國立中央大學 107 學年度碩士班考試入學試題

所別： 電機工程學系 碩士班 固態組(一般生)　　共2頁 第1頁

科目： 半導體元件

本科考試禁用計算器　　＊請在答案卷(卡)內作答

1. (5%) (a) At 300 K, the lattice constant for Si is 0.543 nm, Calculate the number of Si atoms per cubic nanometer.
(5%) (b) What is the distance between nearest neighbors in Si? Give your answer in nm. $\sqrt{2} = 1.732$.

2. (4%)(a) If the continuity equation for hole is $\frac{\partial p}{\partial t} = c_1 \frac{\partial J_p}{\partial x} + (G_p - R_p)$, J_p is the hole current density, G_p is the hole generation rate, and R_p is the hole recombination rate. Find the expression for c_1.
(3%)(b)Assuming an n-type sample under uniform illumination, the continuity equation for hole in (a) can be used to find $p_n(t)$. $R_p = \frac{p_n - p_{no}}{\tau_p}$, τ_p is the hole life time. In steady state ($t < 0$), $\frac{\partial p_n}{\partial t} = 0$, and for uniform distribution, $\frac{\partial^2 p_n}{\partial x^2} = 0$, and $G_p = G_L$, find $p_n(t)$ for $t < 0$.
(3%)(b) At $t = 0$, the light is turned off. Find $p_n(t)$ for $t \geq 0$.

3. Consider a silicon pn junction with doping concentrations of $N_a = 1 \times 10^{17}$ cm^{-3} and $N_d = 2 \times 10^{17}$ cm^{-3}. Assume $V_{bi} = V_{bi}^p + V_{bi}^n$, $W = x_p + x_n$. V_{bi}^p is the built-in voltage across the p-side of the junction, and x_p is the depletion width across the p-side of the junction.
(5%)(a) If $V_{bi}^p = V_{bi}/(1 + r_1)$, calculate r_1.
(5%)(b) If $x_n = W/(1 + r_2)$, calculate r_2.

4. For steady state and electric field $E = 0$, the excess minority carrier hole concentration $\delta p(x)$ in the n region is determined from with $\delta p(0) = c_1$, and $\delta p(x_B) = c_2$.
(10%) (a) If $\delta p(x) = Ae^{sx} + Be^{-sx}$, find s. If $A = \frac{f_1}{2\sinh(\frac{x_B}{L_p})}$, and $B = \frac{f_2}{2\sinh(\frac{x_B}{L_p})}$, find f_1 and f_2.
(5%) (b) If $\delta p(x) = f_3 \cdot \sinh(\frac{x_B - x}{L_p}) + f_4 \cdot \sinh(\frac{x}{L_p})$, find f_3 and f_4.
(5%) (c) If $\frac{x_B}{L_p} \to 0$, and $\delta p(x) = f_5 \cdot \frac{x_B - x}{x_B} + f_6 \cdot \frac{x}{x_B}$, find f_5 and f_6.

5. Consider a p-type silicon substrate doped to $N_a = 1 \times 10^{16}$ cm^{-3}. The oxide is silicon dioxide with a thickness of $t_{ox} = 18$ nm. Note that $kT/q = 0.026$ V, $n_i = 1 \times 10^{10}$ cm^{-3}, $E_g = 1.12$ eV, the electron affinity $X = 4.01$ V, $\epsilon_{Si} = 11.7 \times 8.85 \times 10^{-14}$ F/cm $= 103.5 \times 10^{-14}$ F/cm, $\epsilon_{ox} = 3.9 \times 8.85 \times 10^{-14}$ F/cm $= 34.5 \times 10^{-14}$ F/cm, $q = 1.6 \times 10^{-19}$ C, $\epsilon_{Si}/q = 64.7 \times 10^5$ 1/V·cm, and $\ln(10^6) = 13.8$.
(7%) (a) If the gate is n^+-polysilicon, find the threshold voltage V_{Ta}.
(3%) (b) If the gate is p^+-polysilicon, the threshold voltage is V_{Tb}. Find the value $V_{Tb} - V_{Ta}$.

注意:背面有試題

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6. (4%) (a) Consider an n-channel MOSFET with the channel width $W = 1$ μm. The inversion charge $|Q'_n| = 10^{-6}$ C/cm^2, the electron velocity is 10^6 cm/s. Calculate the channel current I_D.
(3%) (b) If $|Q'_n(y)| = C_{ox}(V_{GS} - V_T - V(y))$, the electron velocity $|v_n(y)| = \mu_n \frac{dV(y)}{dy}$, and $I_D(y) = f_1 \cdot (V_{GS} - V_T - V_y)\frac{dV_y}{dy}$, find f_1.
(3%) (c) At $y = L$, $V(y) = V_{DS}$, $y = 0$, $V(y) = 0$. Assuming $I_D(y) = I_D$ at any y, and μ_n is constant, find I_D for $(V_{GS} - V_T - V_{DS}) \geq 0$.

7. (10%) Assume the following transistor parameters: the base doping $N_B = 1 \times 10^{15}$ cm^{-3}, the emitter doping $N_E = 1 \times 10^{17}$ cm^{-3}, the diffusion coefficient in the emitter $D_E = 10$ cm^2/s, the diffusion coefficient in the base $D_B = 20$ cm^2/s, the base width $x_B = 0.6$ μm, and the emitter width $x_E = 0.8$ μm. The minority carrier diffusion length in the base, $L_B = 10.0$ μm. $x_B << L_B$ and $x_E << L_E$. Find the emitter injection efficiency γ, the base transport factor α_T, and the common-emitter current gain β.

8. In an npn Ebers-Moll model, V_{BE} and V_{BC} can be obtained as functions of I_C, I_B, I_{ES}, I_{CS}, α_F, and α_R.
(5%) (a) If $V_{BE} = V_t \cdot \ln(\frac{f_1+t_1}{t_1})$, find f_1. Note that $t_1 = I_{ES}(1 - \alpha_F\alpha_R)$, and $V_t = kT/q$.
(5%) (b) If $V_{BC} = V_t \cdot \ln(\frac{f_2+t_2}{t_2})$, find f_2. Note that $t_2 = I_{CS}(1 - \alpha_F\alpha_R)$.

9. (5%) (a) The hybrid-pi ac model for an npn bipolar transistor is shown in Fig. 1. Assume $i_b = g_{11}v_{be} + g_{12}v_{ce}$, and $i_c = g_{21}v_{be} + g_{22}v_{ce}$. If $g_{11} = \frac{\partial x}{\partial y}|_z$, find x, y, and z.
(5%) (b) Find r_π and g_m, which are functions of g_{11}, g_{12}, g_{21}, and g_{22}.

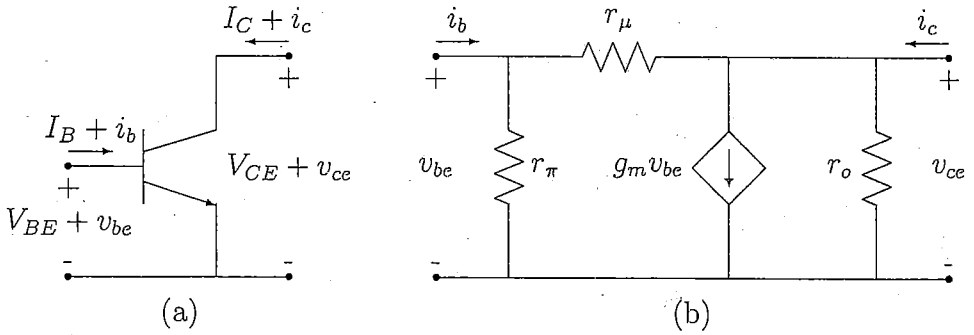

Fig. 1

注意:背面有試題

參考