EECS 523: Homework #5

1- Sketch the threshold voltage V_{th} for a long-channel NMOS as a function of the Boron implant dose Q for Q = 10^{11}, 5x 10^{11} , 10^{12} and $5x10^{12}$ cm^{-2} for V_{SB} = 0V. Assume the following:

i. Boron is implanted at 30keV. A thermal cycle of 1000°C for one hour is performed after the B implants to drive in and activate the dopants. A sacrificial oxide of 400A was present during the implant and then is stripped off during a later step.

ii. There is no dopant redistribution.

iii. Use the step-profile approximation $N_S X_S = D_I$ with $N_S = 0.5N_{O.}$

iv. $N_{SUB} = 10^{15}$ cm^{-3}, N_{GATE} (N-type) = $10^{20} cm^{-3}$, X_{OX} = 200 A

2- For a long-channel MOSFET with channel length L:

(a) Derive equations for the channel voltage V(y) and the y-directed electric field $E_y(y)$ based upon the long-channel theory presented in lecture. Express both as functions of the threshold voltage V_{th}, geometric dimensions, and applied voltages (i.e., V_{gs}, etc. ...). For your derivation, note that I_d is constant along y and take $V_s = V_b = 0$ V.

(b) From the expressions derived, obtain equations for V(y) and $E_y(y)$ that are valid when the MOSFET is at the edge of saturation.

(c) Using the results above, sketch $-E_y(y)*L/(V_{gs}-V_{th})$ as a function of y over the range y = 0 to y = L for $V_{gs}>V_{th}$ and V_{ds} = 0.25, 0.50, 0.75, and 1 times V_{dsat}

(d) Explain why $E_y(y)$ approaches a constant value when V_{ds} is small.

(e) Find an expression for the total inversion charge in the channel (in Coulombs), in a transistor with width W, as a function of V_{gs}.

3- In this problem, we will perform the same fabrication sequence as we did in Homework 4 but this time in the Process Simulator **TSUPREM4**. The code for simulation is given in the problem and the processing steps are the same as they were in Homework 4. However, this is only for the NMOS device but the processing steps (annealing, oxidation) due to other devices (like capacitor, PMOS) have been taken care of. So we should get similar results as we got from our hand calculations for the gate oxide thickness, Source/Drain depths, Impurity concentration etc. You have to perform the simulation and extract the values that the simulation gives and include them with your homework.

Go through the given program and see that it follows the same steps as Homework 4. Comments are included to help you visualize the steps. When you run the program, the program plots the device cross-section after each step so that you can see how the device and impurity concentration looks after each step. The simulation is done to produce the left half of the device and then a REFLECT statement is used to make the complete device. This will become clear as you see the plots. In the plots the following colors correspond to the following regions:

Yellow – Silicon
Blue - Silicon Dioxide
Orange - Silicon Nitride
Green – PolySilicon
Red – Aluminum
Dotted Blue lines - Arsenic concentration lines
Dotted Red lines - Boron concentration lines

You can copy the source file from the GSI's directory by doing the following:

Log in to your CAEN account. Copy the file to your directory by typing the command

cp /afs/engin.umich.edu/u/c/y/cyew/Public/nmos/*.* ~/

Run the file by typing **TSUPREM4 NMOS** on the **UNIX** prompt. You should run the simulation only on SUN/HP workstations. After the simulation is over, a file called nmos.out will be created. You should read the file and extract information like gate oxide thickness and Source/Drain thickness from there.

Answer the following questions:

(a) What is the value of R_p and ΔR_p for the threshold voltage adjust implant?
(b) What is the gate oxide thickness?
(c) What is the Source/Drain junction depth?