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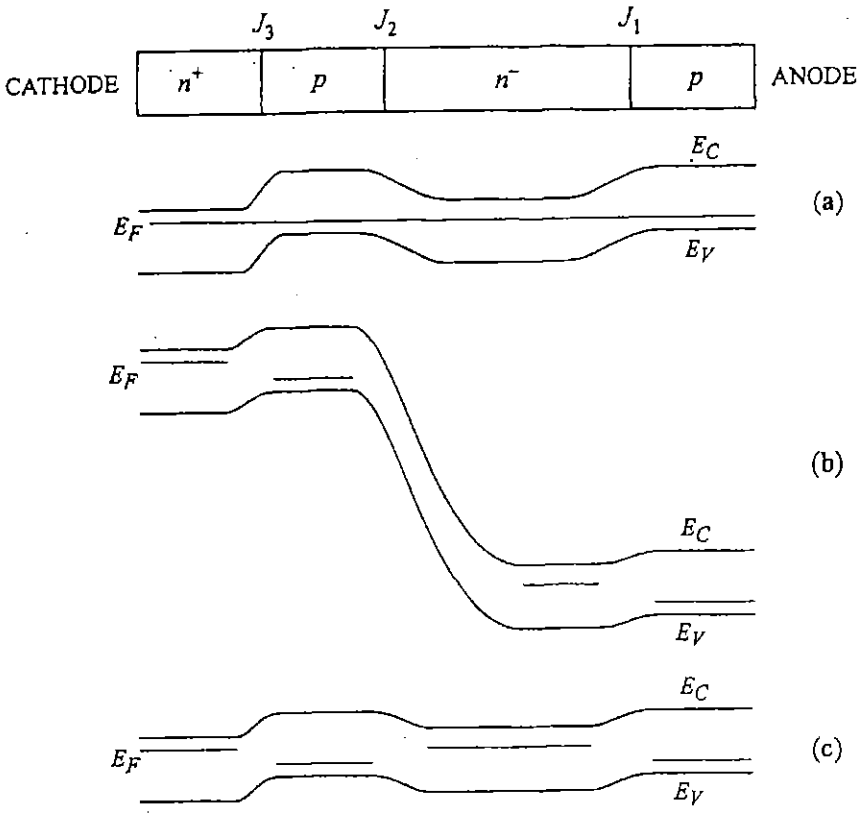
※請在答案卷內作答

1. The band diagrams and majority-carrier quasi-Fermi levels of a SCR with the application of the external bias are shown as follow. Answer the following questions with briefly explanation of the reason of your choice. (Note that there may be multiple choices and may be no choices at all for each problem. No credits will be given without brief explanation.)



(a) Which diagrams (a), (b), or (c) indicate that the anode is positively biased with respected to cathode? Explain.(4%)

(b) Which diagrams (a), (b), or (c) indicate that this SCR is in equilibrium? Explain. (4%)

(c) For diagrams (c), is the junction J_2 positively or negatively biased? Explain. (4%)

(d) Which diagrams (a), (b), or (c) exhibit a highest electric field? Explain. (4%)

(e) Which diagrams (a), (b), or (c) exhibit a largest depletion region? Explain. (4%)

2. Two silicon p^+/n step junction diodes maintained at 300 °K are physically identical except for the n-side doping. In diode #1, $N_D = 1 \times 10^{17}$ cm^{-3}; and in diode #2, $N_D = 1 \times 10^{15}$ cm^{-3}. Answering the following questions.

(a) At the same reverse bias voltage V_A, which diode will exhibit a larger depletion width? What is the ratio of depletion width between diode #1 and diode #2? (5%)

(b) At the same reverse bias voltage V_A, which diode will exhibit a larger junction capacitance? What is the ratio of junction capacitance between diode #1 and diode #2? (5%)

(c) Which diode will exhibit a larger breakdown voltage? What is the approximate ratio of breakdown voltage between diode #1 and diode #2? (Assuming the breakdown field is the same) (5%)

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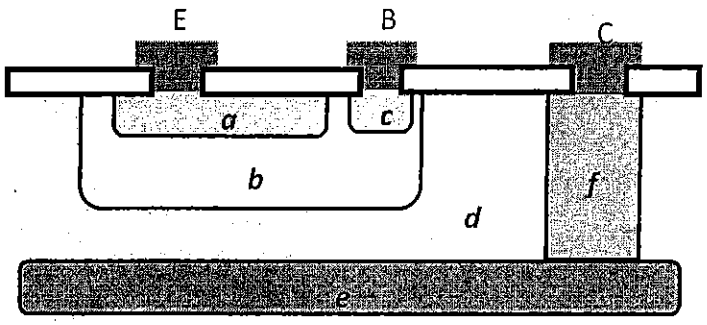
3. For two npn transistors, Q_1 and Q_2, with a base width $W_B = W_0$ and $W_B = 2W_0$, respectively, answer the following questions. Assume all other structure and doping voltage are identical for the two devices.
   (a) On the same plot, sketch qualitatively the Gummel plots of Q_1 and Q_2. (5%)
   (b) Assume that both transistor are biased in forward-active mode, let the diffusion capacitance of Q_1 and Q_2 be $C_{\pi 1}$ and $C_{\pi 2}$, respectively. Under the same collector current, find the capacitance ratio of $C_{\pi 1}/C_{\pi 2}$. Ignore depletion capacitance and recombination inside base region. (10%)

4. For each area in Figure below, please indicate how each region (***a,b,c,d,e,f***) should be doped (for example, n+, n, intrinsic, p or p+) to make a good pnp transistor and identify each region and its purpose. (15%)



5. In MOSFETs, the gate is generally consist of degenerately doped poly-silicon, for n-channel MOSFET, whose Fermi level is at the bottom of Silicon's conduction band.
(a) Draw the energy band diagram of the across the oxide for the typical n-channel MOSFET for gate voltage, $V_G = 0$ and $V_G > V_{TH}$, threshold voltage, respectively . (10%)
(b) If the gate is made by metal instead, assume, the metal's work function is the same as that of the Si, $\Phi_M = \Phi_S$, repeat problem (a). (10%)

6. For a short-channel MOSFET, answer the following questions by assuming other device parameters remains the same.
(a) How will the transit frequency, f_T, change if the channel width is reduced by 2X? Explain why. (5%)
(b) How will how the sub-threshold slope change if gate dielectric thickness is reduced by 2X? Explain why. (5%)
(c) How will how the gate-induced-drain-leakage current change when gate dielectric thickness reduces? Explain why. (5%)

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