The LNM Institute of Information Technology, Jaipur

Department of Electronics and Communication Engineering

Modeling and Simulation of MOS Transistor (ECE4181)

End Term

Maximum Marks: 50

Time: 180 Minutes **Date:** 5/12/2019

Instructions: All the Questions are Compulsory. Please check that there must be 5 questions in the paper, consisting of 2 printed pages.

Q.1: a) Draw and explain the MOS structure [1]

i. Three-terminal MOS structure in flat-band condition, with $V_{CB} = 0$. [1]

ii. The structure of (i) with a larger V_{GB} causing surface inversion [1]

iii. The structure of (ii) with a positive V_{CB}, which reduces electron concentration at the surface. [1]

iv. The structure of (iii) with further increased V_{GB}, which restores electron concentration at the surface to the level in (ii) [1]

v. Plot the conduction energy band edge vs. horizontal position along a line adjacent to the surface for the situation (i), (ii), (iii) and (iv). [2]

b) For a three terminal MOS structure plot various quantities given below characterizing the structure vs. V_{GB} and V_{GC}. (a) Surface potential; (b) gate capacitance to the rest of the structure per unit area; (c) logarithm of inversion layer charge magnitude per unit area; (d) inversion layer charge magnitude per unit area. Plot for V_{CB}=0 and for a V_{CB} of a given positive value. Where V_{CB} is the voltage source between the n+ region (added to the basic MOS two terminal structure) and substrate region. [1+1+1+1]

Q.2: a) Explain Body effect in MOSFET. [2]

b) Explain and find the expression for pinch off voltage in a MOSFET with body effect. [2]

c) Draw the inversion layer charge vs V_{CB} (channel to body bias) for different gate to body voltage. [2]

d) Calculate the change in threshold voltage due to an applied source to body voltage V_{CB}=1 V. Consider an n-channel silicon MOSFET at T = 300 K. Assume the substrate is doped to N_a= 3 x 10^{16} cm^{-3} and assume the oxide is silicon dioxide with a thickness of t_{ox}= 500 Angstrom. [4]

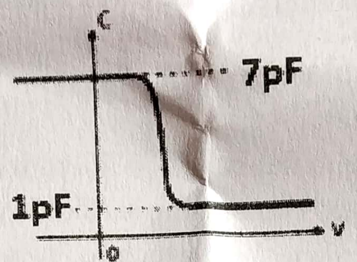
[Assume n_i=1.5 x 10^{10} cm^{-3}, the relative permittivities of Si and SiO_2 are 11.7 and 3.9 respectively and ε_0 =8.85 x 10^{-14} F/cm]

Q.3: a) Why velocity saturation occurs in MOSFET? Derive and find the expression for drain current with velocity saturation? [1+3]

b) Briefly describes channel-length modulation and how it affects MOSFET current–voltage characteristics. [2+2]

c) Write short notes on Hot carrier effects in a Short channel MOSFET [2]

Q.4: a) The figure shows the high frequency capacitance-voltage (C-V) characteristics of MOS capacitor having an area of 1×10^{-4} cm^2. Assume that the permittivity of Silicon and SiO_2 are 1×10^{-12} and 3.5×10^{-13} F/cm respectively. Find the gate oxide thickness in the MOS capacitor. Find the maximum depletion width in Silicon. [2+2]



b) Briefly explain about different oxide-semiconductor interface charges in a MOS capacitor. [1+1+1+1]

c) Calculate the flat-band voltage for an MOS capacitor with a p-type semiconductor substrate. [2]

Consider an MOS structure with a p-type semiconductor substrate doped to $N_a=10^{16}$ cm^{-3}, a silicon dioxide insulator with a thickness of t_{ox}= 500 Angstrom and an n+ polysilicon gate. Given interface trapped Charge $Q_o = 10^{11}$ electronic charges per cm^2. Assume $\varepsilon_{ox} = 3.9$ for SiO_2, work function difference $\phi_{ms} = -1.1$V.

Q.5: a) Consider a uniformly doped GaAs pn junction at T= 300 K. The junction capacitance at zero bias is C_J (0) and the junction capacitance with a 10 V reverse bias voltage is C_J (10). The ratio of the capacitance is [3]

$$C_J(0) / C_J(10) = 3.13$$

Also under reverse bias, the space charge width in to the p region is 0.2 of the total space charge width. Determine Built in potential (V_{bi}) and find N_d/N_a .

b) Why Punch through occurs in MOSFET and what is its effect on drain current [3]

c) Explain the concept of drain induced barrier lowering in a short channel device. [4]

MASMT - 2019 : End Sem Sol^n :

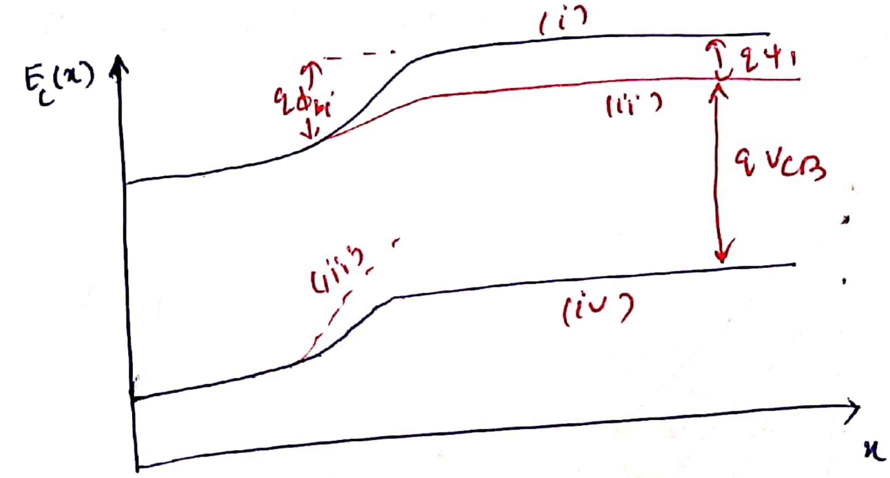
Q) 1 : a) i) Diagram, Explanation (Refer class Note) — [1 mark]

ii) " " "

iii) " " "

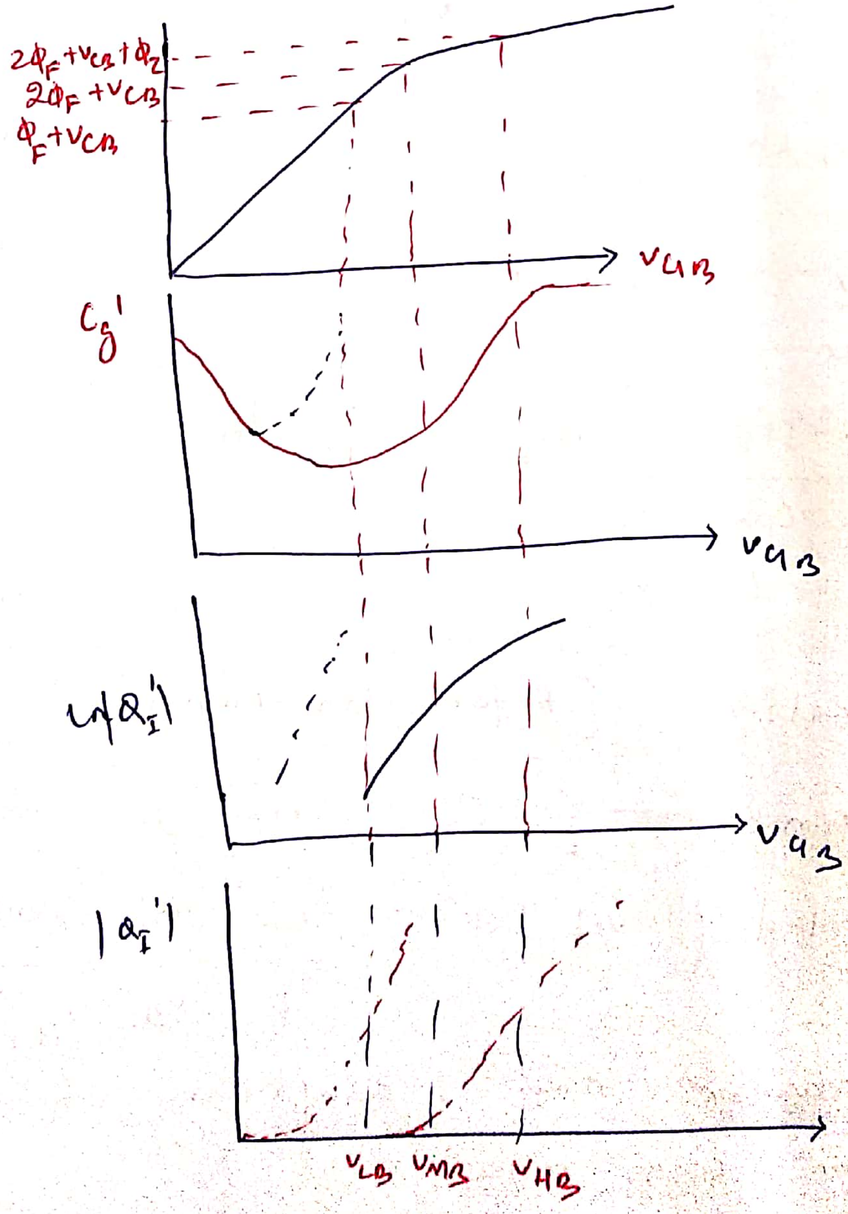
iv) " " "

v)



— [2 mark]

(1) b:



→ [1 mark]

→ [1 mark]

— [1 mark]

— [1 mark]

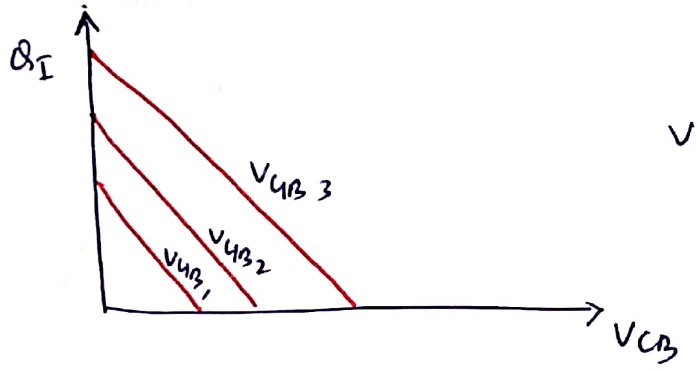
Q)2:- a) Diagram, Explanation —— [2 mark]

$V_{CB}\uparrow$, $\Rightarrow |Q_I'|\downarrow$, for fixed V_{GC}

b) Explanation (Refer class Note) —— [1 mark]

$$V_p = \left(-\frac{r}{2} + \sqrt{\frac{r^2}{4} + V_{GB} - V_{FB}}\right)^2 - \phi_0 \rightarrow [1 mark]$$

c)



$V_{GB1} < V_{GB2} < V_{GB3}$

→ [2 mark]

d) $\phi_{Fp} = V_t \ln\left(\frac{N_a}{n_i}\right) = 0.376V$ —— [1 mark]

$C_{ox} = \frac{\varepsilon_{ox}}{t_{ox}} = 6.9\times10^{-8}\ F/cm^2$ —— [1 mark]

$\Delta V_T = \frac{\sqrt{2q\varepsilon_s N_a}}{C_{ox}}\left[\sqrt{2\phi_{Fp} + V_{SB}} - \sqrt{2\phi_{Fp}}\right)$ —— [1 mark]

$\Delta V_T = 0.66V$ —— [1 maru]

Q)3:. a) Explanation – [Refer class Note] —— [1 mark]

Derivation – ["] —— [3 mark]

I_{DSN} including vel. Sat^n = $\frac{I_{DSN}, \text{ not Counting } V_{sat}}{1 + V_{DS}/(LE_c)}$

b) Explanation and diagram —— [4 mark]
Refer class note.

c) Explanation and diagram and Effects — [2mark]

Scanned by CamScanner

Q) 4 :-

(a) - $C_{ox} = C_{max} = \frac{\varepsilon_{ox}}{t_{ox}} = 7\,pF$ —— 1 mark.

$\Rightarrow \frac{3.5 \times 10^{-13}}{t_{ox}} = 7\,pF$

$\Rightarrow t_{ox} = 50\,nm$ —— [1 mark]

$\frac{1}{C_{min}} = \frac{1}{C_{ox}} + \frac{1}{C_{dep}}$

$\frac{1}{1pF} = \frac{1}{7} + \frac{1}{C_{dep}}$ —— [1 mark]

$\Rightarrow C_{dep} = 7/6$

$\Rightarrow \frac{\varepsilon_{si} A}{W_{dep}} = \frac{1 \times 10^{-12} \times 1 \times 10^{-4}}{W_{dep}} = 7/6$.

$\Rightarrow W_{dep} = 0.857\,nm$ —— [1 mark]

4) b :-
Oxide fixed charge —— [1 mark]
oxide trapped charge —— [1 mark]
Mobile ionic charge —— [1 mark]
Interface trap charge —— [1 mark]

4) c :-
$C_{ox} = \frac{\varepsilon_{ox}}{t_{ox}} = 6.9 \times 10^{-8}\ F/cm^2$. —— [0.5]

$Q_{ss}' = (10^{11})(1.6 \times 10^{-19}) = 1.6 \times 10^{-8}\ C/cm^2$ — [0.5]

$V_{FB} = \phi_{ms} - \frac{Q_{ss}'}{C_{ox}} = -1.1 - \left(\frac{1.6 \times 10^{-8}}{6.9 \times 10^{-8}}\right) = -1.33\,V$

—[1 mark]

5) a:-

$$\frac{C_j(0)}{C_j(10)} = 3.13 = \left(\frac{V_{bi}+V_R}{V_{bi}}\right)^{1/2}$$

For $V_R = 10V$, we find

$$(3.13)^2 V_{bi} = V_{bi} + 10$$

$\Rightarrow V_{bi} = 1.14V$ —— [2 mark]

$x_p = 0.2W = 0.2(x_n + x_p)$

$$\frac{x_p}{x_n} = 0.25 = \frac{N_d}{N_a}$$ —— [1 mark]

5) b:- Diagram —— [2 mark]
Explanation —— [1 mark]
(Refer class Note)

c:- Diagram —— 1 mark
Explanation —— 3 marks
(Refer class note)