Self-Exercise 2-16
A *pn* junction diode has $V_R = 1.5$ V, $C_j = 5$ fF, $C_{j0} = 9$ fF, $N_A = 10^{16}\text{cm}^{-3}$, and $T = 300$ K. Calculate N_D.

Answer: $N_D = 1.73 \times 10^{15}$ cm^{-3}.

2.7. Summary

The construction of integrated circuits depends on a strong physical theory. Chapter 2 introduced these essential concepts using a few modeling equations to deepen our thought processes. The purpose is qualitative understanding of the language and physical flow of semiconductor current, related doping properties, and diode characteristics. The diode depletion region is one of the essential properties of transistors. These ideas permeate later chapters. More information can be found in [1,2].

Bibliography

[1] D. A. Neamen, *Semiconductor Physics and Devices—Basic Principles*, 3rd Ed., McGraw Hill, 2010.

[2] Robert F. Pierret, *Semiconductor Device Fundamentals*, Addison-Wesley Pub. Co., 1996.

Exercises

Assume silicon material and use the constants given in this chapter.

Free Carrier Concentration

2-1. If $n_i = 1.67 \times 10^{11}$ (carriers/cm^3), what is the temperature?

2-2. What fraction of Si atoms is ionized at $T = 100^\circ$C?

2-3. The intrinsic carrier concentration ratio at two temperatures is 303. If the lower temperature is at room temperature (300 K), what is the other temperature?

2-4. Plot n_i versus temperature for $T = 250$ K, 300 K, 350 K, and for 400 K. Why would a log plot be preferred over a linear plot? What does the plot tell us?

2-5. A semiconductor chip is operating at 100°C. What temperature would reduce the intrinsic carrier concentration by a factor of five?

Extrinsic Semiconductors

2-6. If $N_A = 10^{17}$ cm^{-3} at 300 K, what is the electron concentration?

2-7. The silicon to donor atom ratio is 10,000:1. What is the hole concentration at $T = 300$ K?

2-8. If $T = 385$ K and acceptor doping $N_A = 6 \times 10^{18}$, calculate the minority carrier concentration.

2-9. The electron concentration in extrinsic silicon at 300 K is 5×10^4 cm^{-3}. The carrier intrinsic concentration of silicon at 300 K was measured at 1.5×10^{10} cm^{-3}. Determine the hole concentration and indicate if the material is *p*-type or *n*-type.

2-10. The minority concentration is $n_o = 4.5 \times 10^4$ and the doping concentration is $N_A = 10^{18}$. What is the temperature of the semiconductor?