ELEC-3140 Semiconductor physics Dec 7, 2021

This is the last exercise!

Exercise 9: pn-junction

1. Resistivity and mobility of the p-side of a silicon diode are $\rho = 0.1\ \Omega\text{cm}$ and $\mu_p = 450\ \text{cm}^2\text{V}^{-1}\text{s}^{-1}$; for n-side $\rho = 2\ \Omega\text{cm}$ and $\mu_n = 1500\ \text{cm}^2\text{V}^{-1}\text{s}^{-1}$. The area of the junction is A = 0.05 cm^2 and minority carrier lifetime in the n-side is 50 μs and in the p-side 15 μs. For silicon $n_i = 1.45 \cdot 10^{10}\ \text{cm}^{-3}$ and $\varepsilon_r = 11.9$ at T = 300 K. For non-biased junction, calculate a) built-in voltage, b) the width of the depletion region and c) the maximum electric field strength.

2. Let us consider an abrupt pn-junction in silicon ($n_i = 10^{10}$ cm^{-3}) with doping concentrations of $N_A = 1 \cdot 10^{16}\ \text{cm}^{-3}$ and $N_D = 5 \cdot 10^{16}\ \text{cm}^{-3}$. a) Calculate the built-in voltage of the junction. b) Calculate the width of the depletion region, the maximal value of the electric field and the potential difference over the n-side in the cases of the external bias V_a value of -2.5, 0, and 0.5 V.

3. A pn-diode has the same doping concentration on both the p- and the n-side. The maximum electric field at thermal equilibrium is –13 kV/cm and the overall width of the depletion region is 1 μm. Use dielectric constant of $\varepsilon = 12\varepsilon_0$. a) What is the built-in voltage of the diode? b) What is the donor concentration in the n-side and the acceptor concentration in the p-side? c) What is n_i at the temperature of 300 K?

4. Calculate the current density caused by generation-recombination in a silicon pn-diode with the reverse bias voltage of $V = -4$ V. Generation rate and effective lifetime are given by

$$g = \frac{n_i}{2\tau_0} \text{ and } \tau_0 = \frac{\tau_n + \tau_p}{2},$$

respectively. Assume that generation rate is constant in the depletion region. Compare the result with the reverse current of an ideal pn-diode with the same bias. Values: $N_a = 10^{17}\ \text{cm}^{-3}$ $N_d = 10^{17}\ \text{cm}^{-3}$, $n_i = 1.5 \cdot 10^{10}\ \text{cm}^{-3}$, $\varepsilon_r = 11.9$, $\tau_p = \tau_n = 10^{-6}$ s, $D_p = 10\ \text{cm}^2/\text{s}$, $D_n = 20\ \text{cm}^2/\text{s}$.