國 立 清 華 大 學 命 題 紙

九十三學年度 電子工程研究所 系（所） ________ 組碩士班入學考試

科目 固態電子元件 科號 2905 共 2 頁第 1 頁 *請在試卷【答案卷】內作答

1. Bipolar Junction Transistor

For an npn bipolar junction transistor (BJT), we usually use a n^+ heavily doped layer as the emitter and a p^- lightly doped layer as the base.

(a) The figure below shows a typical common-emitter current gain or short-circuit current gain (β) versus the collector current (I_C) curve. The value of common-emitter current gain decreases at both low and high currents. Please explain the mechanisms for the decrease of β at these two regions. (5%)

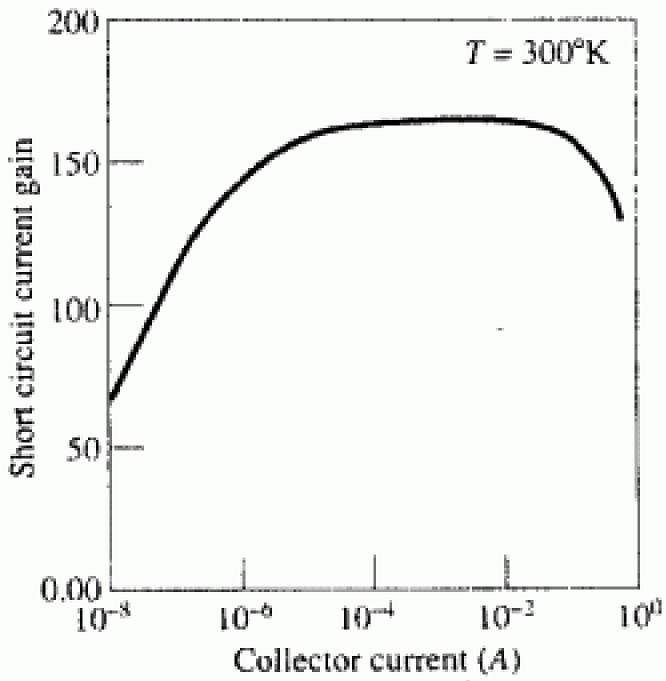
(b) The heavily doped emitter region often causes the bandgap narrowing effect in BJT. Please describe the influence of bandgap narrowing on the common-emitter current gain (β). (5%)

(c) The lightly doped base region often causes the current crowding phenomenon in the BJT.

(i) Explain concisely the term of current crowding phenomenon. (5%)

(ii) Describe the disadvantage of current crowding phenomenon for the BJT. Is it beneficial for the performance of BJT at high frequency? Explain your answer. (5%)

(iii) Please suggest a method of device design to avoid this phenomenon for a high-speed BJT to deliver a high current. (5%)



2. Field-Effect Transistor (FETs):

(a) State concisely, what is the primary difference between the long-channel and the two-region short-channel I_D-V_{DS} theories for FET. (5%)

(b) We usually use GaAs MESFET for the high-speed applications. Is the MESFET a depletion-type or an enhancement-type FET? Please explain your answer and explain why it is appropriate for the high-speed applications. (5%)

3. MOS capacitor

(a) Plot the the capacitance-voltage (*C-V*) relationship for a $n^+ - poly - Si / SiO_2 / n - Si$ MOSC. Assumed that the poly-Si is so heavily doped that it can be taken to be a metal. Assume also that the SiO_2 is ideal and the area of the MOSC is *A*. You must describe all three cases including low-frequency, high-frequency and deep-depletion *C-V* measurements. (4%)

(b) Denote the thickness of SiO_2 as t_{ox} and the doping level of n-Si as N_D. Assume again that the poly-Si is so heavily doped that it can be taken to be a metal. Plot the band diagram of the MOSC when it is biased at threshold voltage. (4%)

(c) Continued to (b), write down, without derivation, the threshold voltage of this $n^+ - poly - Si / SiO_2 / n - Si$. You must explain any other symbol in your formula if it is not given above. (4%)

(d) Explain the effect of fixed charge, interface traps and mobile ions on your high-frequency *C-V* measurements. (4%)

(e) Suppose now that the poly-Si is doped with As to a doping level of N_{poly} which is not high enough so that there may be depletion in the poly-Si at high bias. Explain how this poly-depletion would affect your low-frequency C-V measurement. (4 %)

4. MOSFET

(a) Explain the following terms：(1) gradual channel approximation, (2) transconductance, (3) subthreshold slope, (4) Drain-induced barrier lowering, (5) body effect. (5%)

(b) Write down, without derivation, the current-voltage relationship of an n-channel MOSFET in the square-law (or fixed bulk charge) model. (5%)

(c) Draw a CMOS inverter gate and explain its advantage over its n-MOS or p-MOS counterpart. (5%)

5. Semiconductor Physics Review (10%)

Explain the influence of band gap and temperature on the intrinsic carrier concentration of a semiconductor.

6. PN Junction Diode (20%)

Plot the log (*I*) vs. *V* curve of a pn junction diode under forward bias conditions.
Label the operation regimes of recombination, diffusion, high-level injection, and ohmic effect on this curve. Give brief explanation for these four operation regimes.