Serie 04

Preamble

PN-junction under bias

In the previous series, we derived the charge, electric field, and electric potential distributions in a PN-junction at thermal equilibrium. By applying a bias to this junction, these previously calculated distributions will change. Since the semiconductor is conductive outside the space charge region **(SCR)**, no electric field can exist in these regions. This implies that any potential applied to the PN-junction will directly affect the potential in the SCR. Essentially, we can rewrite the previous equations by replacing the built-in potential ϕ_b with the built-in potential ϕ_b minus the applied forward voltage V_F.

Given constants

$n_i(Si) = 1.5 \cdot 10^{10}\,[cm^{-3}] \quad @ \quad T = 300\,[K]$
$k = 8.62 \cdot 10^{-5}\,[eV/K]$
$q = 1.60 \cdot 10^{-19}\,[C]$
$\epsilon_0 = 8.85 \cdot 10^{-14}\,[F/cm]$
$\epsilon_{Si} = 11.7 \cdot \epsilon_0$

Exercise 01

We consider a PN-junction with known dopant concentrations of $N_A = 10^{16}\left[cm^{-3}\right]$ for the P-type region $N_D = 10^{15}\left[cm^{-3}\right]$ for the N-type region. At room temperature, with an applied forward bias voltage of $U = -5\,[V]$, find the depletion width and the maximum electric field.

Exercise 02

Find the concentrations of dopants N_a and N_d of a PN junction using the room-temperature Mott-Schottky plot given below. Assume that the N-type and P-type regions are doped only with their respective dopants. The slope of the graph is $\alpha = -1350 \left[\left(\frac{\mu F}{cm^2} \right)^{-2} V^{-1} \right]$and the intersection with the horizontal axis is$V_0 = 855\, [mV]$.Your hypothesis is that the diode is asymmetrically doped $(N_a \gg N_d)$. Verify this hypothesis.

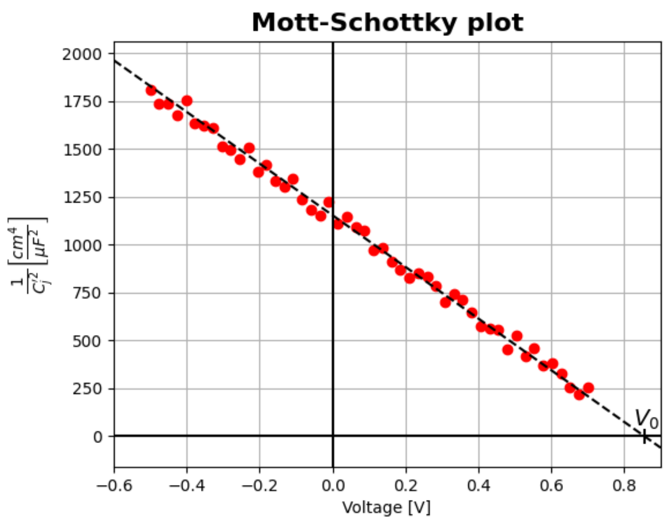

Figure 1: Mott-Schottky plot.

Exercise 03

As an electrical engineer, you are tasked with designing a VHF transmitter operating on the guard frequency (reserved for aircraft emergencies) at $f = 121.5\,[MHz]$. To achieve this, you decide to use the depletion capacitance of a diode (used as a varicap) to select the frequency in a simple LC oscillator.

The selected diode is a silicon diode with uncompensated doping, operating at room temperature, with the following dopant concentrations: $N_A = 4 \cdot 10^{16}\,\left[cm^{-3}\right]$ and $N_D = 8 \cdot 10^{15}\,\left[cm^{-3}\right]$ for the p-type and n-type regions, respectively. The p-n junction of the diode has a total length of $L_D = 900\,[\mu m]$ and a circular cross-section with an area of $A = 1\,\left[mm^2\right]$.The chosen inductance is $L = 12\,[nH]$.

Find the bias voltage required to tune the transceiver to the correct frequency.

Hint: As a reminder, the resonance frequency of an LC circuit is given by:

$$f_0 = \frac{1}{2\pi\sqrt{LC}} \tag{1}$$

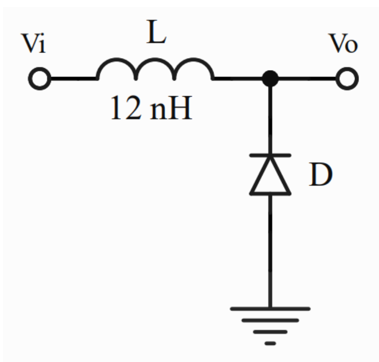

Figure 2: Basic LC resonator schematic.