ECE 3150: Microelectronics

Spring 2016

Homework 5 **Due on March 03, 2016 at 7:00 PM**

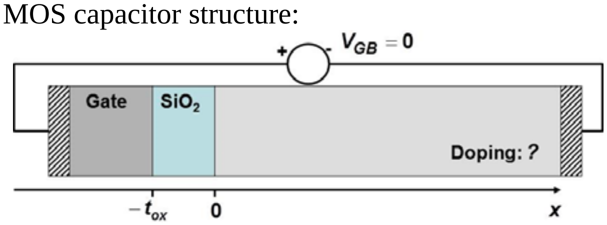
Suggested Readings:
a) Lecture notes

Important Note:
a) First two problems are from past mid-terms.

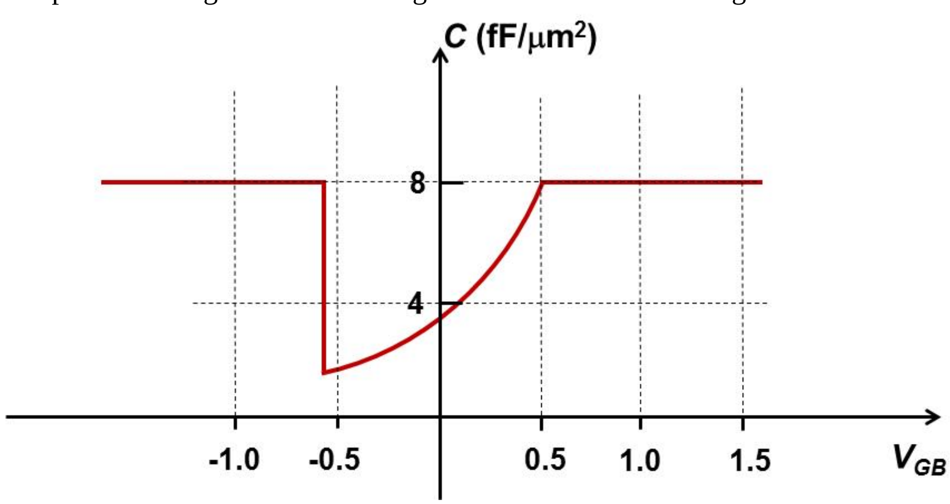
Important Note:
1) MAKE SURE THAT YOU INDICATE THE UNITS ASSOCIATED WITH YOUR NUMERICAL ANSWERS. OTHERWISE NO POINTS WILL BE AWARDED.
2) Lab 2 is scheduled for the week of March 07
3) Unless noted otherwise, always assume room temperature.

Problem 5.1: (Mystery MOS Capacitor)

Consider the following MOS capacitor structure:



The type of the MOS structure is unknown (whether NMOS of PMOS). A graduate student decides to measure its capacitance vs gate-to-bulk voltage and obtains the following results:



a) What is the flatband voltage?

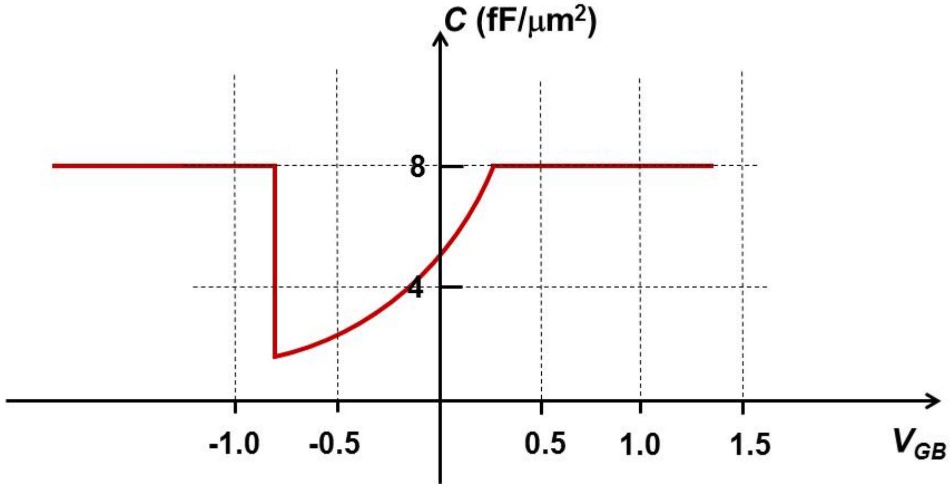
b) What is the threshold voltage?

c) What is the oxide thickness?

d) What is the substrate type (N or P)?

e) What is the substrate doping (in $1/cm^3$)?

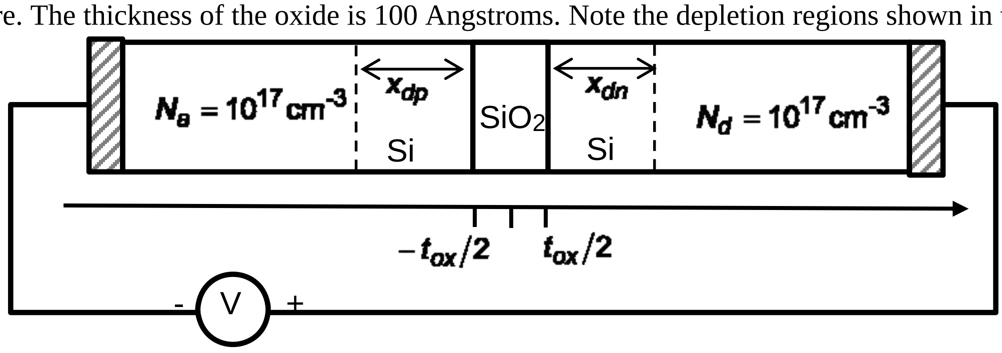
f) The student accidentally leaves his MOS device uncovered at night and exposed to moisture and impurities. When he comes back in the morning and measures the device again he obtains, to his horror, the following curve:



The student concludes that the oxide got contaminated with charged impurities. If one models the charged impurities as a uniform charge density ρ_o, find the sign and magnitude of the charge density ρ_o.

Problem 5.2: (A Symmetric SOS Capacitor)

Consider the following symmetrically doped SOS (semiconductor oxide semiconductor) capacitor structure. The thickness of the oxide is 100 Angstroms. Note the depletion regions shown in the figure.



a) Assuming V=0, sketch the electrostatic potential in equilibrium from one metal contact to the other. Label your sketch. Indicate important potential values.

b) Assuming V=0, sketch the electric field in equilibrium from one metal contact to the other. Label your sketch.

c) What is the built-in potential ϕ_B for this structure?

d) What is the thickness of each depletion region (indicated in the Figure)?

e) Suppose a voltage bias is now applied (V>0). At what value of V will the surfaces of the semiconductors, at $x = -t_{ox}/2$ and $x = +t_{ox}/2$, invert (i.e. an inversion layer will form)? Indicate the inversion layer charge (i.e. either due to holes or electrons at $x = -t_{ox}/2$ and $x = +t_{ox}/2$.

Problem 5.3: (NMOS FET)

Suppose one is interested in obtaining and plotting the channel potential $V_{CS}(y)$ as a function of position y inside the channel from the source end ($y = 0$) to the drain end ($y = L$). Suppose that one is operating in the linear (or the triode) regime: $V_{DS} < V_{GS} - V_{TN}$ in which the current is:

$$I_D = \frac{W}{L}\,\mu_n\,C_{ox}\left(V_{GS} - V_{TN} - \frac{V_{DS}}{2}\right)V_{DS}$$

a) Start from the current equation:

$$I_D = W\,\mu_n\,C_{ox}\left(V_{GS} - V_{TN} - V_{CS}(y)\right)\frac{dV_{CS}(y)}{dy}$$

and integrate the above equation from $y = 0$ to $y = y$. Solve the resulting equation for $V_{CS}(y)$ as a function of y and plot (sketch) your answer for $0 \le y \le L$. Note that $V_{CS}(y = 0) = 0$ and $V_{CS}(y = L) = V_{DS}$.

b) The electric field is the derivative of the potential:

$$E_y(y) = -\frac{dV_{CS}(y)}{dy}$$

Find and plot (sketch) the electric field from $y = 0$ to $y = L$. Is the field constant/uniform? If not, explain why not (using physical rather than mathematical arguments).

c) From your answer in part (b), find the magnitude of the field at the Drain end ($y = L$) when V_{DS} approaches $V_{GS} - V_{TN}$ from below and the current approaches:

$$I_D = \frac{W}{2L}\,\mu_n\,C_{ox}\left(V_{GS} - V_{TN}\right)^2$$

Explain your answer (using physical rather than mathematical arguments).