DRAFT

MOS Capacitor

Lecture 6

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Advanced Devices (EC760)

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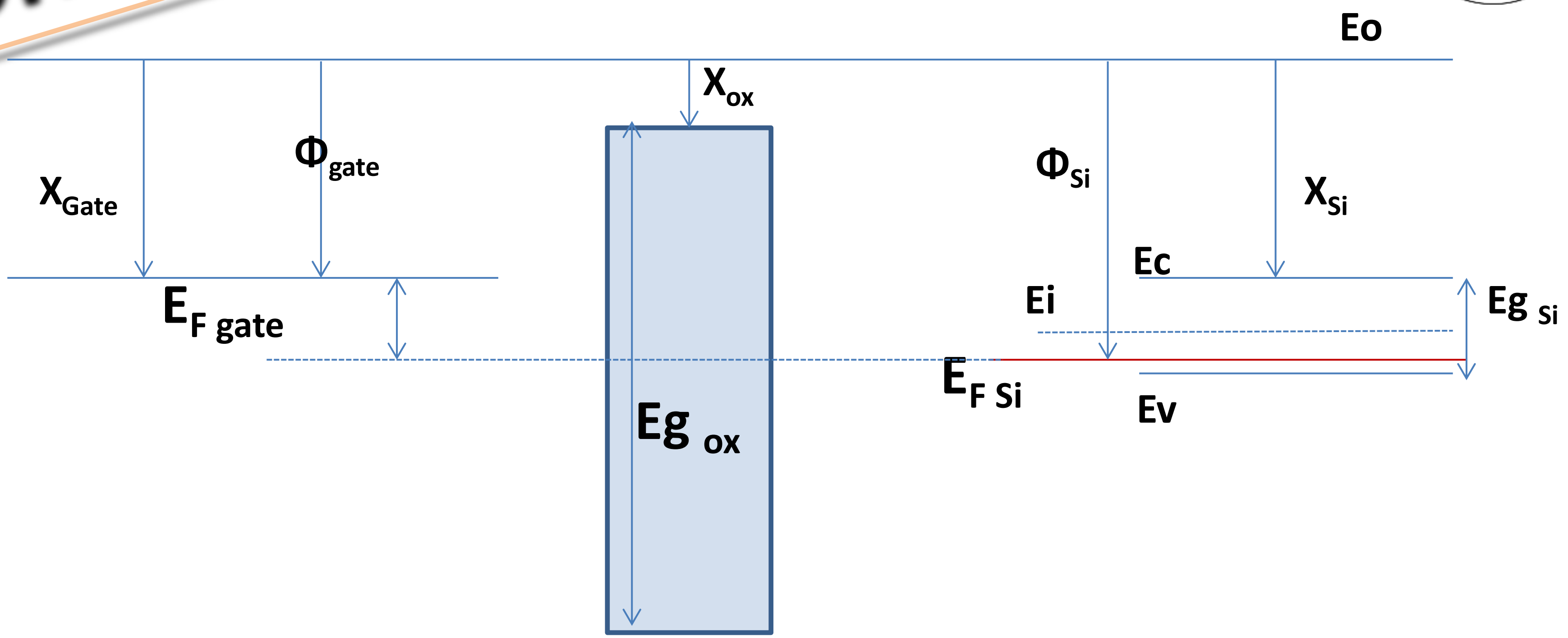
Outline

- Depletion Approximation
- Potential Drop Equation
- Threshold Voltage (***V_{th}***) and Flatband Volatge (***V_{FB}***)
- Capacitance Voltage (C-V) Characteristics

Flatband Voltage (V_{FB})



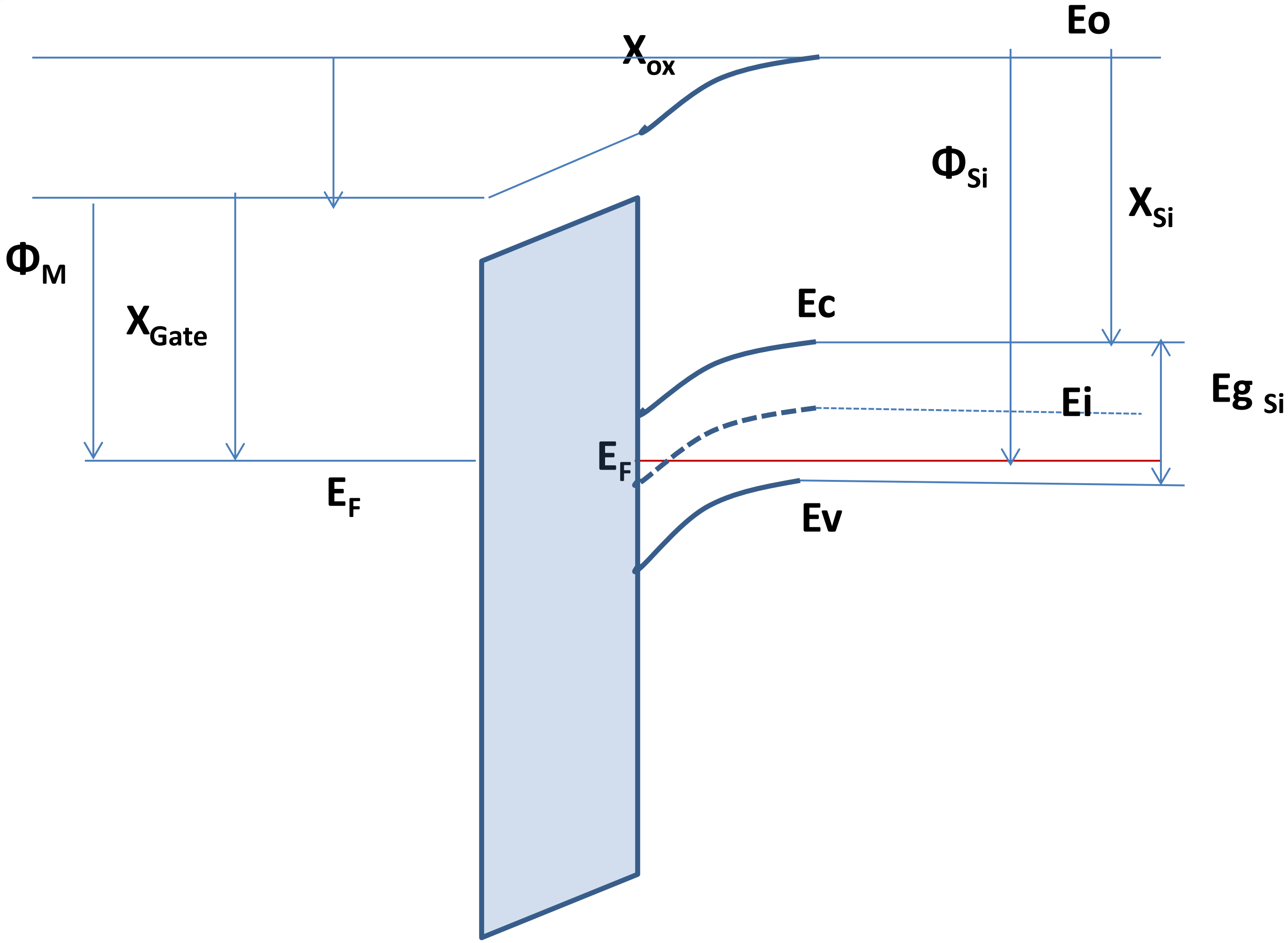
$$V_{FB} = Gate\ Workfunction - Semiconductor\ Workfunction$$

$$qV_{FB} = \Phi_{gate} - \Phi_{Si} = E_{F\,gate} - E_{F\,Si}$$

$$= (X_{gate} + E_{C\,gate} - E_{F\,gate}) - (X_{Si} + E_{C\,Si} - E_{F\,Si})$$

$$= (X_{gate} + E_{C\,gate} - E_{F\,gate}) - (X_{Si} + K_B T \ln \frac{N_C}{N_A})$$

Potential Drop Equation: No Applied Gate Voltage



Potential Drop Equation: Applied Gate Voltage

$$V_g + (\Phi_{si} - \Phi_g) = V_{ox} + \Psi_s$$

$$V_g - V_{FB} = V_{ox} + \Psi_s$$

$$V_{ox} = -\frac{Q_s}{C_{ox}}$$

In Inversion:

$$Q_s = Q_{dep} + Q_{inv}$$

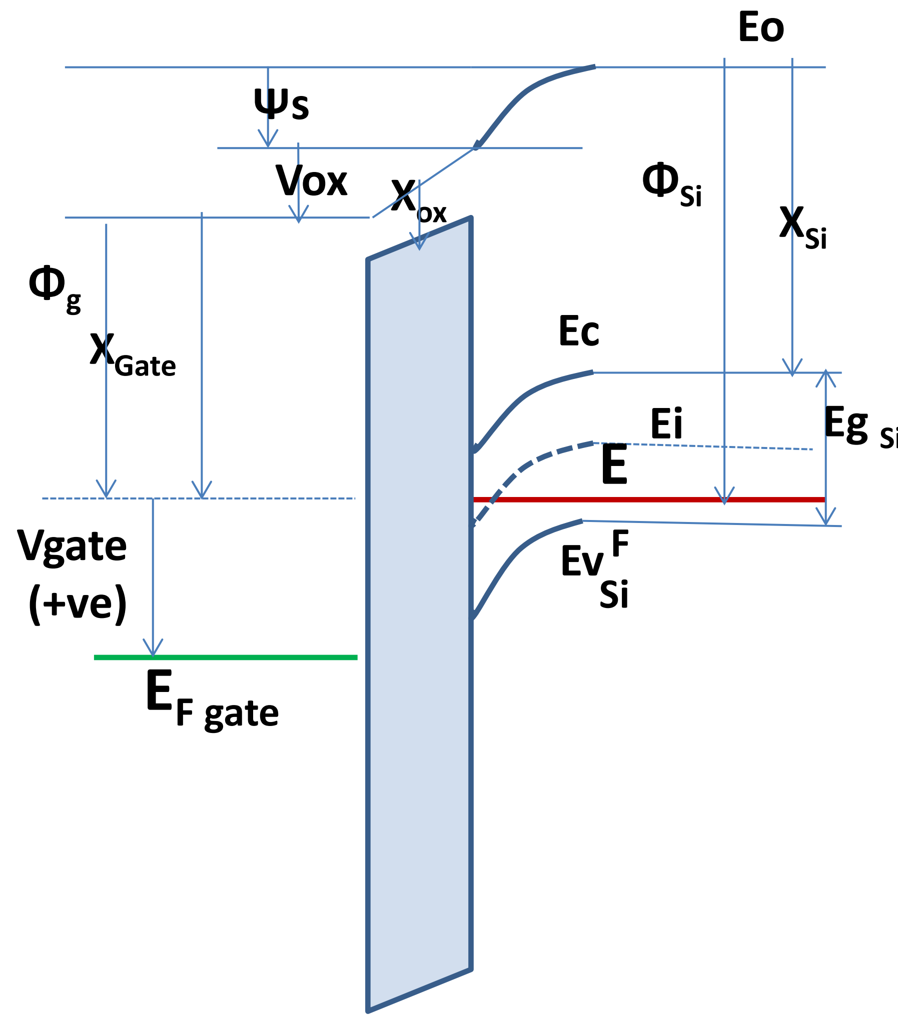
$$Q_{dep} = -qN_A W_{dep} = -\sqrt{2\varepsilon_{si} q N_A \Psi_s}$$

In Strong Inversion:

$$Q_{inv} \approx -\sqrt{\frac{2\varepsilon_{si} K_B T\, n_i^{\,2}}{N_A}}\, e^{q\psi_s/2KBT}$$

In-between: use Q_s equation

In Depletion: $Q_s \approx Q_{dep}$



Threshold Voltage (V_{th}) under Depletion Approximation

At $0 > \Psi_s \geq 2\,\Psi_{Bulk}$:

- No free carriers (i.e. no inversion electrons)
- Only depletion charges from ionized dopants

At $\Psi_s \geq 2\,\Psi_{Bulk}$:

- No more changes in surface potential
- Fixed Q_{dep}
- Only changes in inversion electrons
- V_{gate} at $\Psi_s \geq 2\,\Psi_{Bulk}$ is called Threshold Voltage (V_{th})

Using: $V_{gate} = V_{FB} - \frac{Q_s}{C_{ox}} + \Psi_s$

At "Onset" of Strong Inversion: $V_{th} = V_{FB} - \frac{Q_{dep}}{C_{ox}} + 2\Psi_{Bulk}$

$$= V_{FB} + \frac{\sqrt{2\varepsilon_{si} q N_A (2\Psi_{Bulk})}}{C_{ox}} + 2\Psi_{Bulk}$$

Inversion Charge(V_{th}) under Depletion Approximation (

In Strong Inversion ($V_g > V_{th}$):

$$V_{gate} = V_{FB} - \frac{Q_{dep} + Q_{inv}}{C_{ox}} + 2\Psi_{Bulk} = \boldsymbol{V_{FB}} - \frac{\boldsymbol{Q_{dep}}}{\boldsymbol{C_{ox}}} + \boldsymbol{2\Psi_{Bulk}} - \frac{Q_{inv}}{C_{ox}}$$

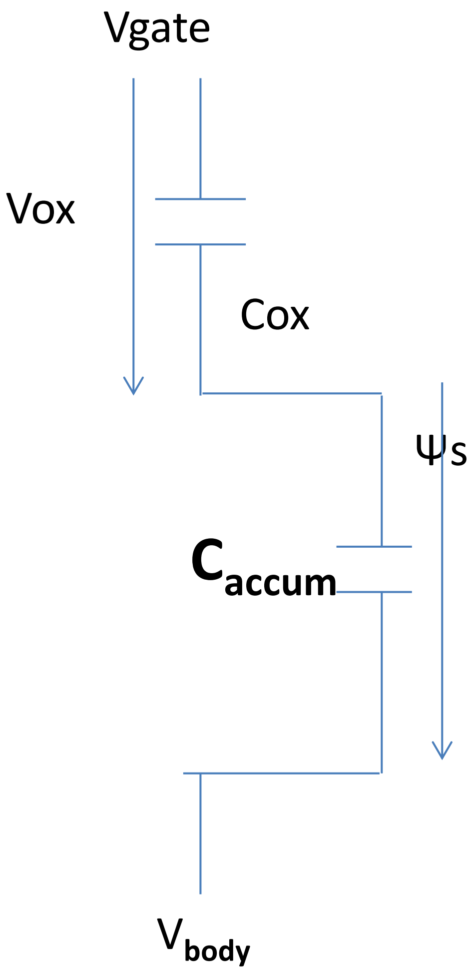
$$V_{gate} = \boldsymbol{V_{th}} - \frac{Q_{inv}}{C_{ox}}$$

$$\rightarrow \boldsymbol{Q_{inv} = -C_{ox}(V_{gate} - V_{th})}$$

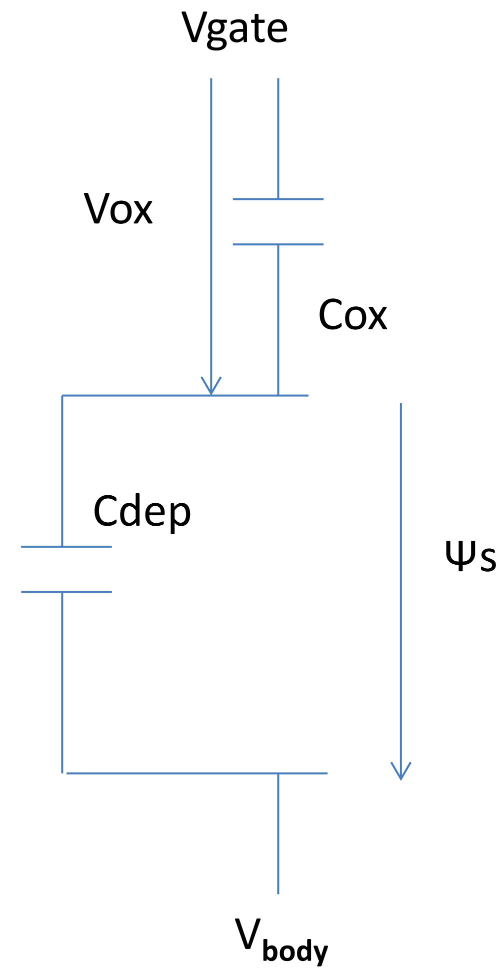
Capacitance-Voltage (C-V) Characteristics

Small Signal: $C_C(Vg) = dQ_C/dV_C$

Accumulation



Depletion



Inversion