

UNIVERSITY OF CALIFORNIA, BERKELEY
College of Engineering
Department of Electrical Engineering and Computer Sciences

EE 130/230M
 Integrated Circuit Devices

Spring 2013
 Prof. Liu & Dr. Xu

QUIZ #5
 Time allotted: 25 minutes

NAME: _____
 (print) Last First Signature

1. Use the values of physical constants provided below. 2. **SHOW YOUR WORK, & write legibly!**
 2. **Underline or box numerical answers, and SPECIFY UNITS where appropriate.**

Physical Constants

Description	Symbol	Value
Electronic charge	q	$1.6 \times 10^{-19} \text{ C}$
Thermal voltage at 300K	kT/q	0.026 V

$$(kT/q) \cdot \ln(10) = 0.060 \text{ V}$$

Properties of silicon (Si) at 300K

Description	Symbol	Value
Energy band gap	E_G	1.12 eV
Intrinsic carrier concentration	n_i	10^{10} cm^{-3}
Permittivity	ϵ_{Si}	$1.0 \times 10^{-12} \text{ F/cm}$

Problem 1 [15 points]

Consider a n-channel Si MOSFET with $W = L = 1 \mu\text{m}$, effective gate-oxide thickness $T_{\text{oxe}} = 3.45 \text{ nm}$ ($C_{\text{oxe}} = 10^{-6} \text{ F/cm}^2$), gate work function $\Phi_M = 4.03 \text{ eV}$ and bulk Si dopant concentration $N_A = 10^{17} \text{ cm}^{-3}$ (corresponding to bulk Si work function $\Phi_S = 5.03 \text{ eV}$ and maximum depletion width $W_T = 100 \text{ nm}$)
 Assume $T = 300\text{K}$ and $V_S = V_B$.

(a) If the fixed oxide charge $Q_F = 10^{12} \text{ q/cm}^2$, what is the flat-band voltage, V_{FB} ? [3 pts]

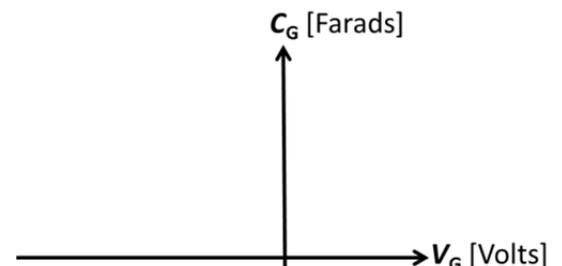
(b) What is the threshold voltage V_T ? [4 pts]

$$Q_{\text{dep}} = \sqrt{2qN_A\epsilon_{\text{Si}}(2\phi_F)} = 1.6 \times 10^{-7} \text{ C/cm}^2$$

(c) Is this an enhancement-mode or depletion-mode device? Justify your answer. [1 pt]

(d) Suppose $V_S = V_D = V_B = 0 \text{ V}$. Sketch the gate capacitance vs. gate voltage on the axes provided. [5 pts]

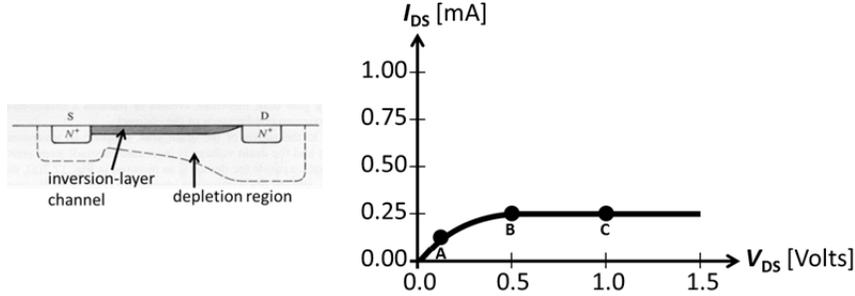
- (i) Indicate the maximum value.
 (ii) Estimate the minimum value.
 (iii) Indicate V_{FB} and V_T .



(e) Should acceptor or donor atoms be implanted into the near-surface region of the channel, in order to adjust V_T to be -0.3 V ? Provide a brief, qualitative justification for your answer. [2 pts]

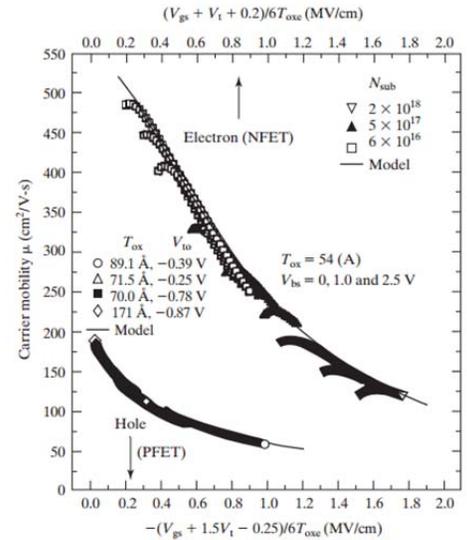
Problem 2 [10 points]

A schematic cross-section of the silicon region within a long n-channel MOSFET with $T_{oxe} = 10$ nm is shown below with its I_{DS} - V_{DS} characteristic for $V_{GS} = 1$ V. Assume $V_S = V_B = 0$ V and the bulk charge factor $m \cong 1$.



(a) Identify the MOSFET operating point on the I - V curve above. (Circle the appropriate letter.) [1 pt]

(b) Add a curve for $V_{GS} = 1.5$ V to the plot above. Indicate approximate values for V_{DSat} and I_{DSat} ; show how you arrived at these values. [4 pts]



(c) Qualitatively, why does the saturation current (I_{DSat}) of a long-channel MOSFET increase \sim quadratically with gate overdrive ($V_{GS} - V_T$)? [3 pts]

(d) What is the body effect? Provide a qualitative explanation for it. [2 pts]

