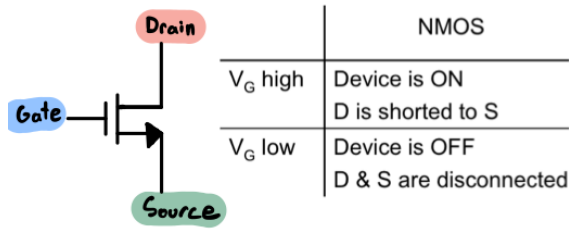


# Basic MOS Device Physics:

## NMOS:



Current flows from Drain to Source

Source  $\xrightarrow{\text{electron}}$  Drain

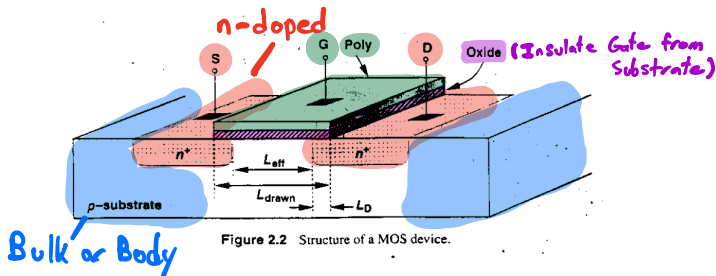
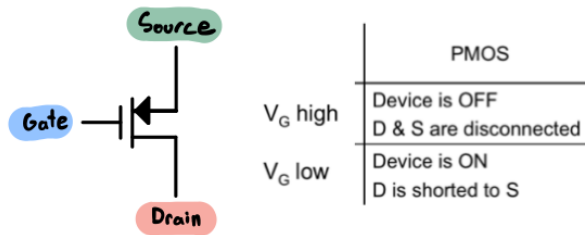


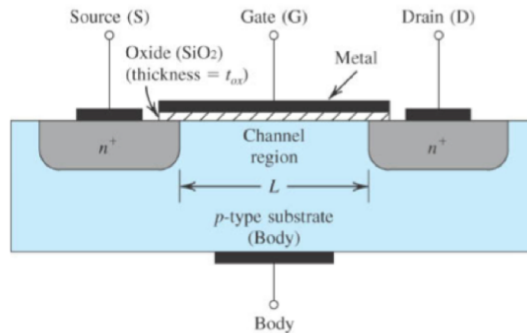
Figure 2.2 Structure of a MOS device.

## PMOS:



Current flows from Source to Drain

Source  $\xrightarrow{\text{hole}}$  Drain



## Threshold Voltage:

- The voltage  $V_{th}$  such that the device is ON if  $V_G > V_{th}$

Analytically:

$$V_{TH} = \Phi_{MS} + 2 \cdot |\Phi_F| + \frac{|Q_{dep}|}{C_{ox}}$$

Where:

$\Phi_{MS}$  = Built-in Potential =  $\Phi_{gate} - \Phi_{Silicon}$   
= the difference between the work functions of the polysilicon gate and the silicon substrate

$$\Phi_F = \text{Work Function (electrostatic potential)} = \frac{K \cdot T}{q} \cdot \ln\left(\frac{N_{sub}}{n_i}\right)$$

$$Q_{dep} = \text{Charge in the depletion region} = \sqrt{4 \cdot q \cdot \epsilon_{si} \cdot |\Phi_F| \cdot N_{sub}}$$

## Long-Channel Current:

$$I_D = \mu_n C_{ox} \cdot \frac{W}{L} \cdot \left[ (V_{GS} - V_{th}) \cdot V_{DS} - \frac{1}{2} V_{DS}^2 \right]$$

## Regions of Operation:

- $V_{DS} \leq V_{GS} - V_{th}$  **TRIODE (LINEAR)**

Current in Triode Region:

$$I_D = \mu_n \cdot C_{ox} \cdot \frac{W}{L} \cdot \left[ (V_{GS} - V_{TH}) \cdot V_{DS} - \frac{1}{2} V_{DS}^2 \right]$$

## Effective Voltage:

$$V_{eff} = V_{GS} - V_{th}$$

\* Sometimes called **Overdrive Voltage**

$$\frac{W}{L} = \text{Aspect Ratio}$$

— Small  $V_{DS}$ ,  $V_{DS} \ll 2(V_{GS} - V_{th})$  **DEEP TRIODE**

The device will behave like a variable resistor



$$I_D = \mu_n \cdot C_{ox} \cdot \frac{W}{L} \cdot (V_{GS} - V_{TH}) \cdot V_{DS}$$

$$R_{ON} = \frac{V_{DS}}{I_D} = \frac{1}{\mu_n \cdot C_{ox} \cdot \frac{W}{L} \cdot (V_{GS} - V_{TH})}$$

—  $V_{DS} > V_{GS} - V_{th}$  **SATURATION (Active)**

channel is pinched off.

$$I_D = \frac{1}{2} \mu_n C_{ox} \frac{W}{L} (V_{GS} - V_{TH})^2$$

Summary:

Current Equation for NMOS:

Current Equation for PMOS: