



Course Title and Code Number:
Semiconductor Devices (EE336)
Third Year (Communications and Electronics)
Time Allowed: 90 Mins

اسم المقرر والرقم الكودي له:
النبأط شبه الموصلة (EE336)
السنة الدراسية الثالثة (اتصالات و الكترونيايات)
الزمن: ٩٠ دقيقة

Answer All Questions:

(45 marks)

Question 1:

(15 marks)

- Plot** the curve of C_s/C_0 value for $k_0=0.05$ in the Czochralski technique. Why is the impurity concentration larger in the center of the wafer than at its perimeter?
- If a silicon oxide layer of thickness x is grown by thermal oxidation, what is the thickness of silicon being consumed? The molecular weight of Si is 28.9 g/mol , and the density of Si is 2.33 g/cm^3 . The corresponding values for SiO_2 are 60.08 g/mol and 2.21 g/cm^3 .
- In a two-step arsenic diffusion process a predeposition layer is formed under a constant-surface-concentration condition at 1000°C where the surface concentration is maintained at 10^{19} cm^{-3} and the diffusion time is an hour. This step is followed by a drive-in diffusion under a constant-total-doping condition for an hour under 1200°C . For arsenic diffusion $D_0=24 \text{ cm}^2/\text{s}$ and $E_a=4.08 \text{ eV}$. **Plot** the diffusion profiles and **calculate** the junction depth after each step. The carrier concentration for constant-surface-concentration and constant-total-doping is given by the following equations, respectively:

$$C(x, t) = C_s \operatorname{erfc}\left(\frac{x}{2\sqrt{Dt}}\right), \quad C(x, t) = \frac{S}{\sqrt{\pi Dt}} \exp\left(-\frac{x^2}{4Dt}\right)$$

where C_s is the surface concentration, erfc is the complementary error function, \sqrt{Dt} is the diffusion length, and S is the total amount of dopant per unit area.

Hint: $\int_0^\infty \operatorname{erfc}(x) dx = \frac{1}{\sqrt{\pi}}$

Question 2:

(15 marks)

For a MOS capacitance with a p-type substrate where the gate is connected to a voltage source V and the substrate is connected to the ground, answer the following questions:

- Plot** the (i) band diagram (ii) charge distribution, (iii) electric-field distribution, and (iv) potential distribution of the ideal MOS capacitance in the depletion region.
- Starting from the Poisson's equation **derive** an expression of the (i) depletion region width, (ii) gate-to-substrate capacitance, and (iii) threshold voltage as a function of the gate voltage.
- Draw** the C-V characteristic curves of a practical MOS capacitance with a flat band voltage of V_{FB} indicating the operation regions, minimum and maximum capacitance values, V_{FB} and V_T on your plot. Show and explain the frequency effect on the C-V characteristics.
- For an ideal MOS capacitor with $d=5 \text{ nm}$, $N_A=10^{17} \text{ cm}^{-3}$, find the applied voltage and electric field at the interface required to (i) make the silicon surface intrinsic, and (ii) to bring about strong inversion. Assume that $KT/q=0.026 \text{ V}$, $\epsilon_s=11.9\epsilon_0$, $\epsilon_{ox}=3.9\epsilon_0$, and $n_i=9.65 \times 10^9 \text{ cm}^{-3}$.

Question 3:**(15 marks)**

- a) **Derive** the I-V characteristics of an n-MOSFET device with the drain and gate connected together and the source and substrate grounded. Can one obtain the threshold voltage from these characteristics? You can start from the ideal MOSFET I-V characteristics given by the following equation:

$$I_D \approx \frac{Z}{L} \mu_n C_o \left\{ \left(V_G - 2\psi_B - \frac{V_D}{2} \right) V_D - \frac{2}{3} \frac{\sqrt{2\epsilon_s q N_A}}{C_o} \left[(V_D + 2\psi_B)^{3/2} - (2\psi_B)^{3/2} \right] \right\}$$

- b) **Plot** the cross section of the MOSFET described in (a) indicating the depletion and inversion regions in different operating modes and **Draw** the I-V characteristic curve for the MOSFET.
- c) Consider a submicron MOSFET with $L=0.25 \mu m$, $Z=5 \mu m$, $N_A=10^{17} cm^{-3}$, $\mu_n=500 cm^2/V\cdot s$, $C_{ox}=3.45 \times 10^{-7} F/cm^2$, $\epsilon_s=11.9\epsilon_0$, and $V_T=0.5 V$. **Find** V_{Dsat} and I_{Dsat} for $V_G=3 V$. Assume that $KT/q=0.026 V$ and $n_i=9.65 \times 10^9 cm^{-3}$.
- d) For the MOSFET described in (c) **find** the channel conductance and transconductance for $V_G=1 V$ and $V_D=0.1 V$.
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Good Luck,

Examiner: Dr. Mohammed Morsy