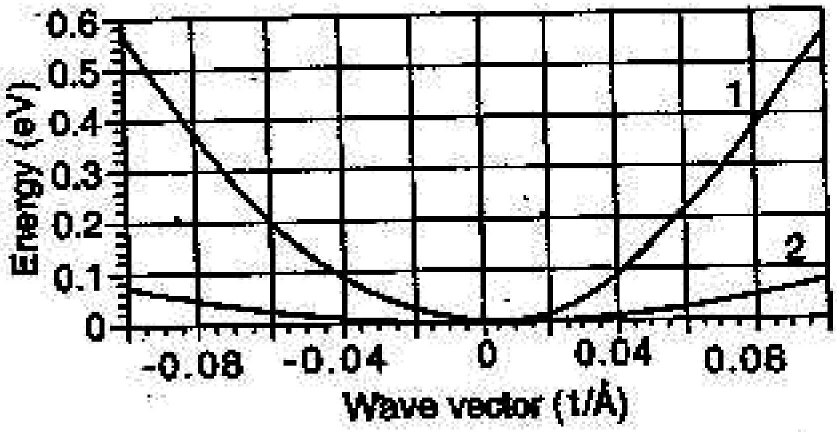
國 立 清 華 大 學 命 題 紙

八十八學年度 電子工程 系(所) ______ 組碩士班研究生招生考試

科目 固態電子元件 科號 4705 共 2 頁第 1 頁 *請在試卷【答案卷】內作答

1. The energy band diagram show a parabolic $E(k)$ dependencies for semiconductors *1* and *2* (as shown in the following figure).



(a) Which one (*1* or *2*) has a larger electron effective mass? Explain why?. (5%)

(b) Calculate the effective masses for semiconductor *1* and *2* in terms of free electron mass m_0. ($\hbar = 1.055 \times 10^{-34}$ Jsec, $q = 1.6 \times 10^{-19}$ C, and $m_0 = 9.11 \times 10^{-31}$ Kg) (10%)

2. Show that the values of the Fermi-Dirac distribution function for a pair of energy symmetric about the Fermi level E_f are complementary i.e. $f(E_f + E) = 1 - f(E_f + E)$ independent of temperature. (5%)

3. Using the condition of $n = p = n_i$, find the position of intrinsic Fermi level. (5%)

4. A compensate semiconductor is doped with the same concentration of donors and acceptors. The carrier concentration will be equal to that of an intrinsic semiconductor. Does its resistivity also equal to that of an intrinsic semiconductor? Explain. (5%)

5. (a) Explain the reason why in a p-n junction, there is no discontinuity or gradient in the equilibrium Fermi level E_F. (10%)

   (b) Plot the band diagram for a p-n junction at equilibrium, under forward bias, and under reverse bias. (5%)

6. (a) Draw the high frequency small-signal equivalent circuit model of a bipolar junction transistor. (5%)

   (b) Derive the expression of the cutoff frequency f_T in terms of the parameters of the equivalent circuit model. (5%)

7. What is the Kirk effect in a bipolar junction transistor? Please explain its physical origin. (10%)

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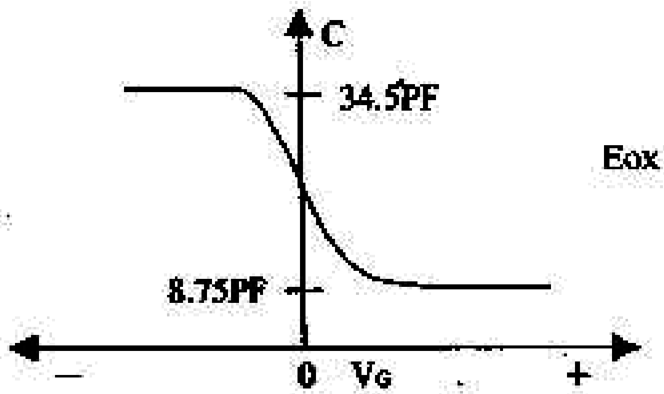
8. For a given high frequency capacitance-voltage characteristics of a metal-oxide-semiconductor capacitor (as shown in the following figure)

(a) What is the oxide thickness? (Assuming the area of capacitor is 10000 μm^2) (5%)

(b) What is the doping concentration of the semiconductor substrate if the doping concentration is constant? (5%)

(c) What is the maximum depletion width of the semiconductor substrate at the strong inversion condition? (Hint: can be calculated from the minimum capacitance) (5%)

(d) What is the threshold voltage? (Assuming oxide and interface charge are negligible, and work function difference between metal and semiconductor is zero) (5%)



Eox = 3.9 × 11.8 × 10^{-14}

(e) From the above calculation and your knowledge, please list five items which affect the threshold voltage. (5%)

($\varepsilon_0 \cong 8.854 \times 10^{-12}$ F/m, $\varepsilon_{ox} \cong 3.9\ \varepsilon_0$, and $\varepsilon_{Si} \cong 11.9\ \varepsilon_0$)

9. For a given n-MOSFET with channel width W; channel length L; and given threshold voltage V_{Th}, the oxide capacitance per unit area Cox; and the electron mobility μ_n

(a) Please calculate the saturation current as the n-MOSFET is biased at V_G = 5V; V_S = 0V; V_D = 5V; Cox = 3.45 fF/μm^2; W = 10 μm; L = 1μm; $\mu_n = 500 \frac{cm^2}{sec \cdot v}$; V_{Th} = 1V. (5%)

(b) For the given I_D vs V_{DS} at different V_{GS} as shown in the following figure, what is the cause of increase of saturation current as the V_{DS} is greater than V_{DSat} (please answer it in one sentence)? I_D: drain current; V_{DS}: drain-to-source voltage; V_{GS}: gate-to-source voltage; V_{DSat}: drain voltage at which drain current saturates (5%)