NE 205: Semiconductor Devices and IC Technology
Indian Institute of Science, Bangalore.
Autumn Semester 2019, Digbijoy N. Nath
Homework V Total points: 40

1. Calculate the shift in the flat band voltage of an MOS capacitor if an oxide charge of $+10^{11}$ cm^{-2} is 3x4 = 12
   a) at the Si/SiO_2 interface
   b) uniformly distributed throughout the oxide
   c) at the gate/SiO_2 interface
   d) exactly at the middle of the oxide layer

2. Consider an n-channel MOSFET at room temperature made from p-doped silicon substrate. C-V measurements are done on the MOS capacitor. It is found from the low-frequency measurements that the maximum and the minimum capacitances per unit area are 1.72 x 10^{-7} F/cm^2 and 2.9 x 10^{-8} F/cm^2 respectively. The channel mobility is 600 cm^2/Vs, and the gate length is 1.5 µm while the gate width is 50 µm. [Assume that the minimum capacitance corresponds to the largest depletion thickness.]
   a) Calculate the oxide thickness
   b) Estimate the p-doping in the channel
   c) Calculate the channel current at saturation when the gate bias is V_{Th} + 1.5 V

   2 + 4 + 4 = 10

3. The threshold for an n-channel MOSFET was defined when strong inversion occurs, i.e.

   $$V_{th} = \psi_s = 2\psi_b = 2(E_i - E_F)$$

   Consider another new criterion in which we say that inversion occurs when the electron density in the channel at the Si/SiO_2 interface becomes 10^{16} cm^{-3}. Calculate the gate threshold voltage needed for an MOS device with the following parameters for the two different criteria: 8

   Oxide thickness = 50 nm,
   Φ_{ms} = 1 V
   $N_A = 10^{13}$ cm^{-3}

4. Consider an n-channel MOSFET made from p-doped silicon ($N_A = 10^{16}$ cm^{-3}) at 300 K. The source and drain contacts are Ohmic (negligible resistance) and are made from n+-doped regions. The other parameters are –

   V_{FB} = -1 V, electron mobility = 500, hole mobility = 100, gate length = 2 µm, gate width = 20 µm, oxide thickness = 50 nm.

a) Calculate the channel conductivity near the Si/SiO_2 interface under flat band condition and at inversion. Use $V_{th} = \psi_s = 2\psi_b$ for inversion

b) Calculate the electron and hole densities at the Si/SiO_2 interface on the source and drain sides of the gate when $V_G = V_{th} + 0.5$ V, and $V_{DS} = 1$ V.

c) If the gate bias is such that Si bands are flat, estimate the current density in the channel for a drain bias of 1 V.