C-V Characteristics of MOS Capacitor

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Introduction

This report analyzes the capacitance-voltage (C-V) characteristics of a MOS capacitor using the Scaps software. The analysis includes the variation of C-V characteristics with different gate metals, substrate doping densities, and oxide thicknesses.

Equations and Analysis

Flatband Voltage (V_{FB})

The flatband voltage V_{FB} is given by:

$$V_{FB} = \phi_m - \phi_s \tag{1}$$

where:

- ϕ_m is the work function of the metal.
- ϕ_s is the work function of the semiconductor.

Threshold Voltage (V_{TH})

The threshold voltage V_{TH} is given by:

$$V_{TH} = V_{FB} + 2\phi_F + \sqrt{\frac{4\varepsilon_s q N_a \phi_F}{C_{ox}}} \tag{2}$$

where:

- ϕ_F is the Fermi potential.
- ε_s is the permittivity of the semiconductor.
- q is the elementary charge.
- N_a is the acceptor ion concentration.
- C_{ox} is the oxide capacitance.

Oxide Charge Density (Q_{ox})

The oxide charge density Q_{ox} is calculated as:

$$Q_{ox} = C_{ox}(V_H - V_T) \tag{3}$$

where:

- V_H is the applied gate voltage.
- V_T is the threshold voltage.

Capacitance (C)

The capacitance C is given by:

$$C = \begin{cases} C_{ox} & \text{if } V_G \leq V_{FB} \\ \frac{1}{\frac{1}{C_{ox}} + \frac{x_d}{\varepsilon_s}} & \text{if } V_{FB} < V_G \leq V_T \end{cases} \tag{4}$$

where:

- V_G is the gate voltage.
- x_d is the depletion width.
- ε_s is the permittivity of the semiconductor.

Observations

- **Gate Metal Work Function (ϕ_m)**: Increasing ϕ_m leads to an increase in both V_{FB} and V_{TH}.
- **Substrate Doping Density (N_A)**: Increasing N_A results in a decrease in V_{FB} and V_{TH}.
- **Oxide Thickness (t_{ox})**: An increase in t_{ox} causes V_{FB} to increase.
- **Polysilicon Gate**: Using a p^+ polysilicon gate results in $V_{FB} \approx 0$ and a significant increase in V_{TH}.

Conclusion

The simulation results are consistent with theoretical predictions. The variations in V_{FB}, V_{TH}, and capacitance C follow the expected trends based on the equations.