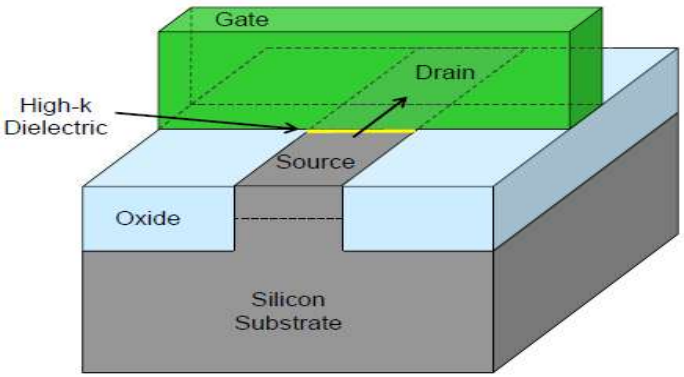
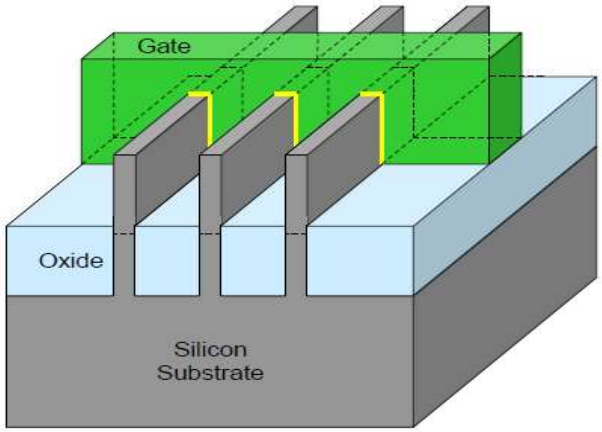
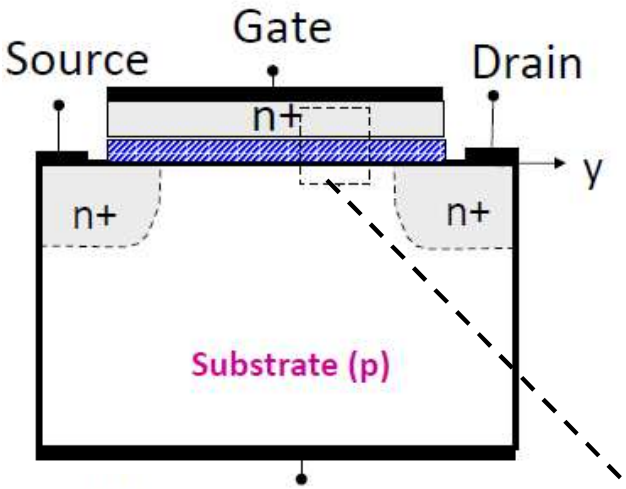
MOS Field-Effect Transistor (MOSFET)

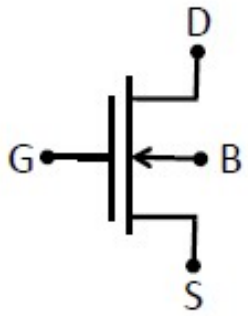
MOS-based devices (MOSFET, FinFET, Power-MOSFET…)

Low-power, integration → **Digital logic/memory, analog, RF, power…**



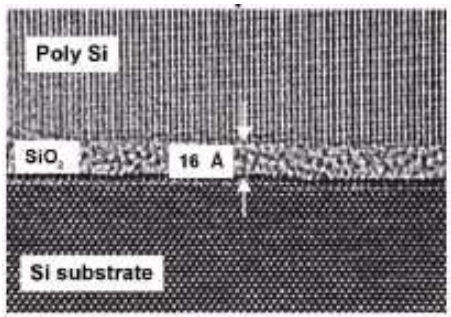






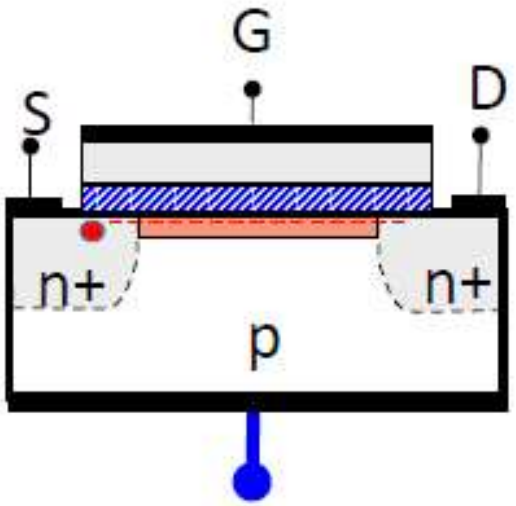
Charge-control

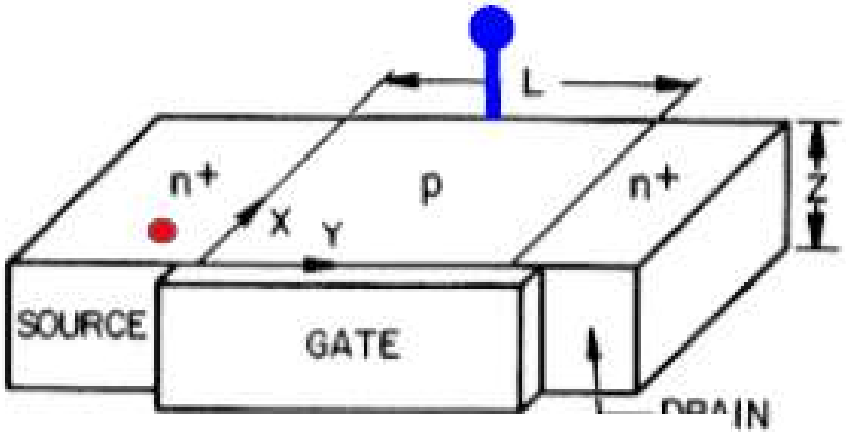
$$J = Q \otimes v$$

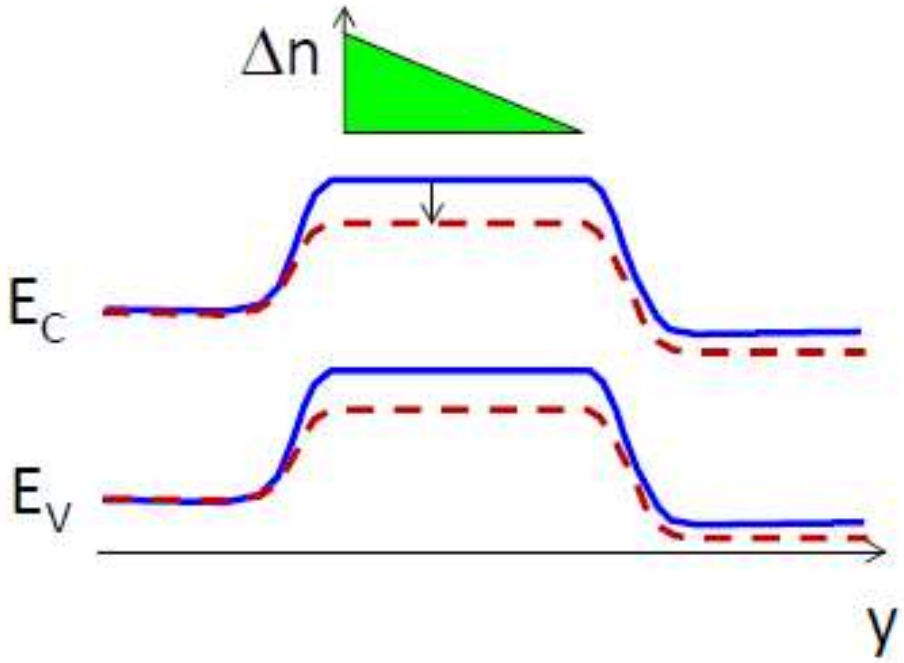


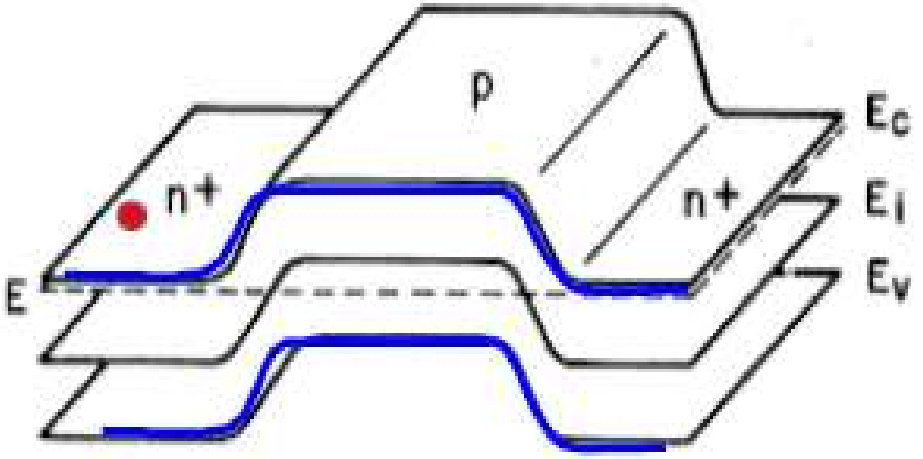
NMOSFET | **PMOSFET?** | **MOSCAP**

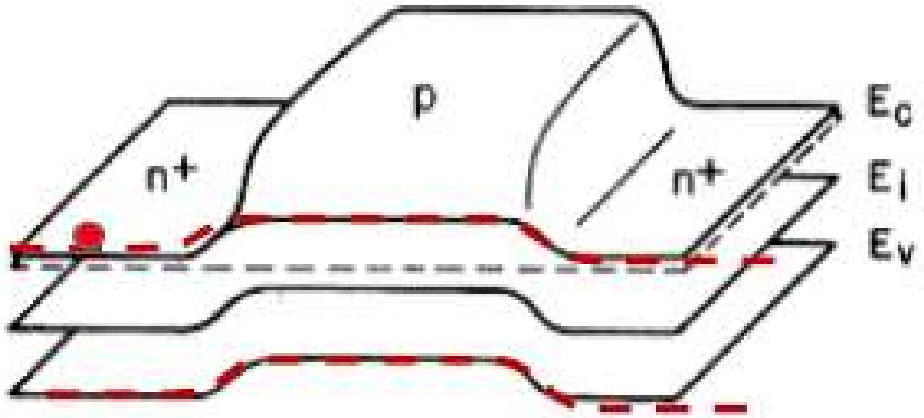
Effect of bias



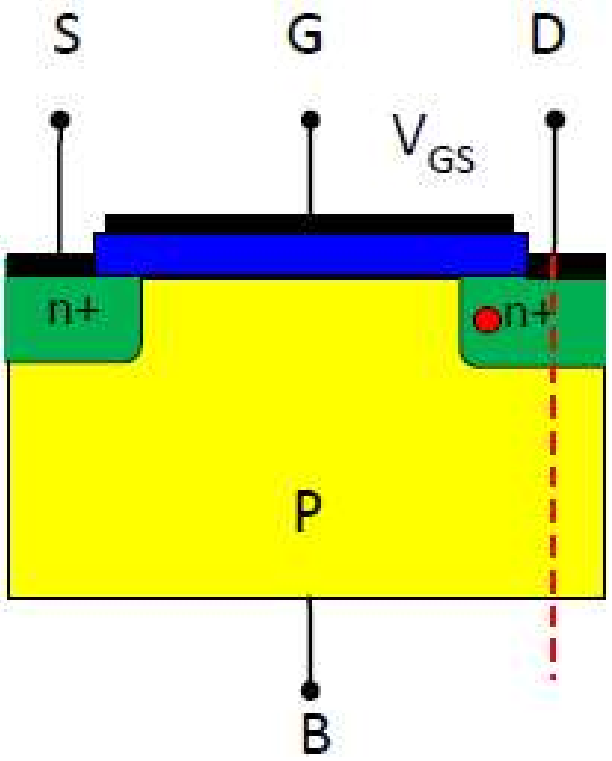


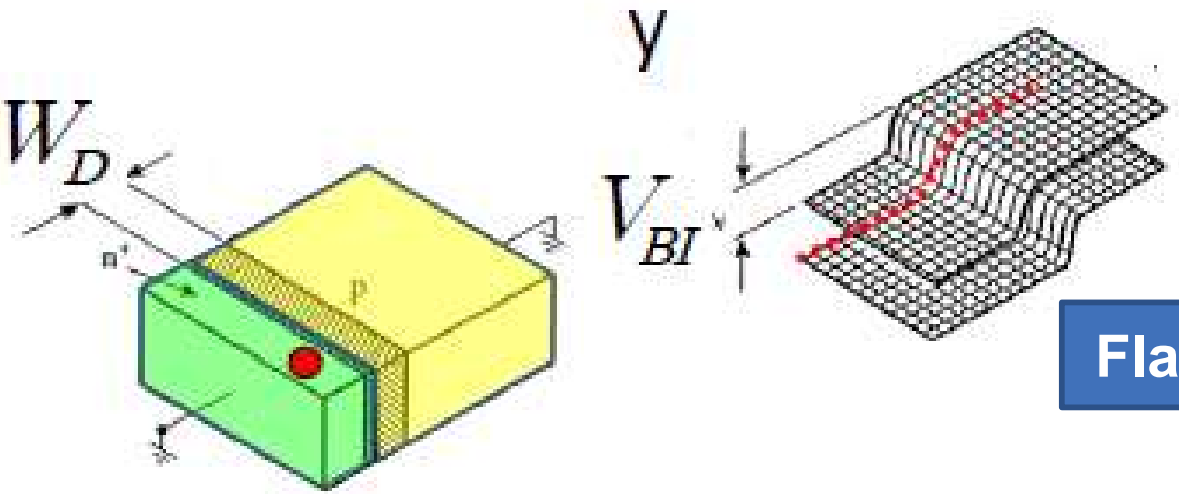




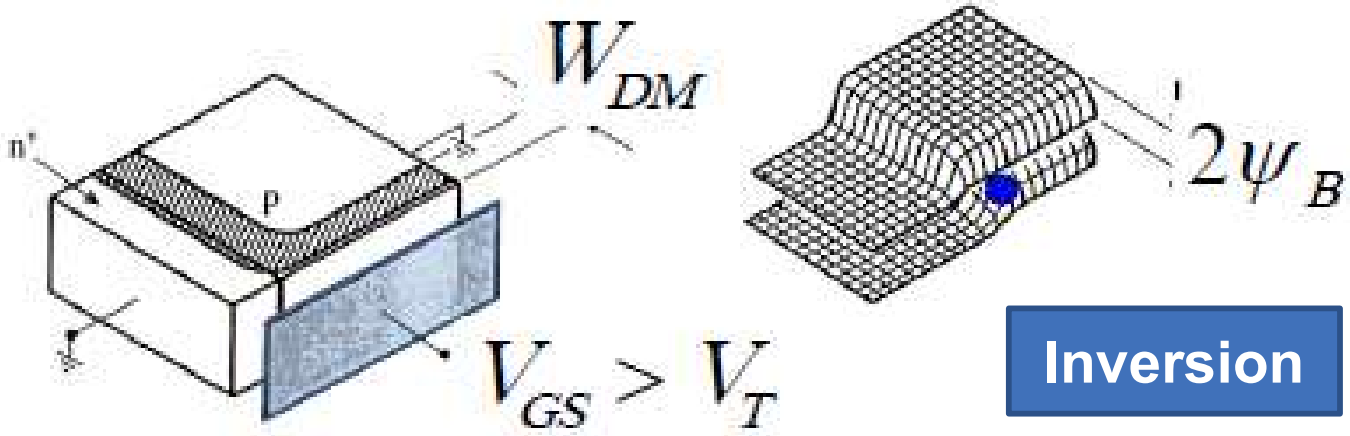


Effect of gate-bias



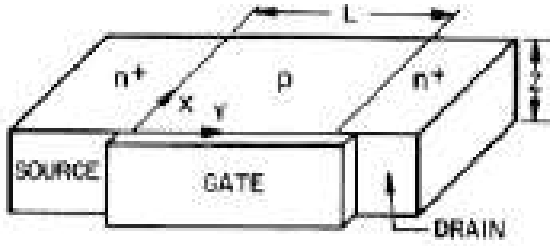


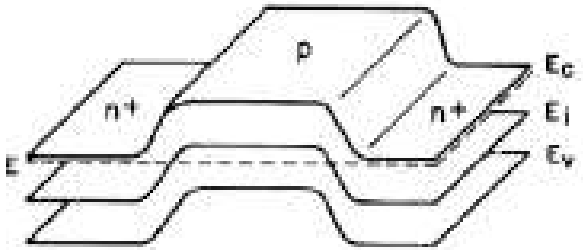
Flat-band

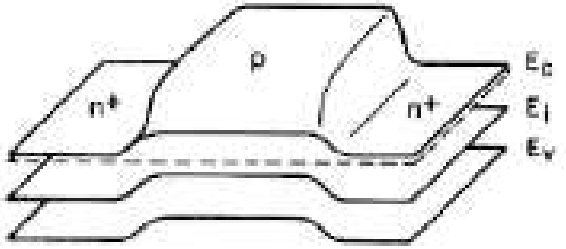


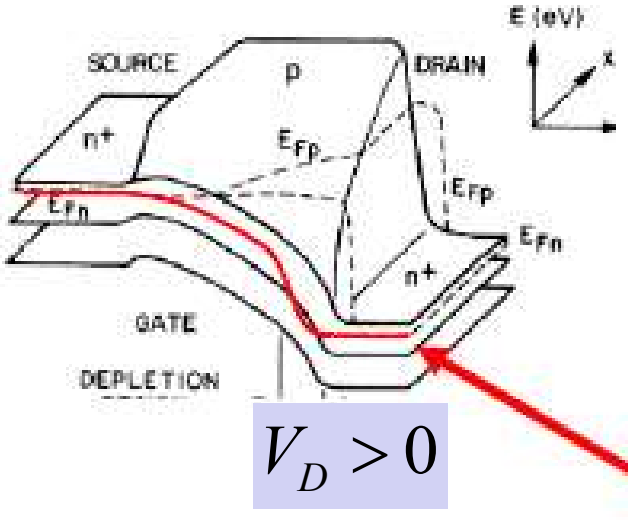
Inversion

Effect of drain-bias



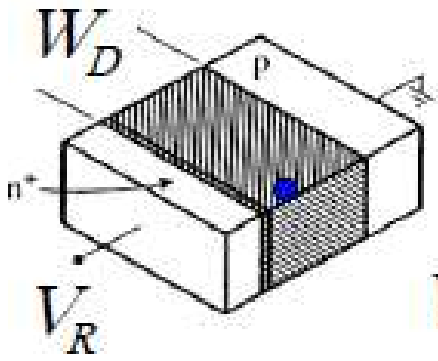


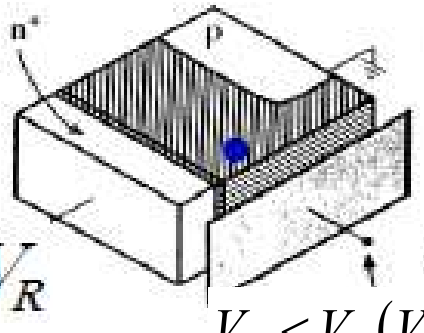




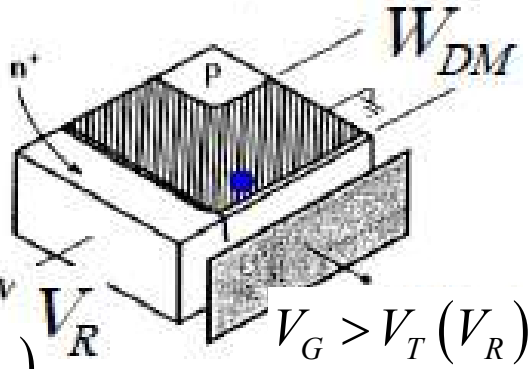
$V_D > 0$

F_N

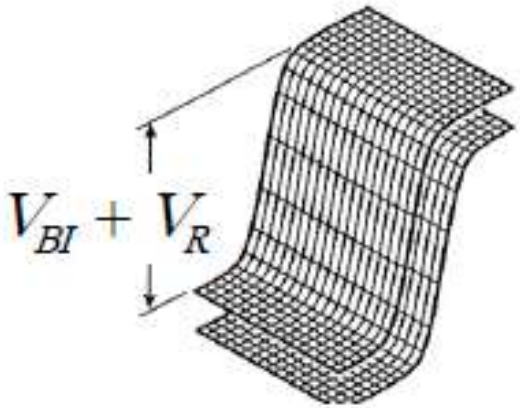


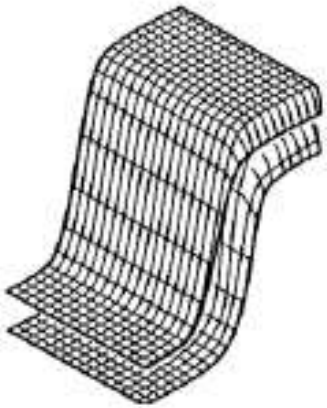


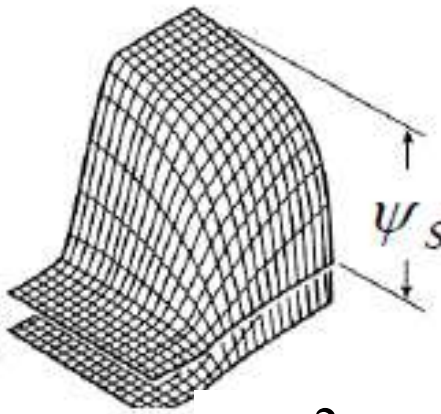
$V_G < V_T(V_R)$



$V_G > V_T(V_R)$

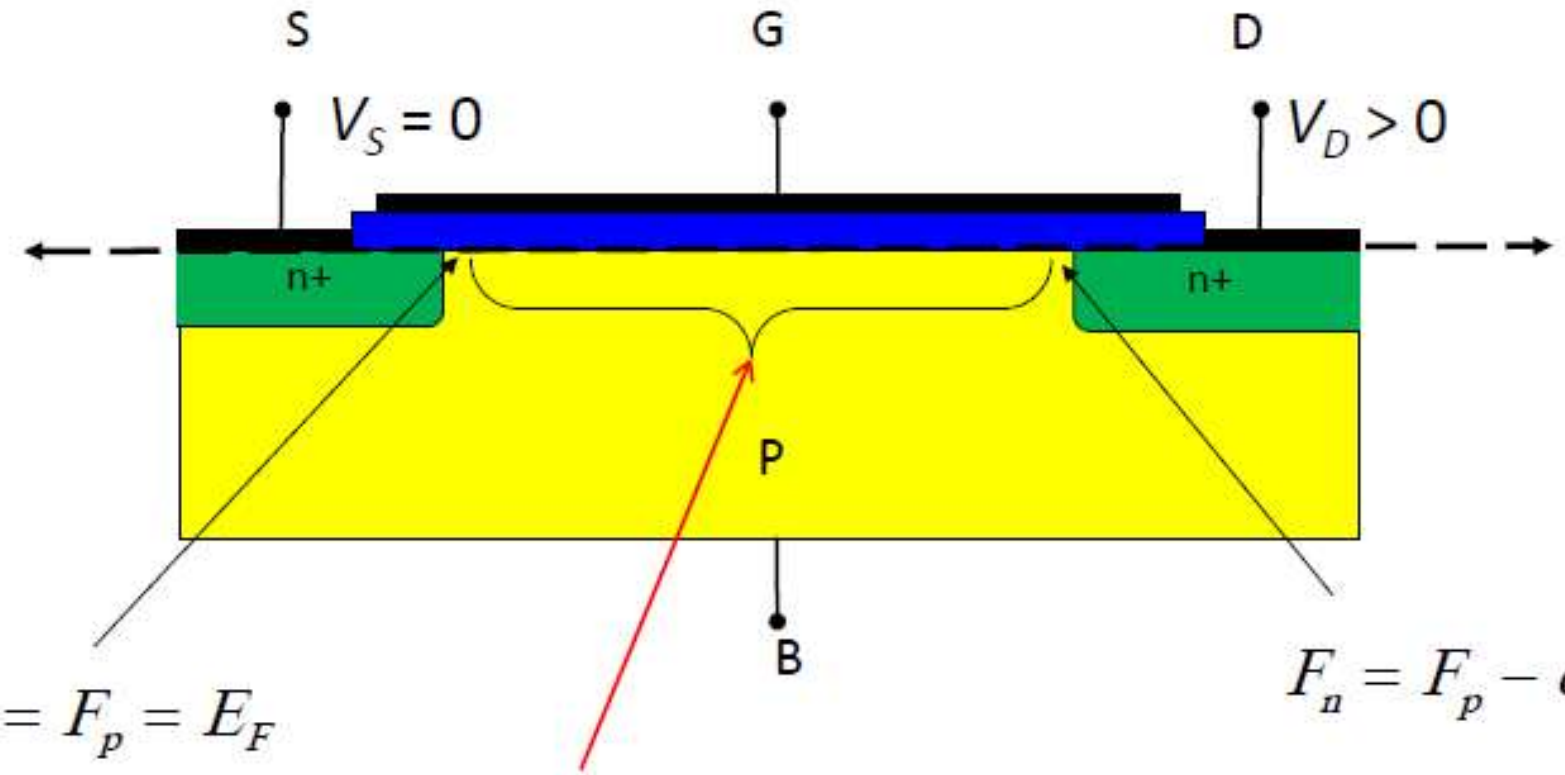






$\psi_S > 2\psi_B + V_R$

MOSFET I – V



F_n increasingly negative from source to drain
(reverse bias increases from source to drain)

Depth-integrated current density

$$J_1 = Q_1 \mu \mathcal{E}_1 = Q_1 \mu \left. \frac{dV}{dy} \right|_1$$

$$J_2 = Q_2 \mu \mathcal{E}_2 = Q_2 \mu \left. \frac{dV}{dy} \right|_2$$

$$J_3 = Q_3 \mu \mathcal{E}_3 = Q_3 \mu \left. \frac{dV}{dy} \right|_3$$

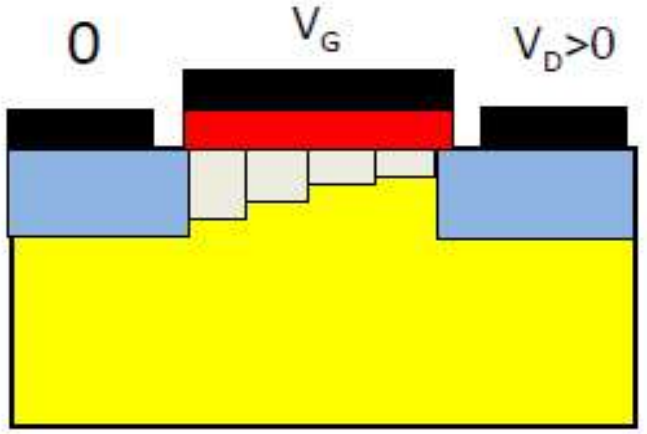
$$J_4 = Q_4 \mu \mathcal{E}_4 = Q_4 \mu \left. \frac{dV}{dy} \right|_4$$

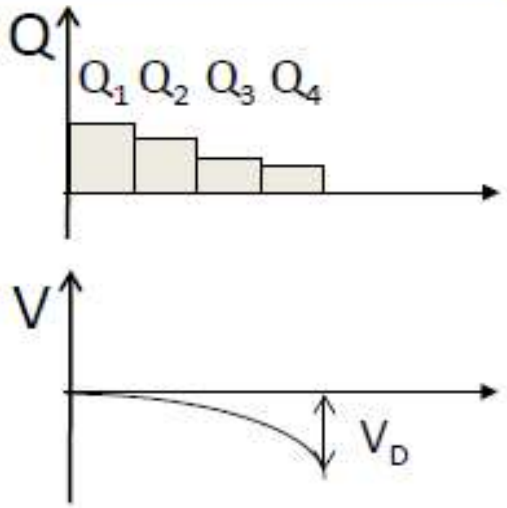
$$\sum_{i=1,N} \frac{J_i dy}{\mu} = \sum_{i=1,N} Q_i \, dV$$

Gradual Channel

$$\frac{J_D}{\mu} \sum_{i=1,N} dy = \int_0^{V_D} C_{ox}(V_G - V_{th} - mV) dV$$

$$J_D = \frac{\mu C_{ox}}{L_{ch}} \left[(V_G - V_{th}) V_D - m \frac{V_D^{\,2}}{2} \right]$$

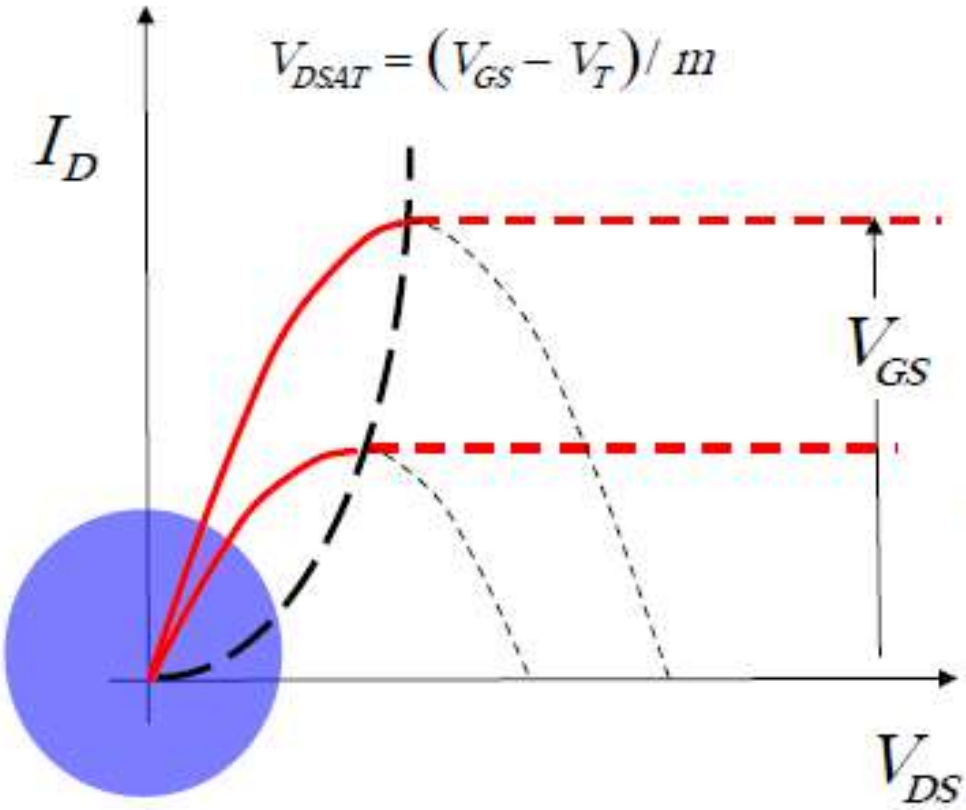




Square-law I-V

$$I_D = W\frac{\mu C_{ox}}{L_{ch}}\left[(V_G - V_{th})V_D - m\frac{V_D^{\,2}}{2}\right]$$

$$\frac{dI_D}{dV} = 0 = (V_G - V_{th}) - mV_D \Rightarrow V_{D,sat} = \left(V_G^{\,*} - V_{th}\right)\Big/ m$$



$$I_D = \frac{W\,\mu C_o}{2mL_{ch}}(V_G - V_T)^2$$

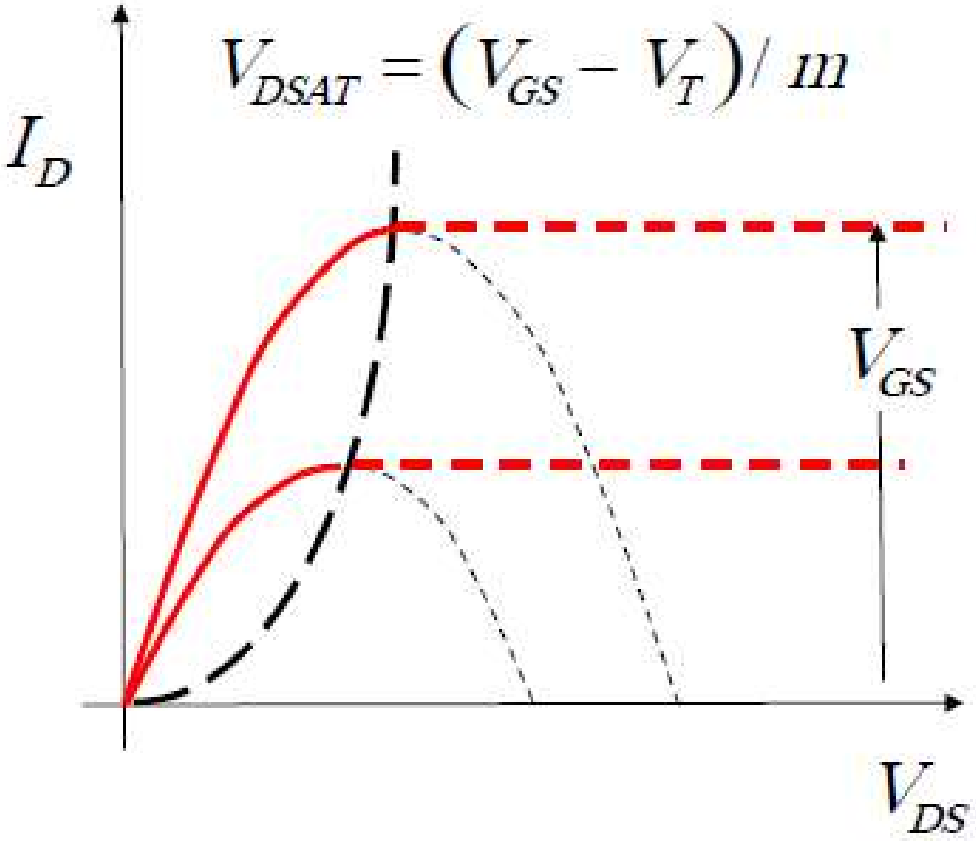
$$J_D = \frac{\mu C_{ox}}{L_{ch}}\left[(V_G - V_{th})V_D - m\frac{V_D^{\,2}}{2}\right]$$

$$I_D = \mu\, C_o\frac{W}{L}(V_G - V_T)V_D$$

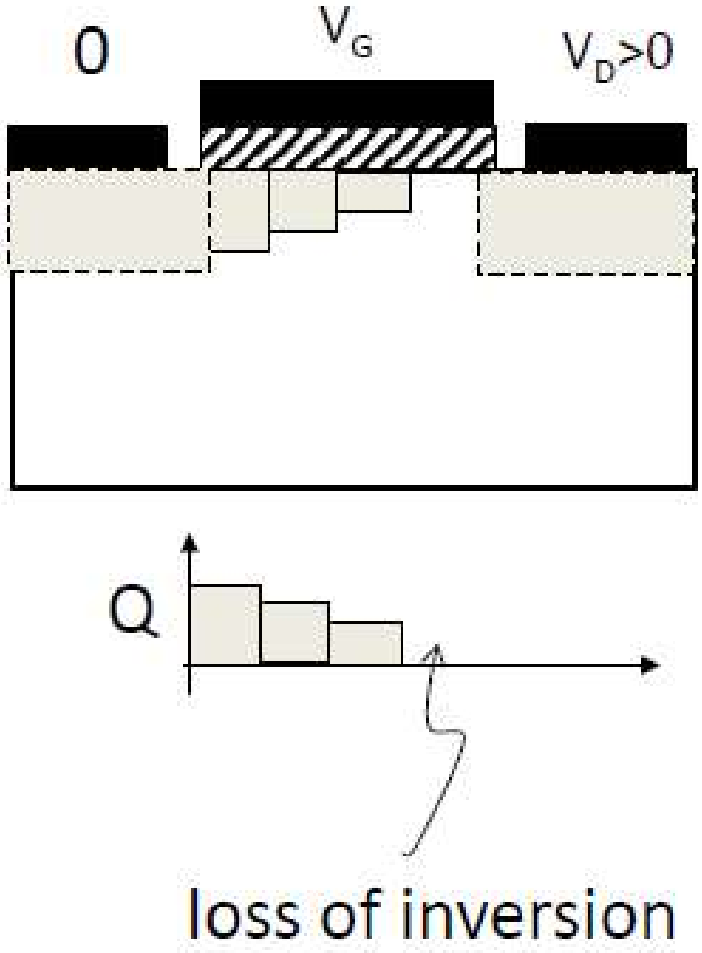
Saturation and pinch-off

$$I_D = \frac{W \mu C_o}{2mL_{ch}}(V_G - V_T)^2$$

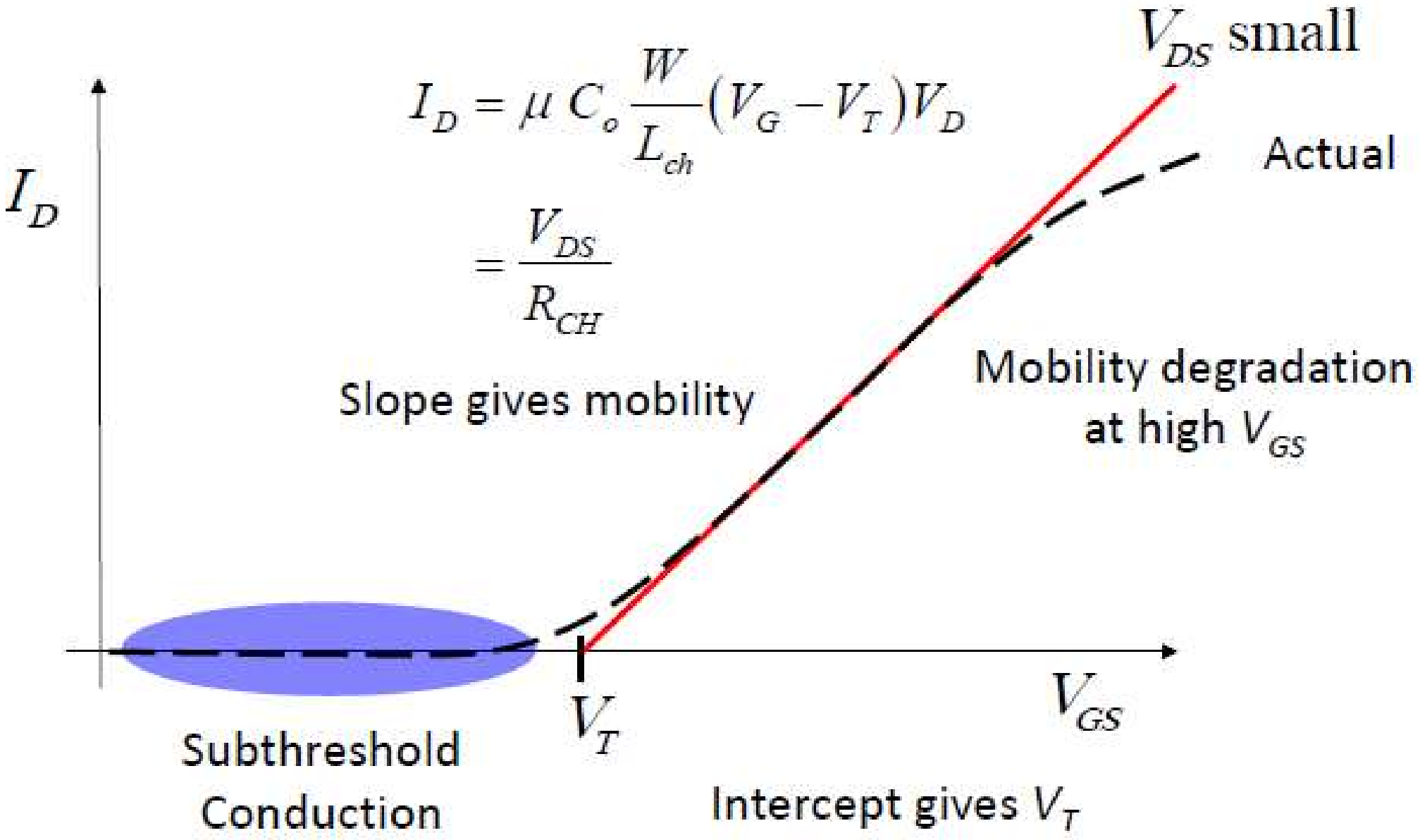
$$V_{DSAT} = (V_{GS} - V_T)/m$$



$$Q_i \approx -C_{ox}(V_G - V_{th} - mV)$$



Linear region (low V_{DS})



Finis

Sources:

1. Prof. M.A. Alam
2. www.nature.com