EE 207 (MBP): Question Set 5

1. Consider a MOS capacitor at 300 K with a p-type silicon substrate doped with $N_a = 4 \times 10^{16}\,\text{cm}^{-3}$, $t_{\text{ox}} = 400\,\text{Å}$, $\phi_m = 4.1\,\text{V}$, $\chi_s = 4.05\,\text{V}$. What is the flat-band voltage? (For silicon at 300 K, $N_c = 2.8 \times 10^{19}\,\text{cm}^{-3}$, $N_v = 1.04 \times 10^{19}\,\text{cm}^{-3}$, $E_g = 1.1\,\text{eV}$, $n_i = 10^{10}\,\text{cm}^{-3}$.)

   (A) 0.45 V (B) 1.1 V (C) −0.9 V (D) −1.23 V

2. For the MOS capacitor described in Q-1, what is the depletion width at the onset of inversion?

   (A) 0.16 μm (B) 0.11 μm (C) 0.32 μm (D) 0.28 μm

3. For the MOS capacitor described in Q-1, what is the threshold voltage?

   (A) 0.44 V (B) 0.81 V (C) 1.06 V (D) 0.65 V

4. For the MOS capacitor described in Q-1, what is total depletion charge (in units of cm^{-2}) at $V_G = V_{\text{th}}$?

   (A) -1.21×10^{11} cm^{-2}
   (B) -6.38×10^{11} cm^{-2}
   (C) -2.44×10^{10} cm^{-2}
   (D) -7.92×10^{10} cm^{-2}

5. For the MOS capacitor described in Q-1, what is the electric field in the oxide for $V_G = V_{\text{th}}$?

   (A) 330 kV/cm (B) 158 kV/cm (C) 113 kV/cm (D) 296 kV/cm

6. For the MOS capacitor described in Q-1, what is the potential drop (magnitude) in the semiconductor at $V_G = V_{\text{th}}$?

   (A) 0.43 V (B) 0.79 V (C) 0.51 V (D) 0.87 V

7. For the MOS capacitor described in Q-1 with $V_G = 1.8\,\text{V}$, what is the inversion charge Q_I (in cm^{-2})?

   (A) -4.0×10^{11} cm^{-2}
   (B) -6.1×10^{11} cm^{-2}
   (C) -2.4×10^{10} cm^{-2}
   (D) -6.3×10^{10} cm^{-2}

8. For the MOS capacitor described in Q-1 with $V_G = 1.8\,\text{V}$, what is the electric field in the oxide (magnitude)?

   (A) 350 kV/cm (B) 162 kV/cm (C) 119 kV/cm (D) 482 kV/cm

9. For the MOS capacitor described in Q-1 with $V_G = 1.8\,\text{V}$, what is the total charge on the metal (in cm^{-2})?

   (A) $1.04 \times 10^{12}\ \text{cm}^{-2}$
   (B) $6.38 \times 10^{11}\ \text{cm}^{-2}$
   (C) $2.1 \times 10^{11}\ \text{cm}^{-2}$
   (D) $7.31 \times 10^{10}\ \text{cm}^{-2}$

10. For a silicon MOS capacitor at 300 K with a p-type substrate, the flat-band voltage was measured to be $V_{FB} = -0.5\,\text{V}$ and the threshold voltage to be $V_{\text{th}} = 0.85\,\text{V}$. If $N_a = 10^{16}\,\text{cm}^{-3}$, what is the oxide thickness?
    ($n_i = 10^{10}\,\text{cm}^{-3}$ at 300 K.)

    (A) 380 Å (B) 268 Å (C) 451 Å (D) 325 Å

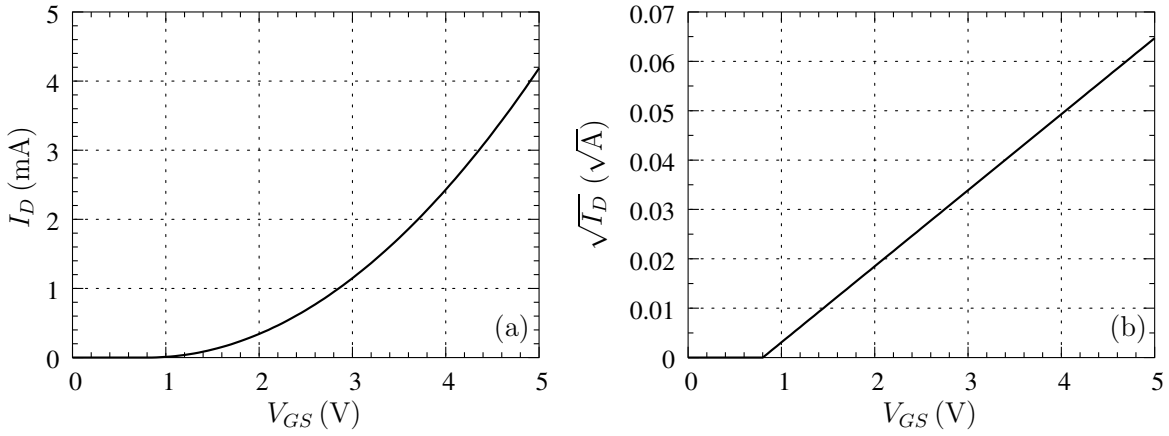
11. For a silicon MOS capacitor at 300 K with an n-type substrate, the flat-band voltage was measured to be $V_{FB} = -0.1\,\text{V}$ and the threshold voltage was measured to be $V_{\text{th}} = -1.5\,\text{V}$. If the oxide thickness is 320 Å, what is the substrate doping density N_d?
    ($n_i = 10^{10}\,\text{cm}^{-3}$ at 300 K.)

    (A) $1.1 \times 10^{17}\ \text{cm}^{-3}$ (B) $2 \times 10^{16}\ \text{cm}^{-3}$ (C) $4.3 \times 10^{15}\ \text{cm}^{-3}$ (D) $8 \times 10^{15}\ \text{cm}^{-3}$

12. An n-channel MOS transistor has the following parameters: $W = 15\,\mu\text{m}$, $L = 1.5\,\mu\text{m}$, $\mu_n = 680\,\text{cm}^2/\text{V-s}$, $C_{\text{ox}} = 65\,\text{nF/cm}^2$. The saturation current I_D^{sat} was measured to be 4.8 mA for $V_{GS} = 5\,\text{V}$. What is the threshold voltage of the transistor?

    (A) 0.6 V (B) 0.12 V (C) 0.34 V (D) 0.88 V

13. The I_D versus V_{GS} and $\sqrt{I_D}$ versus V_{GS} curves for a silicon NMOS transistor operating in the saturation region are shown in the figure. If $W/L = 10$ and $t_{\text{ox}} = 400$ Å, what is the mobility μ_n?

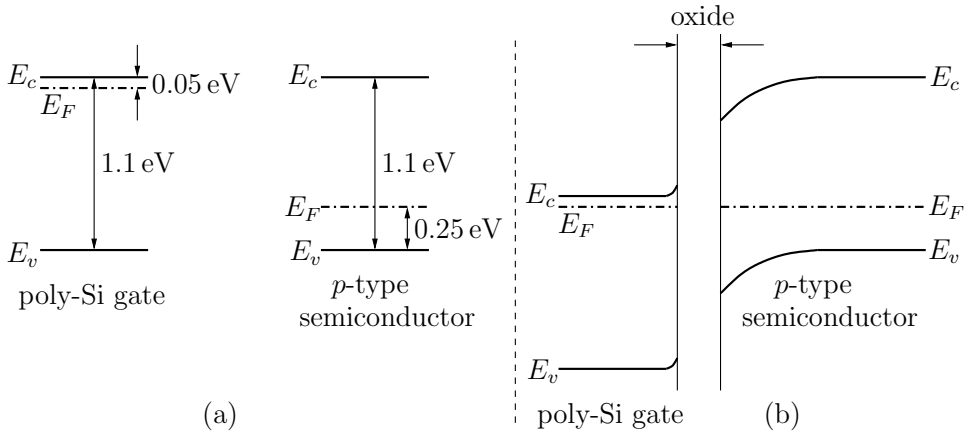


    (A) 720 cm^2/V-s (B) 460 cm^2/V-s (C) 650 cm^2/V-s (D) 520 cm^2/V-s

14. For a PMOS transistor, the drain saturation current was measured to be 12.8 μA for $V_{GS} = -2\,\text{V}$ and 64.8 μA for $V_{GS} = -3\,\text{V}$. What is I_D^{sat} for $V_{GS} = -4\,\text{V}$?

    (A) 157 μA (B) 88 μA (C) 120 μA (D) 36 μA

15. In modern MOS technology, the metal gate of the MOS transistor is generally replaced with n^+ or p^+ polysilicon. The following figure shows band diagrams for isolated gate and substrate materials, and also the band diagram for the corresponding MOS capacitor. What gate voltage would you apply to make the bands flat?



(A) -0.35 V (B) -0.8 V (C) -0.63 V (D) -0.5 V