EE 735
Assignment –6

Date: 04-10-2023

Hints, assumptions and instructions:

1. Assume uniform doping of p and n regions wherever needed. Also consider an abrupt junction for PN junction case.
2. Assume Ohmic contacts.
3. Refer to the user manual whenever you need help. For example, refer to chapter-16 of sdevice_ug.pdf for recombination model.
4. You can use equations to give explanations but you also need to give a physical/intuitive reasoning for full credit.
5. Ensure that every plot has properly labelled x, y-axes with units and a corresponding legend.
6. Specify any physical quantity with its units.
7. It is mandatory to submit your code with the report (in pdf) in a single zip folder. Name the file as "**RollNumber_Assignment6**" for this assignment.

Questions:

Q1. Consider a PN junction as shown in Figure 1; $N_A = 10^{17}$ cm^{-3} and $N_D = 10^{17}$ cm^{-3}

Plot the I-V in semi-log scale for the following cases with the voltage ranging from -10V to 2V:

Note: For part (a) use only SRH and for part (b) use only band-to-band recombination models.

(a) SRH

(a.1) With and without SRH (Shockley-Read-Hall) recombination. Explain the difference in the I-V characteristics (if any).

(a.2) In the "models.par" file, change the value of "taumax" to "1e-7" and "3e-8" for electrons and holes respectively. Explain the changes in the I-V characteristics (semi-log).

(a.3) Repeat (a.2) for "taumax"="1e-4" and "3e-5" for electrons and holes respectively. Explain the changes in the I-V characteristics (semi-log).

(b) Band-to-band

(b.1) With and without band-to-band recombination (E2 model). Explain the difference in the plots (if any).

(b.2) For various doping levels of $N_A = N_D = 5x10^{17}$, 10^{18} and 10^{19} cm^{-3} with band-to-band recombination. Explain the trend.

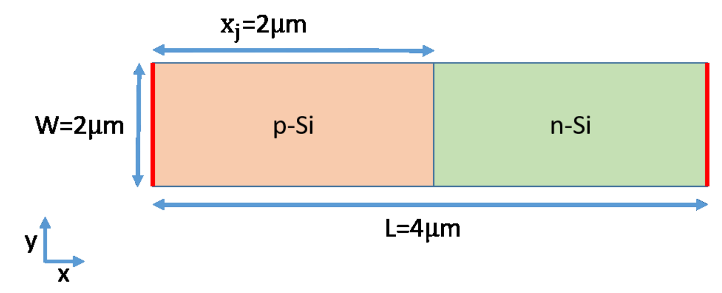

Figure 1

Q2. Simulate and plot the band diagram and charge profiles (electron and hole) of a MOS capacitor (n-MOS) biased at $V_g = V_T$ (inversion region) based on the data given in part (a). Use Al as gate metal. Figure 2 shows the schematic of a typical MOS device. Consider L = W = 1µm.

a) Take gate-oxide (SiO_2) thickness t_{ox} = 3 nm and Si substrate doping $N_A = 3x10^{16}$ cm^{-3}.

b) Now, change the SiO_2 thickness to 2 nm for the same substrate doping as in part-a

c) Consider t_{ox} = 3 nm and change the substrate doping to $N_A = 3x10^{17}$ cm^{-3}.

Note: Please write your observations on how oxide thickness and substrate doping concentration affect the V_T.

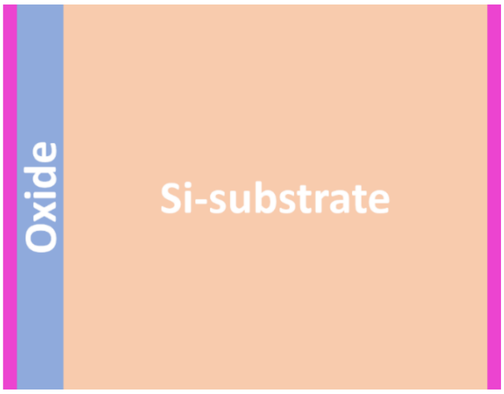

Figure 2: Schematic of a MOS capacitor

Q3. Simulate and plot the C-V (at 100 kHz) of a MOS capacitor (n-MOS) for a voltage range of -5V to 2V. Use substrate doping of $3x10^{17}$ cm^{-3} and Al as gate metal. Consider L = W = 1µm.

a) Take gate-oxide (SiO_2) thickness t_{ox} = 2 nm and plot C-V characteristics

b) Now, replace the SiO_2 gate oxide with HfO_2 and plot C-V characteristics together with part (a). Write your observations and how this change of gate oxide affects the C-V & the threshold voltage.

c) Use HfO_2 as gate-oxide with EOT of part (a) and plot the C-V together with part (a) & (b). Write your observations and how this change of gate oxide and EOT affects the C-V characteristics and the threshold voltage in all three cases.