ASSIGNMENT 3

ANALYSIS OF JUNCTION DIODE WITHOUT DEPLETION APPROXIMATION

(EE 735 MICROELECTRO1NICS SIMULATION LAB)

Due Date: 1st September 2023

Introduction

Use Newton-Raphson method to solve Poisson's equation for the given devices under thermal equilibrium conditions at 300 Kelvin temperature. Use finite central difference scheme for numerical solutions.

The 1-dimensional Poisson's equation is

$$\frac{d^2V}{dx^2} = -\frac{\rho}{\varepsilon}$$

where ρ is charge per unit volume, and ε is the permittivity. Use Maxwell-Bolzmann statistics for electron and hole concentrations. Consider complete ionization of donor (ND) and acceptor (NA) dopants.

Use material parameters specific to silicon unless mentioned otherwise.

Plot the following profiles as a function of x (i.e. spatial variation) for all the questions:

1. Potential (V)
2. Electric Field(E)
3. Charge concentration (ρ/q) (where q is electron charge)
4. Electron (n) and hole (p) concentrations
5. Energy band diagram depicting conduction band minimum (E_C), Valence band maximum (E_V), mid gap energy level (E_{mid}) and Fermi energy level (E_F) .

Note: 1. State your assumptions, if any.

2. Last 2 digits of your roll no are a, b respectively. Ex: Roll No. 22M1132, a=3, b=2

3. ε_r=11.8, n_i=1.5*10^{10}/cm3

Q1. P-N junction diode (see Figure 1:(a)). Thickness of the P and N regions is L = 1.5 µm each. For the following doping profiles, plot **profiles 1-3** (from introduction section) **with and without depletion approximation** and plot **profiles 4-5**(from introduction section) **without depletion approximation**

a) Abrupt junction (see Figure 1:(b)) with dopant concentrations N_A = $(1+a)10^{15}$/cm3 N_D = $(1+b)10^{15}$/cm3.
b) Linearly graded junction (see Figure 1:(c)) with bulk dopant concentrations NA = ND = $(1+b)10^{15}$/cm3

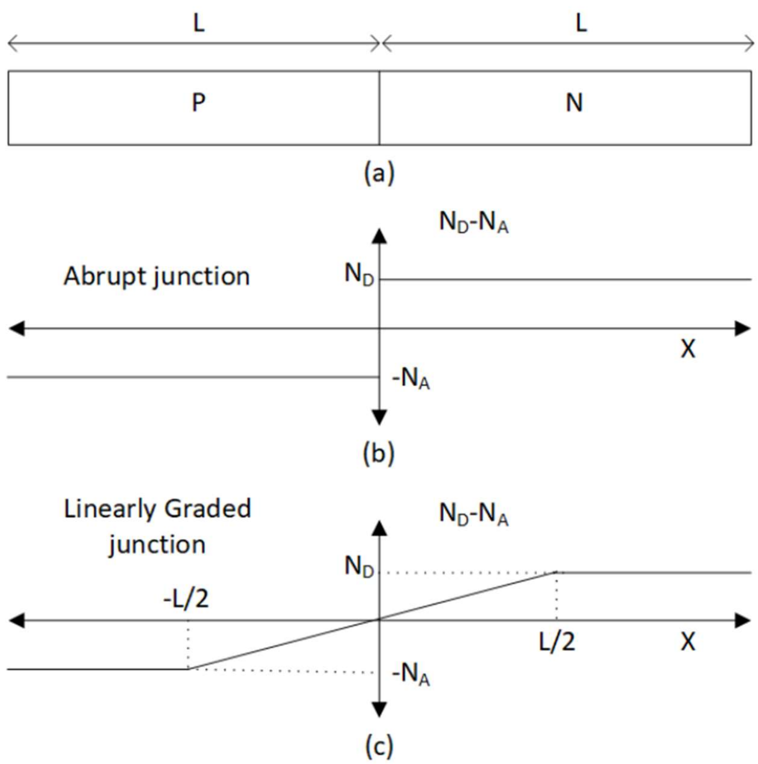

Figure 1:

Note: Shown doping profile exists only in the depletion region

Q2. P^+-N-N^+ structure with abrupt junctions. $N_A = 10^{17}$ /cm3 inside P^+ region; whereas $N_D = 10^{17}$ /cm3 inside N^+ region and 10^{15} /cm3 inside N region. With the thickness of P^+ and N^+ regions fixed at 0.5 µm each, vary the thickness of N region over the range (1, 2, 3) µm.

Show the variation of (V vs X) as a function of N region length (L_N). (Plot all the profiles in a single plot)

Discuss your observation. (The profiles asked in the Introduction section should be plotted only for LN = 2µm).

Q3. Design a N^+ - N junction diode with a built in potential of "0.06+ $\frac{ab}{300}$"V (take upto 2 digits) with 5% tolerance, at a temperature of 300K. Consider intrinsic concentration of the material used only in the range of [$1*10^{10}$, $2*10^{10}$]/cm3 at all temperatures. Consider E_g=1.12eV at all temperatures. Consider relative permittivity to be 11.8.

For the final structure the following questions are to be answered

a) State the lengths of N^+, N regions respectively.
b) State doping concentrations of both regions and intrinsic concentration.
c) Plot all the profiles asked in the introduction section.
d) For the same structure, plot Potentials at 300 K and 300+1.5*a K.
e) Is the voltage obtained for 300+1.5*a (from d part) correct? State your reasoning

Note: Consider your doping concentrations such that Boltzmann approximation should hold