EE105
Microelectronic Devices and Circuits:
MOSFET

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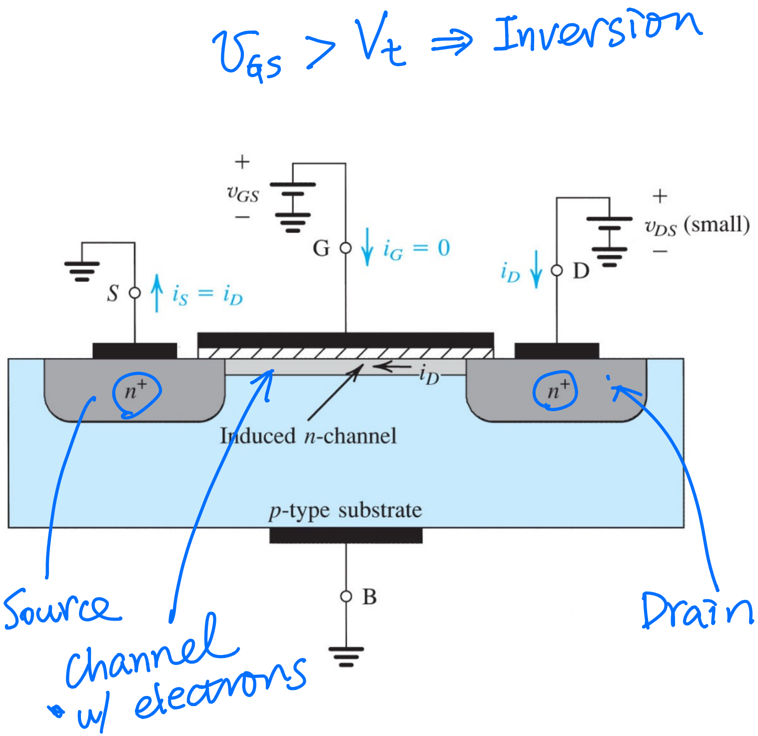
Creating a "Channel" for Current Flow



MOS is a capacitor across an insulator (oxide)

When a positive voltage is applied at Gate, electrons are induced under the gate.

At "thresold", sufficient number of electrons form a "channel" between Source and Drain, forming a conductive channel.

Total charge in the channel:

$$|Q| = C_{ox} \cdot WL \cdot (v_{GS} - V_t)$$

where $C_{ox} = \dfrac{\varepsilon_{ox}}{t_{ox}}$ is oxide capacitance per unit area

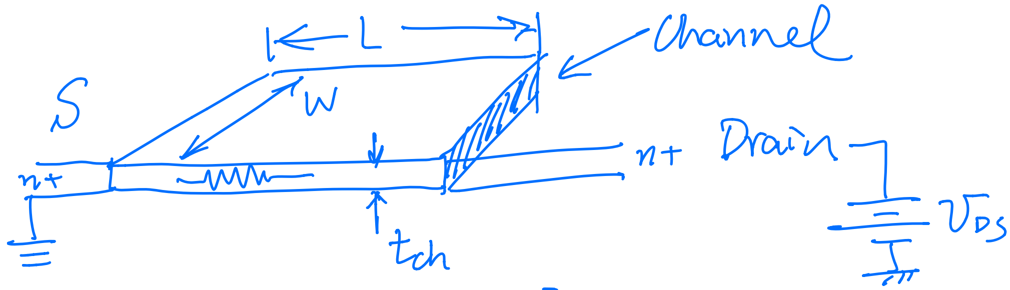
$$\varepsilon_{ox} = 3.9\varepsilon_0 = 3.9 \times 8.854 \times 10^{-12} \text{ F/m}$$

W : gate width

L : gate length

V_t : Threshold voltage

$v_{GS} - V_t \equiv v_{OV}$ is called "Overdrive Voltage"



$$J = \sigma \cdot E = (n q \mu_n) \cdot \frac{V_{DS}}{L}$$

$$E = \frac{V_{DS}}{L}$$

MOS capacitor

$$n: \quad Q = CV = C_{ox} \cdot (V_{GS} - V_t) \cdot W \cdot L$$

(C_{ox}: per unit area; $W \cdot L$: area)

$$n q = \frac{Q}{W \cdot L \cdot t_{ch}}$$

$$I_{DS} = J \times t_{ch} \cdot W$$

$$= n q \mu_n \cdot \frac{V_{DS}}{L} \cdot t_{ch} \cdot W$$

$$= \underbrace{\frac{C_{ox}(V_{GS} - V_t) \cdot \cancel{W} \cdot \cancel{L}}{\cancel{W} \cdot \cancel{L} \cdot \cancel{t_{ch}}}}_{n} \cdot \mu_n \cdot \cancel{t_{ch}} \cdot W \cdot \frac{V_{DS}}{L}$$

$$I_{DS} = \mu_n C_{ox} (V_{GS} - V_t)\left(\frac{W}{L}\right) \cdot V_{DS}$$

Equivalent resistance

$$R_{ch} = \frac{V_{DS}}{I_{DS}} = \frac{1}{\mu_n C_{ox} \underbrace{(V_{GS} - V_t)}_{\text{gate bias}} \cdot \left(\frac{W}{L}\right)}$$

($\frac{W}{L}$: Geometry)