

SOLUTIONS MANUAL for CMOS Digital Integrated Circuits Analysis and Design 4th Edition by Kang

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Exercise Problems

3.1 Consider a MOS system with the following parameters:

$$\begin{aligned}t_{ox} &= 1.6 \text{ nm} \\ \phi_{GC} &= 1.04 \text{ V} \\ N_A &= 2.8 \times 10^{18} \text{ cm}^{-3} \\ Q_{ox} &= q \cdot 4 \times 10^{10} \text{ C/cm}^2\end{aligned}$$

- a. Determine the threshold voltage V_{th} under zero bias at room temperature ($T = 300 \text{ K}$).
Note that $\phi_{ms} = 3.97 \text{ eV}$ and $\phi_s = 11.7 \text{ eV}$.

SOLUTION :

First, calculate the Fermi potentials for the p-type substrate and for the n-type polysilicon gate:

$$\phi_{(substrate)} = \frac{kT}{q} \ln \frac{N_A}{N_i} = 0.026 \text{ V} \ln \frac{2.8 \times 10^{18}}{1.45 \times 10^{10}} = 0.49 \text{ V}$$

The depletion region charge density at $V_{gs} = 0$ is found as follows:

$$\begin{aligned}Q_{as} &= \sqrt{2 q N_A \epsilon_s \left(2 \phi_{(substrate)} \right)} \\ &= \sqrt{2 \cdot 1.6 \times 10^{19} \cdot (2.8 \times 10^{18}) \cdot 11.7 \cdot 8.85 \times 10^{-14} \cdot 2 \cdot 0.49} \\ &= 9.53 \times 10^7 \text{ C/cm}^2\end{aligned}$$

The oxide-interface charge is:

$$Q_{ox} = q N_{ox} = 1.6 \times 10^{19} \text{ C} \cdot 4 \times 10^{10} \text{ cm}^{-2} = 6.4 \times 10^8 \text{ C/cm}^2$$

The gate oxide capacitance per unit area is calculated using the dielectric constant of silicon dioxide and the oxide thickness t_{ox} :

$$C_{ox} = \frac{\epsilon_{ox}}{t_{ox}} = \frac{3.97 \cdot 8.85 \times 10^{-14} \text{ F/cm}}{1.6 \times 10^{-7} \text{ cm}} = 2.2 \times 10^6 \text{ F/cm}^2$$

Now, we can combine all components and calculate the threshold voltage.

$$\begin{aligned}V_{th-GC} &= 2 \phi_{(substrate)} + \frac{Q_{as}}{C_{ox}} + \frac{Q_{ox}}{C_{ox}} \\ &= 1.04 + (0.98) + (0.53) + (0.03) = 0.44 \text{ V}\end{aligned}$$

- b. Determine the type (p-type or n-type) and amount of channel implant (N_D/cm^2) required to change the threshold voltage to 0.6 V .

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Roger L. Tokheim



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