國立中央大學100學年度碩士班考試入學試題卷

所別：電機工程學系碩士班 固態組(一般生)　科目：半導體元件　共 1 頁 第 1 頁

本科考試禁用計算器

*請在試卷答案卷（卡）內作答

1. The lattice constant of a simple cubic cell is a. (a) (5%) Calculate the distance between the nearest parallel (110) planes. (b) (5%) Calculate the surface density of atoms on the plane (110).

2. (10%) Calculate the electron diffusion current density. Assume that the electron mobility is 1000 cm^2/V-s at $kT/q = 0.026$ V, $q = 1.6 \times 10^{-19}$ C, and $\frac{dn}{dx} = 1 \times 10^{21}$ cm^{-4}.

3. (10%) In a pn junction, N_a is the p-type doping density, N_d is the n-type doping density. The electric potential $\phi(-x_p) = 0$, and $\phi(x_n) = V_{bi}$, x_p is the p-type depletion width, and x_n is the n-type depletion width. Both x_p and x_n are positive. V_{bi} is the built-in potential. If $\phi(x) = a(x - x_n)^2 + V_{bi}$ for $0 \le x \le x_n$, find a in terms of N_d.

4. (10%) The total forward-bias current in a pn diode is the sum of the recombination and the ideal diffusion current densities as $J = J_{rec} + J_D$. $J_D = J_s(\exp(\frac{V_a}{V_t}) - 1)$. $J_{rec} = J_{r0}(\exp(\frac{V_a}{2V_t}) - 1)$. $J_{r0} > J_s$. Sketch $\ln(J)$ versus $\frac{V_a}{V_t}$ for $V_a > 0$. Show the $\ln(J_{r0})$, $\ln(J_s)$ on your plot.

5. Consider a Schottky barrier diode with n-type silicon doped to N_d. (a) (5%) Find the theoretical barrier height ϕ_{B0} in terms of the metal work function ϕ_m and the silicon electron affinity χ. (b) (5%) Find the built-in potential barrier V_{bi} in terms of the effective density of states in the conduction band N_c.

6. Consider an npn transistor with a base region from $x = 0$ to x_B. The excess electron concentration $\Delta n_B(x) = \Delta n_B(0) = \Delta n_{B1}$ at $x = 0$. $\Delta n_B(x) = \Delta n_B(x_B) = \Delta n_{B2}$ at $x = x_B$. $\Delta n_{B1} > 0$ and $\Delta n_{B2} < 0$ (a) (5%) Plot $\Delta n_B(x)$ versus x if $x_B >> L_B$, where L_B is the electron diffusion length in the base region. (b) (5%) If $\Delta n_B(x) = m_1 \cdot \Delta n_{B1} + m_2 \cdot \Delta n_{B2}$ for $x_B << L_B$, find m_1 and m_2 in terms of x and x_B.

7. (a) (5%) Sketch the basic Ebers-Moll equivalent circuit for an npn bipolar transistor with the following parameters: α_F, α_R, I_{ES}, I_{CS}, V_{BE}, and V_{BC}. (b) (5%) The Ebers-Moll model has four parameters: α_F, α_R, I_{ES}, and I_{CS}. According the reciprocity relationship, the four parameters can be reduced to three independent parameters: α_F, α_R, and I_S. Find I_S in terms of α_F and I_{ES}.

8. (10%) Using superposition, the shift in the flat-band voltage due to a fixed constant charge distribution $\rho(x) = \rho_1$ in the oxide region can be given by $\Delta V_{FB} = a\rho_1 t_{ox}^2$. Find the expression of a in terms of ϵ_{ox}, where ϵ_{ox} is the permittivity of the oxide, and t_{ox} is the oxide thickness.

9. (a) (5%) Sketch the C-V characteristics of an MOS capacitor with a p-type substrate under the low-frequency condition and the high-frequency condition in a same plot. (b) (5%) Sketch the differential charge distributions under the low-frequency condition and the high-frequency condition respectively.

10. (10%) $I_D = \frac{W\mu_n C_{ox}}{2L}[2(V_{GS} - V_T)V_{DS} - V_{DS}^2]$ for an n-channel MOSFET in the nonsaturation region. Describe how to determine the inversion carrier mobility μ_n and the threshold voltage V_T from the I-V experimental results. For a fixed V_{DS}, $I_D = I_{D1}$ if $V_{GS} = V_{GS1}$, and $I_D = I_{D2}$ if $V_{GS} = V_{GS2}$.