VE320 Intro to Semiconductor Devices
Summer 2022 — Homework 5

July 5, 2022

Homework description

For your homework 5, which is the part of the pn junction, there will be less content to calculate. There will be only one research question. This homework will be a group assignment, and each group only needs to submit ONE report. Please note that the data may vary for each group. Please choose your teammates freely and sign up in Canvas-people-group before 6.26 this Sunday. On June 27th, we will randomly assign students who do not have teammates yet. Please note that homework 5 will be due on July 11th 23:59 with a one-day grace period.

Exercise 5.1

Suppose a silicon PN junction diode has a p-type and n-type doping at a concentration of $(50+m) \times 10^{15}$ cm^{-3} and $(120-m) \times 10^{15}$ cm^{-3}, respectively, in which m is your team number. When we solve the Poisson's equation, we assume $p(x)$ and $n(x)$ are zero in the depletion region so that we can derive the analytical solution of $V(x)$ as shown in the figure below. Now please write a code to find the numerical solution of $V(x)$ if we assume $n(x)$ and $p(x)$ are not zero but the expressions below. Please write a short report showing the $V(x)$ curves found from the analytical and numerical solution, respectively. Please estimate the accuracy of the analytical solution in terms of depletion region width, electric field intensity and ac capacitance.

$$
\begin{aligned}
\frac{d^2V(x)}{dx^2} &= -\frac{\rho(x)}{\varepsilon} \\
&= -\frac{q}{\varepsilon}\left[N_d(x) - N_a(x) + p(x) - n(x)\right] \\
&= -\frac{q}{\varepsilon}\left[N_d(x) - N_a(x) + n_i \exp\left(\frac{E_i(x)-E_F}{kT}\right) - n_i \exp\left(\frac{E_F - E_i(x)}{kT}\right)\right] \\
&= \begin{cases} -\frac{q}{\varepsilon}\left[-N_a + N_a \exp\left(\frac{-qV(x)}{kT}\right) - N_d \exp\left(\frac{q[V(x)-V_{bi}]}{kT}\right)\right] & 0 \le x \le x_p \\ -\frac{q}{\varepsilon}\left[N_d + N_a \exp\left(\frac{-qV(x)}{kT}\right) - N_d \exp\left(\frac{q[V(x)-V_{bi}]}{kT}\right)\right] & -x_n \le x < 0 \end{cases}
\end{aligned}
$$

Hint:

1. You could refer to this diagram.
2. $x = x_p$ or x_n, the second derivative of $V(x)$ equal to 0 can be used as a boundary condition.

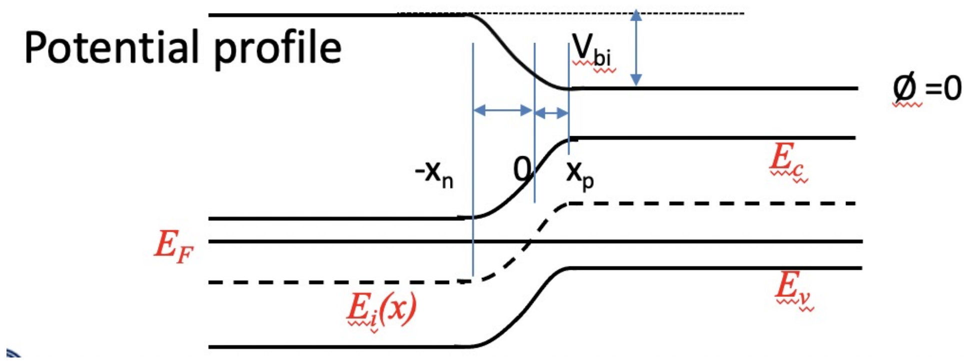

Figure 1: band diagram

Attach your code after your report.

Reference

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