1.

(a) Sketch the thermal equilibrium energy-band diagram of the isotype junction.
(b) Using the energy-band diagram, determine the built-in potential barrier.
(c) Discuss the charge distribution through the junction.

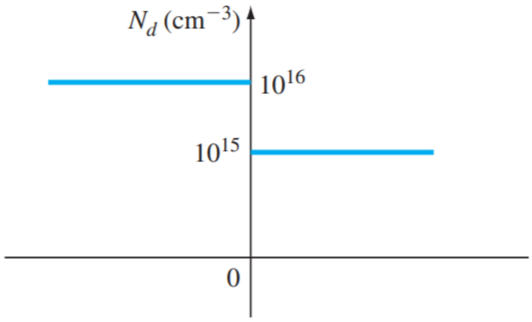

Figure 1: Figure for Problem 5.2

Exercise 5.3

An ideal one-sided silicon p^+n junction at $T = 300$ K is uniformly doped on both sides of the metallurgical junction. It is found that the doping relation is $N_a = 80N_d$ and the built-in potential barrier is $V_{bi} = 0.740$ V. A reverse-biased voltage of $V_R = 10$ V is applied. Determine

(a) N_a, N_d ;

(b) x_p, x_n ;

(c)$|\mathrm{E}_{\max}|$;

(d) C'_j.

Exercise 5.4

A silicon p^+n junction has doping concentrations of $N_a = 2 \times 10^{17}$ cm^{-3} and $N_d = 2 \times 10^{15}$ cm^{-3}. The cross-sectional area is 10^{-5} cm^2. Calculate

(a) V_{bi}

(b) the junction capacitance at (i) $V_R = 1$ V, (ii) $V_R = 3$ V, and (iii) $V_R = 5$ V.

(c) Plot $1/C^2$ versus V_R and show that the slope can be used to find N_d and the intercept at the voltage axis yields V_{bi}.

Exercise 5.5

A silicon pn junction at $T = 300$ K has the doping profile shown in Figure 2. Calculate
(a) V_{bi},
(b) x_n and x_p at zero bias, and
(c) the applied bias required so that $x_n = 30\mu$m

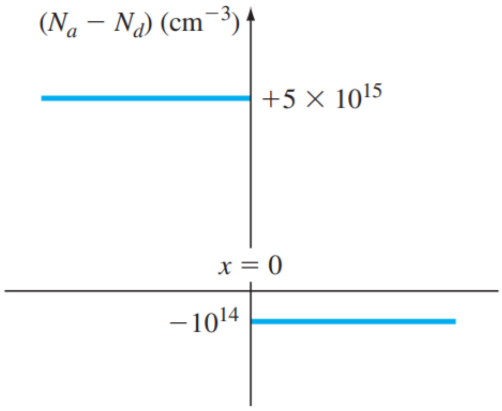

Figure 2: Figure for Problem 5.5

Exercise 5.6

Consider a silicon pn junction with the doping profile shown in Figure 3. $T = 300$ K.

(a) Calculate the applied reverse-biased voltage required so that the space charge region extends entirely through the p region.

(b) Determine the space charge width into the n^+region with the reverse-biased voltage calculated in part (a).

(c) Calculate the peak electric field for this applied voltage.

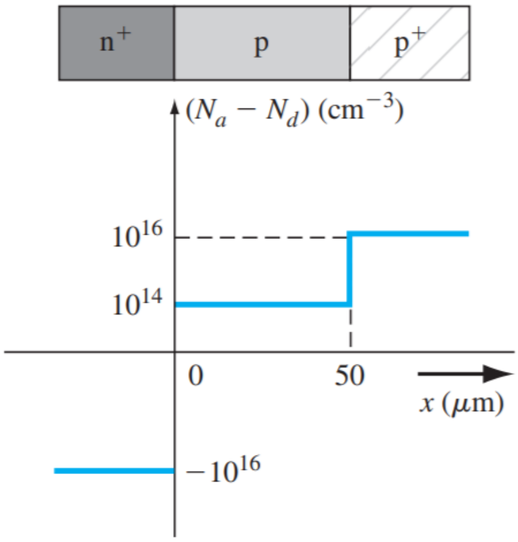

Figure 3: Figure for Problem 5.6

Exercise 5.7

Consider a silicon n^+p junction diode. The critical electric field for breakdown in silicon is approximately $E_{crit} = 4 \times 10^5$ V/cm. Determine the maximum p-type doping concentration such that the breakdown voltage is

(a) 40 V and

(b) 20 V.

Reference

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