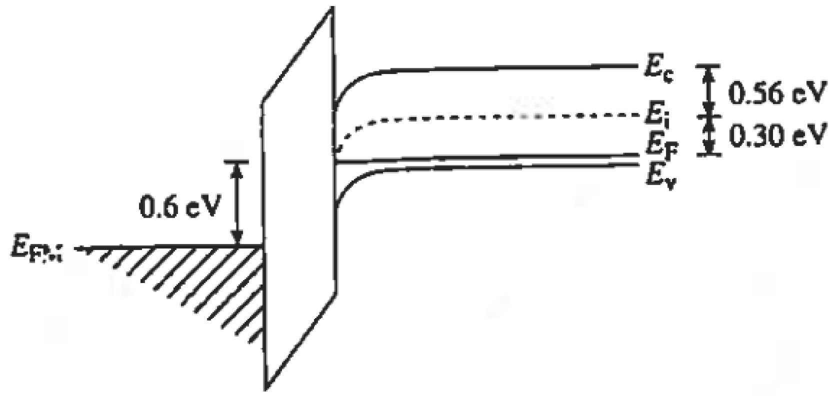
Notice: The assignments are open-book and everyone is free to discuss homework with each other. But the homework you submit must be your own.

Please finish the homework before the deadline, then convert it into a PDF document, and finally submit it through the ISPACE system. The home work should be written in English.

Assignments-4-MOSFET

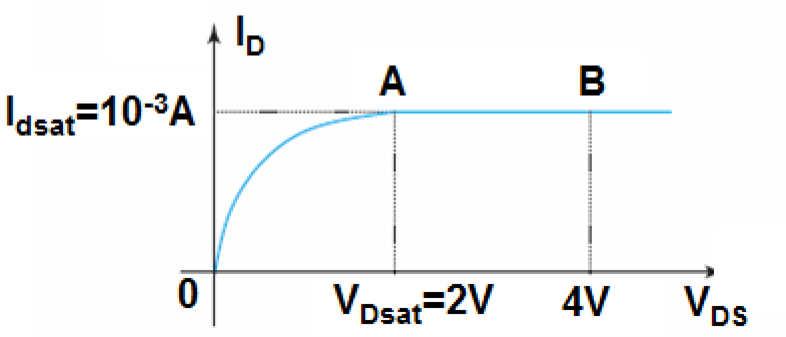
1. An ideal MOS structure is maintained at T=300 K, t_{ox}=0.1 μm, and the p-Si substrate doping concentration is $N_A=10^{15}$ cm^{-3}. Determine:
   (1) Fermi potential φ_F;
   (2) W_{dep} when semiconductor's surface potential $\varphi_s=2\varphi_F$;
   (3) E_s (surface electric field) when semiconductor's surface potential $\varphi_s=2\varphi_F$;
   (4) Threshold voltage V_T.
2. The following figure shows the energy band diagram for an ideal MOS structure operated at T=300 K with $V_G \neq 0$. Note that $E_F=E_i$ at the Si-SiO_2 interface.
   (1) Does the equilibrium condition prevail inside the semiconductor?
   Determine (2) Fermi potential φ_F; (3) semiconductor's surface potential φ_s; (4) applied gate voltage V_G; (5) oxide layer's thickness t_{ox}.



3. For a NMOSFET, assume that its channel width W is a function of y-coordinate, i.e., $W(y)=W_0+y$, where y=0 and y=L represent the source and drain terminals separately. Using the square law theory, determine the equations for I_D and I_{Dsat}.
4. For a NMOSFET, W/L=5, t_{ox}=20 nm, μ_n=600 cm^2/(V•s), and the square law theory is utilized.
   (1) When the device is working at the deep linear region (V_{DS} is very small but non-zero), the on-resistance is 500 Ω, determine the Q_{inv};
   (2) Determine the required $V_{GS}-V_T$ for making on-resistance 500 Ω.
5. For a NMOSFET, its I_D-V_{DS} plot is shown in the following figure. W=2.5 μm, L=0.5 μm, t_{ox}=10 nm. The square law theory is utilized.
   (1) If V_T=0.5 V, determine the V_{GS}.

(2) When the device is biased to work at point A in the figure, determine the Q_{inv} at the drain terminal point.

(3) If the V_{GS} is changed to V_{GS}-V_T=3 V, and V_{DS}=4 V, determine the I_D.



6. Prove that, when NMOSFET works at saturation region, $C_{gs}=(2/3)WLC_{ox}$.
7. For a NMOSFET, W=50 μm, L=5 μm, t_{ox}=50 nm, $N_A=3\times10^{15}$ cm^{-3}, μ_n=800 cm^2/(V•s), heavily doped n$^+$ poly-Si is utilized as gate electrode, Q_{ox}=0.
   Determine: (1) V_T; (2) I_{Dsat} when V_{GS}=2 V; (3) g_{ds} when V_{GS}=2 V and V_{DS}=0 V; (4) g_m when V_{GS}=2 V and V_{DS}=2 V.
8. Assume that n$^+$ poly-Si gate electrode is adopted for NMOSFET, t_{ox}=1.1 nm, $N_A=10^{18}$ cm^{-3}, Q_{ox}=0. Determine: (1) V_T; (2) Subthreshold swing S; (3) I_{off} when W=1 μm, L=18 nm, considering that I_D=100W/L (nA) when $V_{GS}=V_T$.
9. For a NMOSFET, heavily doped n$^+$ poly-Si is utilized as gate electrode, $Q_{ox}=q\times8\times10^{10}$ cm^{-2}, L=2 μm, W=50 μm, t_{ox}=5 nm, $N_A=10^{15}$ cm^{-3}.
   Determine: (1) V_{FB}; (2) V_T;
   (3) If the V_T is desired to be modulated to 0.5 V, which type of dopants should be added? What is the dose?
10. A MOSFET has the following parameters: n$^+$ poly-Si as gate electrode, t_{ox}=8 nm, $N_A=10^{17}$ cm^{-3}, and $Q_{ox}=5\times10^{10}$ cm^{-2}.
    (1) What is the V_T of this MOSFET?
    (2) Is this MOSFET enhancement mode or depletion mode?
    (3) What type of dopants and dose are required such that V_T=0?