Home work # 2

Question 1 (25pts):

Consider a diffusion area in Si that is 20 by 40 microns with an abrupt junction depth of .2 microns. Assume that the doping is uniform in the diffused area and that the doping levels are:

$$N_D := 10^{19}\text{cm}^{-3} \quad N_A := 10^{16}\text{cm}^{-3} \quad L := 20\cdot 10^{-4}\text{cm} \quad W := 40\cdot 10^{-4}\text{cm}$$

$$xj := .2\cdot 10^{-4}\text{cm}$$

$$q := 1.6\cdot 10^{-19}\text{C} \quad ni := 1.5\cdot 10^{10}\text{cm}^{-3} \quad k := 1.38\cdot 10^{-23}\frac{\text{J}}{\text{K}} \quad T := 300\text{K}$$

$$\phi_0 := \frac{k\cdot T}{q}\cdot \ln\left(\frac{N_D\cdot N_A}{ni^2}\right) \quad \phi_0 = 872.708\times 10^{-3}\text{V} \quad \varepsilon_{Si} := 11.8\cdot 8.85\cdot 10^{-14}\frac{\text{F}}{\text{cm}}$$

$$V_D := 5\text{V}$$

Since the doping is the same on the bottom of the diffused area as the side walls, We only need to calculate One Built in voltage and depletion width, W.

First add up the areas:

$$\text{Area\_sidewall\_1} := 2\cdot L\cdot xj \quad \text{Area\_sidewall\_1} = 80\times 10^{-9}\text{cm}^2$$

$$\text{Area\_sidewall\_2} := 2\cdot W\cdot xj \quad \text{Area\_sidewall\_2} = 160\times 10^{-9}\text{cm}^2$$

$$\text{Area\_bottom} := W\cdot L \quad \text{Area\_bottom} = 8\times 10^{-6}\text{cm}^2$$

$$\text{Area\_Total} := \text{Area\_sidewall\_1} + \text{Area\_sidewall\_2} + \text{Area\_bottom}$$

$$\text{Area\_Total} = 8.24\times 10^{-6}\text{cm}^2 \quad V_D := -5\text{V}$$

$$C_{j0} := \sqrt{\frac{\varepsilon_{Si}\cdot q}{2}\cdot\left(\frac{N_A\cdot N_D}{N_A + N_D}\right)\cdot\frac{1}{\phi_0}}$$

$$\text{Area} := \text{Area\_Total}$$

$$C_j := \frac{\text{Area}\cdot C_{j0}}{\left(1 - \frac{V_D}{\phi_0}\right)^{.5}} \quad C_j = 98.231\times 10^{-15}\text{F}$$

Question 2 (25pts):

The electrical length of a mosfet is all ways smaller than the physical length of the polysilicon. THe junction undercuts the gate on bothe ends by rj. THen the deplition width shrinks the gate length even more. The depetion width on the drain side moves with the voltage applied while the source side is tied to ground.

$$L_{eff} = L_{Drawn} - 2 \cdot r_j - x_{d\_source} - x_{d\_drain}$$

Sometimes what you draw is manipulated by the3 mask maker as well.

Question 3 (25pts):

$N_{A\_bottom} := 5\cdot 10^{17} cm^{-3}$ $\quad$ $N_D := 5\cdot 10^{20} cm^{-3}$

$N_{A\_sidewall} := 1\cdot 10^{19} cm^{-3}$ $\quad$ This is the channel stop doping.

$$\phi_{j0} := \frac{k\cdot T}{q}\cdot \ln\left(\frac{N_D\cdot N_{A\_bottom}}{ni^2}\right) \qquad \phi_{j0} = 1.075\times 10^0 V$$

$$\phi_{sidewall0} := \frac{k\cdot T}{q}\cdot \ln\left(\frac{N_D\cdot N_{A\_sidewall}}{ni^2}\right) \qquad \phi_{sidewall0} = 1.153\times 10^0 V$$

The areas get manipulated a bit. In this case the botton junction and the sidwall of the gate have the same doping profile, will the other threee sides of the jucntion have a differnt one.

$$C_{j0} := \sqrt{\frac{\varepsilon_{Si}\cdot q}{2}\cdot\left(\frac{N_{A\_bottom}\cdot N_D}{N_{A\_bottom}+N_D}\right)\cdot\frac{1}{\phi_0}} \qquad C_{j0} = 2.187\times 10^{-3}\frac{1}{m^2}F$$

$$C_{sidewall0} := \sqrt{\frac{\varepsilon_{Si}\cdot q}{2}\cdot\left(\frac{N_{A\_bottom}\cdot N_D}{N_{A\_bottom}+N_D}\right)\cdot\frac{1}{\phi_{sidewall0}}}$$

$$C_{sidewall0} = 1.903\times 10^{-3}\frac{1}{m^2}F$$

$Y := 25\cdot 10^{-4} cm \quad L_D := .25\cdot 10^{-4} cm \quad W_N := 15\cdot 10^{-4} cm \quad x_j := 1.5\cdot 10^{-4} cm$

$Area\_Bottom := W_N\cdot L_D \qquad Area\_Bottom = 37.5\times 10^{-9} cm^2$

$Area\_Sidewall\_Gate := W_N\cdot x_j \qquad Area\_Sidewall\_Gate = 225\times 10^{-9} cm^2$

$Area\_1 := Area\_Bottom + Area\_Sidewall\_Gate \qquad Area\_1 = 262.5\times 10^{-9} cm^2$

$Area\_Sidewall\_NotGate := W_N\cdot x_j \qquad Area\_Sidewall\_NotGate = 225\times 10^{-9} cm^2$

$Area\_Sidewall := 2\cdot L_D\cdot x_j \qquad Area\_Sidewall = 7.5\times 10^{-9} cm^2$

$Area\_2 := Area\_Sidewall + Area\_Sidewall\_NotGate \qquad Area\_2 = 232.5\times 10^{-9} cm^2$

$$K_{eqbottom} := \frac{-2\cdot\sqrt{\phi_0}}{-5V-(-2.5V)}\cdot\left[\sqrt{\phi_0-(-5V)}-\sqrt{\phi_0-(-2.5V)}\right]$$

$$K_{eqbottom} = 438.6\times 10^{-3}$$

$$K_{eqsidewall} := \frac{-2\cdot\sqrt{\phi_{sidewall0}}}{-5V-(-2.5V)}\cdot\left[\sqrt{\phi_{sidewall0}-(-5V)}-\sqrt{\phi_{sidewall0}-(-2.5V)}\right]$$

$$K_{eqsidewall} = 488.939\times 10^{-3}$$

$$C_{eq} := Area\_1\cdot C_{j0}\cdot K_{eqbottom} + Area\_2\cdot C_{sidewall0}\cdot K_{eqsidewall}$$

$$C_{eq} = 46.806\times 10^{-15}F$$

Question 4 (25pts):

$V_{T0} := .8V \qquad \lambda := .05V^{-1} \qquad \phi_F := \frac{.58V}{2} \qquad KP := 20\cdot 10^{-6}\frac{A}{V^2}$

$\gamma := .2V^{\frac{1}{2}}$

$V_G := 2.8V \qquad V_D := 5V \qquad V_S := 1V \qquad V_B := 0V \qquad I_D := .24\cdot 10^{-3}A$

$V_T := V_{T0} + \gamma\cdot\left[\sqrt{2\cdot\phi_F + (V_S - V_B)} - \sqrt{2\cdot\phi_F}\right] \qquad V_T = 899.081\times 10^{-3}V$

$V_{GS} := V_G - V_S \qquad V_{GS} = 1.8\times 10^{0}V$ This is above VT

$V_{DS} := V_D - V_S \qquad V_{DS} = 4\times 10^{0}V$

$V_{GS} - V_T = 900.919\times 10^{-3}V$ This is less than VDS so we are in saturation.

$\frac{KP}{2}\cdot(V_{GS} - V_T)^2\cdot(1 + \lambda\cdot V_{DS})\cdot\frac{1}{I_D} = 40.583\times 10^{-3}$

$WL\_Ratio := \frac{1}{40.583\cdot 10^{-3}} \qquad WL\_Ratio = 24.641\times 10^{0}$

Part B:

$V_G := 5V \qquad V_D := 4V \qquad V_S := 2V \qquad V_B := 0V$

$V_T := V_{T0} + \gamma\cdot\left[\sqrt{2\cdot\phi_F + (V_S - V_B)} - \sqrt{2\cdot\phi_F}\right] \qquad V_T = 968.932\times 10^{-3}V$

$V_{GS} := V_G - V_S \quad V_{GS} = 3 \times 10^0 \, V$ This is above VT

$V_{DS} := V_D - V_S \quad V_{DS} = 2 \times 10^0 \, V$

$V_{GS} - V_T = 2.031 \times 10^0 \, V$ This is slightly bigger than VDS so we have to use linear..

$$I_D := \frac{KP}{2} \cdot WL\_Ratio \cdot \left[2 \cdot \left(V_{GS} - V_T \right) \cdot V_{DS} - V_{DS}^{\,2} \right] \quad I_D = 1.016 \times 10^{-3} A$$

Part C

$$\mu_N := 500 \frac{cm^2}{V \cdot s} \qquad C_g := 1 \cdot 10^{-15} F$$

$$C_{ox} := \frac{KP}{\mu_N} \qquad C_{ox} = 40 \times 10^{-9} \frac{F}{cm^2}$$

$$W = WL\_Ratio \cdot L$$

$$C_g = C_{ox} \cdot (WL\_Ratio \cdot L) \cdot L$$

$$L := \sqrt{\frac{C_g}{C_{ox} \cdot WL\_Ratio}} \qquad L = 31.852 \times 10^{-6} \, cm$$

$$W := WL\_Ratio \cdot L \quad W = 784.87 \times 10^{-6} \, cm$$