

Series 1

Method of simulation and modeling of semiconductors.

Exercise 1:

Briefly answer the following questions:

1. What is an intrinsic semiconductor?
2. Why dope a semiconductor?
3. How do we dope Si to obtain an N-type semiconductor?
4. How do we dope Si to obtain a P-type semiconductor?
5. What parameter does the application of a low-amplitude electric field to a Si bar generate?
6. What does the polarization of a PN junction cause?
7. What does the mobility of carriers in a semiconductor depend on?
8. What creates the movement of carriers in the PN junction?
9. What are the charges that move in a PN junction?
10. Calculate the intrinsic concentration n_i at 300 K ($E_g=1.1$ eV, $A=5.23 \times 10^{15} \text{cm}^{-3} \text{K}^{-3/2}$, $k=8.61 \times 10^{-5} \text{eV/K}$)
11. What charges move in a pn junction, electrons or holes?
12. What charges move in a conductor, electrons or holes?
13. Explain what happens when holes moving in a semiconductor reach the conductor (metal).
14. Explain the concept of majority and minority carriers in a pn junction.
15. What is the overall charge of an N-doped semiconductor?
16. What creates the movement of carriers in a conductor?
17. What creates the movement of carriers in a pn junction?

Exercise 2:

Consider an N-doped silicon with a resistivity of 0.1 Ωcm .

- 1 Explain the basic principle of doping semiconductors.
- 2 What is the conductivity of doped silicon?
- 3 Deduce the concentration of electrons and holes in doped silicon.

Exercise 3:

An intrinsic semiconductor (Germanium) Ge at 300°K, we have: $E_g = 0.66\text{eV}$, $m^*_e = m^*_h = 0.5m_0$ and the mass $M_{\text{Ge}} = 72.59\text{g}$, the density $\rho = 5.33\text{g/cm}^3$ and $N_A = 6.1023$ Avogadro number

1. Determine the Fermi level (E_{Fi})?
2. The intrinsic concentration (n_i)?
3. How many Ge atoms give rise to an electron-hole pair?

Exercise 4

Consider an intrinsic semiconductor whose equivalent densities of energy states in the conduction band and in the valence band are denoted respectively N_C and N_V .

1. Recall the expressions for the electron density n in the conduction band and the hole density p in the valence band?
2. Deduce the expression for the intrinsic density n_i and the position of the intrinsic Fermi level E_{Fi} ?
3. The semiconductor considered is silicon with a band gap $E_g = 1.1\text{eV}$ and for which $N_C = 2.7 \times 10^{19}\text{cm}^{-3}$ and $N_V = 1.1 \times 10^{19}\text{cm}^{-3}$.
4. Calculate its intrinsic density and the position of the Fermi level at 27°C, 127°C and 227°C.

We recall that at 300°K, $kT = 0.026\text{ eV}$, we will take as energy reference, the top of the valence band ($E_V = 0\text{eV}$).

Exercise 5

Germanium is characterized by:

Band gap energy: $E_g = 0.67\text{ eV}$.

Boltzmann constant: $K_B = 8.62 \times 10^{-5}\text{ eV /}^\circ\text{K}$.

Effective density of energy states at 300 °K: $N_C = 1.04 \times 10^{19}\text{cm}^{-3}$ and $N_V = 6 \times 10^{18}\text{cm}^{-3}$.

- 1- Calculate the intrinsic concentration n_i at 300 °K.
- 2- Determine the position of the intrinsic Fermi level E_{Fi} at 300 °K. We will take as energy reference, the top of the valence band ($E_V = 0\text{ eV}$)

Exercise 6

A silicon (Si) single crystal is doped with 10^{16}cm^{-3} of phosphorus (P). We give 10^{10}cm^{-3} at 300 °K. 1- Give the type of doped material. 2- Calculate the electron and hole densities.