參考用

1. (a) (10%) Draw the schematic energy band representations for an insulator, a semiconductor, and a conductor, respectively. (b) (10%) The bandgap of **Si** (silicon) is 1.12eV, the measured ionization energy for the donor **P** (phosphorus) is 0.045, and for the acceptor **B** (boron) is 0.045. Draw the schematic energy band with donor and acceptor ions.

2. (20 %) When a sufficiently large reverse voltage is applied to a p-n junction, the junction breaks down and conducts a very large current. Describe two important breakdown mechanisms in detail.

3. (10%) The forward current-voltage characteristics (I-V) of a p-n diode at 300 K can be represented empirically by an equation. Write down this equation with ideality factor. For the different values of ideality factor, different mechanisms dominate. Explain the relationship between the value of ideality factor and the different mechanisms.

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4. (a)(5%) For an MOS capacitor with a p-type substrate, the threshold voltage is given as

$$V_{TN} = a_1\phi_{ms} + a_2Q'_f + a_3qN_ax_{dT}$$

where ϕ_{ms} is the work function difference, Q'_f is the fixed charge located at the interface between the oxide layer and the silicon substrate. q is the electronic charge. N_a is the p-type doping concentration. x_{dT} is the maximum space charge width. Find the expressions for a_1, a_2, and a_3.

(b)(5%) For an MOS capacitor with an n-type substrate,, the threshold voltage is given as
$$V_{TP} = a_1\phi_{ms} + a_2Q'_f + a_3qN_dx_{dT}$$

where N_d is the n-type doping concentration. Find the expressions for a_4, a_5, and a_6.

5. (a)(5%) Sketch the C-V characteristics of an MOS capacitor with n-type semiconductor substrate under high-frequency and low-frequency conditions.

(b)(5%) Find the value of C/C_{ox} if the MOS capacitor is in strong inversion and under high-frequency condition. Assume the permittivity ratio $\epsilon_{Si}/\epsilon_{ox} = 3$, and $x_{dT}/t_{ox} = 6$, where x_{dT} is the maximum space charge width, t_{ox} is the thickness of the oxide layer.

6. (a)(5%) In an MOS capacitor, there are two fixed charges Q'_1 and Q'_2 in the oxide layer. Q'_1 is located at $x = t_{ox} \times \frac{1}{3}$, and Q'_2 is at $x = t_{ox} \times \frac{2}{3}$, where t_{ox} is the thickness of the oxide layer. Assume that the shift in the flat-band voltage due to the two fixed charges in the oxide layer is given by

$$\triangle V_{FB} = a_1Q'_1 + a_2Q'_2.$$

Find the expressions for a_1 and a_2. Note that Q'_1 and Q'_2 are given in coulomb per unit area.

(b)(5%) Sketch the electric distribution, E versus x, under flat-band condition. Assume $\phi_{ms} = 0$ V.

7. (a)(4%) Describe the physical meaning of the base transit time in an npn bipolar transistor.

(b)(3%) Describe the physical meaning of the base transport factor in an npn bipolar transistor.

(c)(3%) Describe the physical meaning of the emitter injection factor in an npn bipolar transistor.

8. (a)(5%) Sketch the minority carrier concentrations, $n(x)$ versus x or $p(x)$ versus x, in a pnp transistor biased in the forward-active mode. Assume $N_{aE} > N_{dB} > N_{aC}$, where N_{aE}, N_{dB}, and N_{aC} are the doping concentrations in the emitter region, the base region, and the collector region, respectively. x_E, x_B, and x_C are the emitter width, the base width, and the collector width, respectively. L_{nE}, L_{pB}, and L_{nC} are the minority diffusion lengths in the emitter region, the base region, and the collector region, respectively. Assume $x_E < L_{nE}$, $x_B < L_{pB}$, and $x_C >> L_{nC}$.

(b)(5%) Repeat (a) with $x_E = 5L_{nE}$, $x_B = 5L_{pB}$, and $x_C >> L_{nC}$.

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