

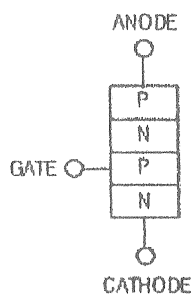
科目：固態電子元件(500B)校系所組：清大電子工程研究所

1. For a semiconductor material,
 - (a) Its conductivity σ (in $\Omega^{-1}\text{-cm}^{-1}$) is affected by carrier concentration and mobility values. Please write down the equation describing the relationship between these physical quantities. Please remember to explicitly write down the units of these quantities in the equation. (5%)
 - (b) The values of carrier concentration and mobility are also dependent on temperature value. Please describe these T-dependences (for example, what kind of mathematical functions.) (5%)
 - (c) Do you know how to measure the mobility value of the semiconductor material? Please describe the method you know. (5%)

2. For an abrupt p-n junction, a potential barrier is established at the junction and the built-in potential V_0 is described by the well known equation: $V_0 = \frac{kT}{q} \ln \frac{N_a N_d}{n_i^2}$ where N_a and N_d are the doping concentrations and n_i is the intrinsic carrier concentration of the semiconductor material.
 - (a) As the temperature T rises, will V_0 increase or decrease? Please explain. (7%)
 - (b) If, at some temperature, a small forward bias voltage V_f is applied to the diode made of the abrupt p-n junction, how will the terminal current I of the diode behave? (4%) If the value of V_f is larger than that of V_0 , is it correct that the potential barrier at the junction will be totally diminished? Please explain. (4%)

3. Consider an npn Bipolar Junction Transistor, with 10^{20} , 10^{18} and 10^{16} cm^{-3} doping levels in emitter, base and collector respectively, answer the following questions.
 - (a) Plot qualitatively its energy band diagrams at zero bias and at forward-active conditions. (5%)
 - (b) Why the emitter is doped more heavily than the collector, in a typical BJT? (5%)
 - (c) How does reducing base width affect the current gain, β ? (5%)
 - (d) If a wide bandgap material with conductor band edge 0.2eV higher and valence band edge 0.3eV lower that of silicon, is chosen to substitute the emitter. Plot the corresponding energy band diagram of the new BJT and explain how this will affect its current gain, β and why? (10%)

4. For a pnpn-SCR shown below, answer the following questions.
 - (a) Describe its basic operation principles. (5%)
 - (b) Sketch qualitatively the IV characteristics between the anode and cathode at the gate current, $I_g=0$ and $I_g>0$ on the same plot. (5%)



注：背面有試題
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5. A CMOS cross-section with four terminals (A, B, C and D) is shown in Figure 1.
- Which terminal is INPUT (V_{IN})? Which terminal is V_{DD} ? (4%)
 - Which terminal is OUTPUT (V_{OUT})? Which terminal is V_{SS} ? (4%)
 - Draw CMOS circuit diagram and mark A, B, C, and D for each terminal. (6%)
6. Consider a MOS (Metal-Oxide-Silicon) capacitor with oxide thickness $T_{ox} = 100\text{\AA}$, and its oxide capacitance $C_{ox} = 10\text{pF}$ and C-V curves are shown in Figure 2.
- What is the type (n or p) of the substrate dopant? (2%)
 - Which is the depletion region (1 ~ 4)? Which region is in accumulation? (4%)
 - If the frequency of small signal is 10MHz, what is the C-V curve (C_A or C_B)? (2%)
 - The minimum depletion capacitance of silicon substrate is $0.25 C_{ox}$, what is the minimum MOS capacitance (pF)? (3%)
 - Follow (d), if the oxide thickness becomes 75\AA , what is the minimum MOS capacitance (pF)? (3%)
7. An n-channel MOSFET with channel length L is shown in Figure 3. The saturation current I_{DSAT} is $300\mu\text{A}$ when the channel length L is $0.1\mu\text{m}$.
- Consider the channel modulation effect, when $\Delta L = 0.025\mu\text{m}$, what is the modified I_{DSAT} (uA)? (4%)
 - Follow (a), will the sub-threshold swing S ($\delta V_{GS} / \delta \log I_D$) increase or decrease? (3%)

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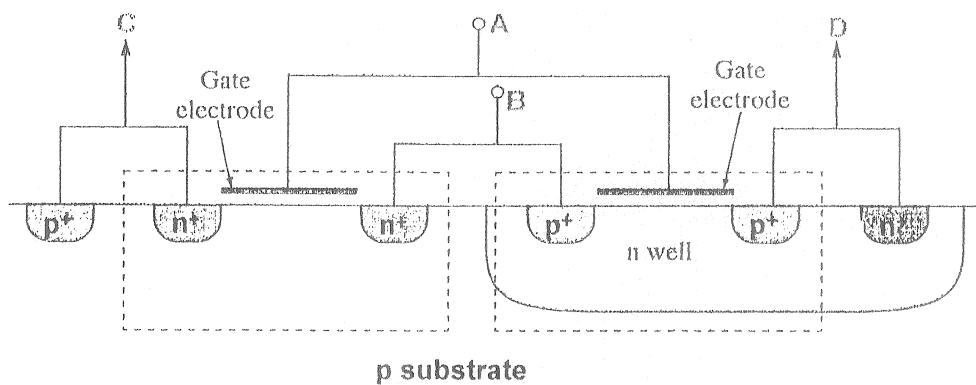


Figure 1

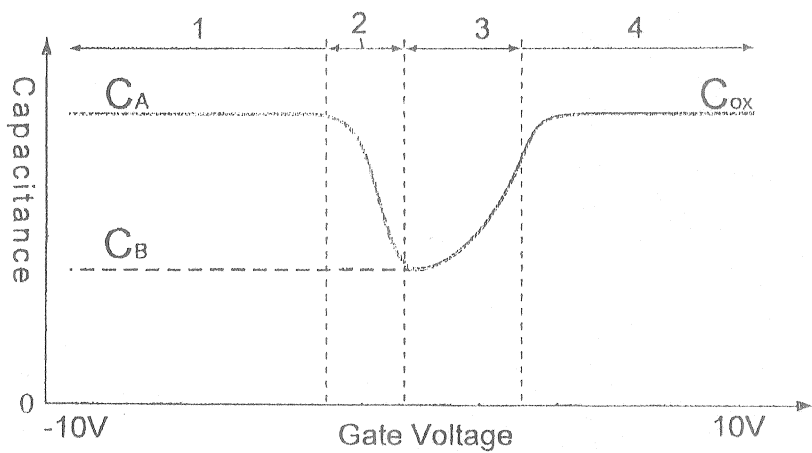


Figure 2

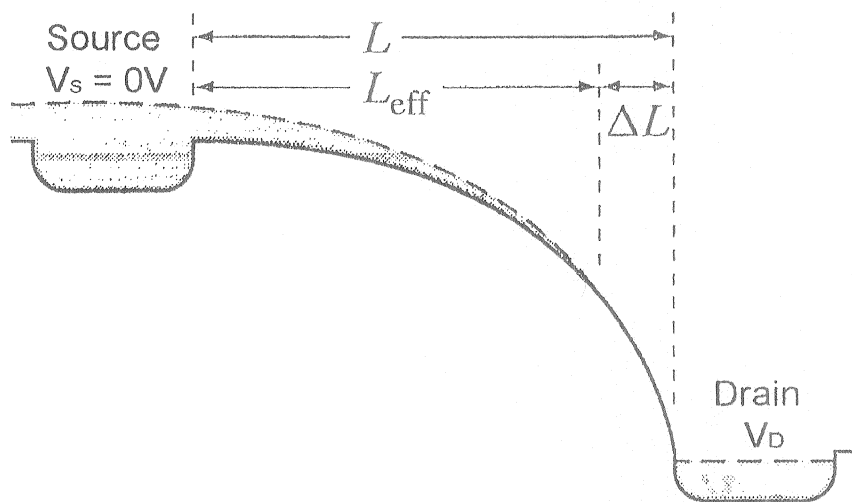


Figure 3