VE320 Intro to Semiconductor Devices
Summer 2022 — Problem Set 8

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Exercise 8.1

The high-frequency $C-V$ characteristic curve of a MOS capacitor is shown in Figure 1. The area of the device is 2×10^{-3} cm^2. The metal-semiconductor work function difference is $\phi_{ms} = -0.50$ V, the oxide is SiO_2, the semiconductor is silicon, and the semiconductor doping concentration is 2×10^{16} cm^{-3}.

(a) Is the semiconductor n or p type?
(b) What is the oxide thickness?
(c) What is the equivalent trapped oxide charge density?
(d) Determine the flat-band capacitance.

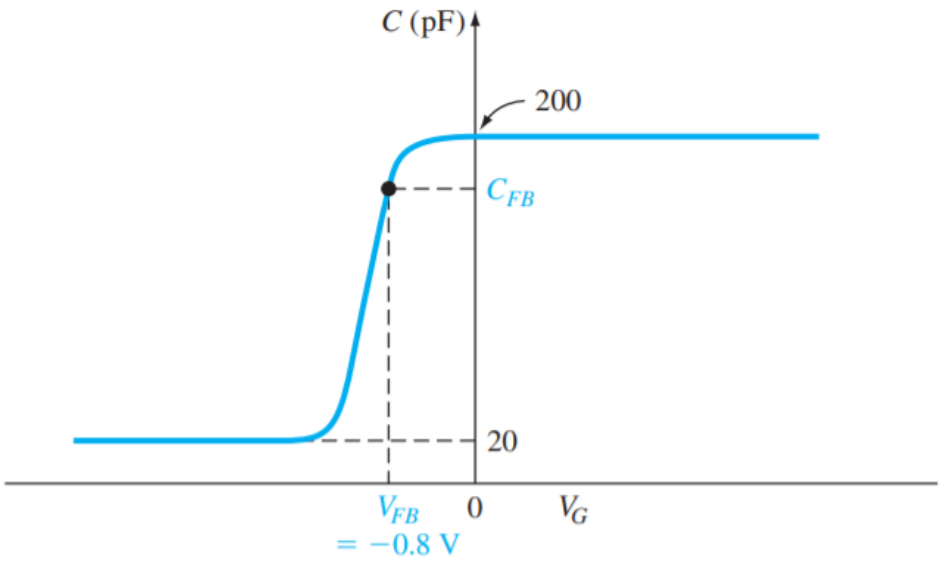

Figure 1: Figure for Problem 8.1

Exercise 8.2

Consider the high-frequency $C - V$ plot shown in Figure 2.

(a) Indicate which points correspond to flat-band, inversion, accumulation, threshold, and depletion modes.

(b) Sketch the energy-band diagram in the semiconductor for each condition.

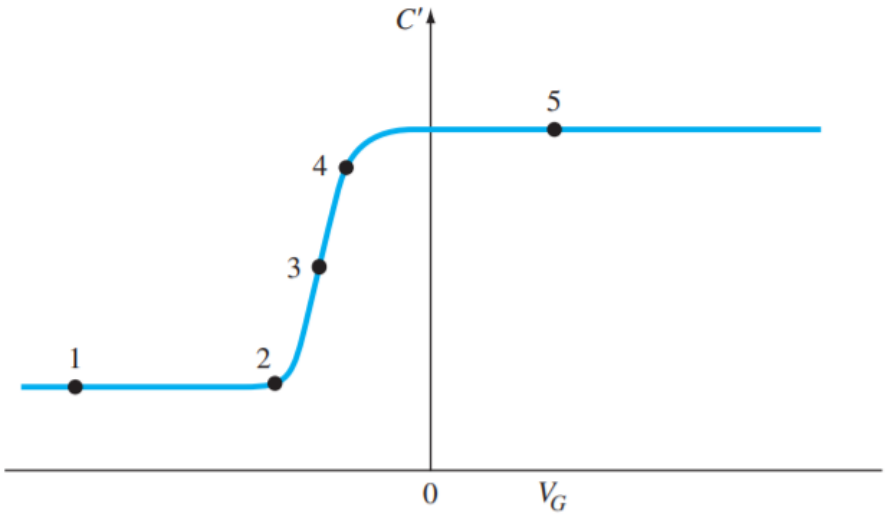

Figure 2: Figure for Problem 8.2

Exercise 8.3

A p-channel MOSFET has the following parameters: $k_p' = 0.10$ mA/V$^2, W/L = 15$, and $V_T = -0.4$ V. Calculate the drain current I_D for

(a) $V_{SG} = 0.8$ V, $V_{SD} = 0.25$ V;
(b) $V_{SG} = 0.8$ V, $V_{SD} = 1.0$ V ;
(c) $V_{SG} = 1.2$ V, $V_{SD} = 1.0$ V;
(d) $V_{SG} = 1.2$ V, $V_{SD} = 2.0$ V.

Exercise 8.4

Consider a p-channel MOSFET with the following parameters: $k_p' = 0.12$ mA/V^2 and $W/L = 20$. The drain current is 100μA with applied voltages of $V_{SG} = 0$, $V_{BS} = 0$, and $V_{SD} = 1.0$ V.

(a) Determine the V_T value.
(b) Determine the drain current I_D for $V_{SG} = 0.4$ V, $V_{SB} = 0$, and $V_{SD} = 1.5$ V.
(c) What is the value of I_D for $V_{SG} = 0.6$ V, $V_{SB} = 0$, and $V_{SD} = 0.15$ V?

Exercise 8.5

One curve of an n-channel MOSFET is characterized by the following parameters: $I_D(\text{sat}) = 2 \times 10^{-4}$ A, $V_{DS}(\text{ sat }) = 4$ V, and $V_T = 0.8$ V

(a) What is the gate voltage?

(b) What is the value of the conduction parameter?

(c) If $V_G = 2$ V and $V_{DS} = 2$ V, determine I_D.

(d) If $V_G = 3$ V and $V_{DS} = 1$ V, determine I_D.

(e) For each of the conditions given in (c) and (d), sketch the inversion charge density and depletion region through the channel.

Exercise 8.6

An NMOS device has the following parameters: n^+poly gate, $t_{ox} = 400\mathring{A}, N_a = 10^{15}$ cm^{-3}, and $Q'_{ss} = 5 \times 10^{10}$ cm^{-2}.

(a) Determine V_T.

(b) Is it possible to apply a V_{SB} voltage such that $V_T = 0$? If so, what is the value of V_{SB} ?

Exercise 8.7

Draw the $I_{\mathrm{D}} - V_{\mathrm{SD}}$ relationship for a p-type MOSFET at different gate voltages, assuming the source is grounded. Explain why there is the saturation region, and how the saturation point changes with different gate voltages.

Reference

1. Neamen, Donald A. Semiconductor physics and devices: basic principles. McGraw-hill, 2003.