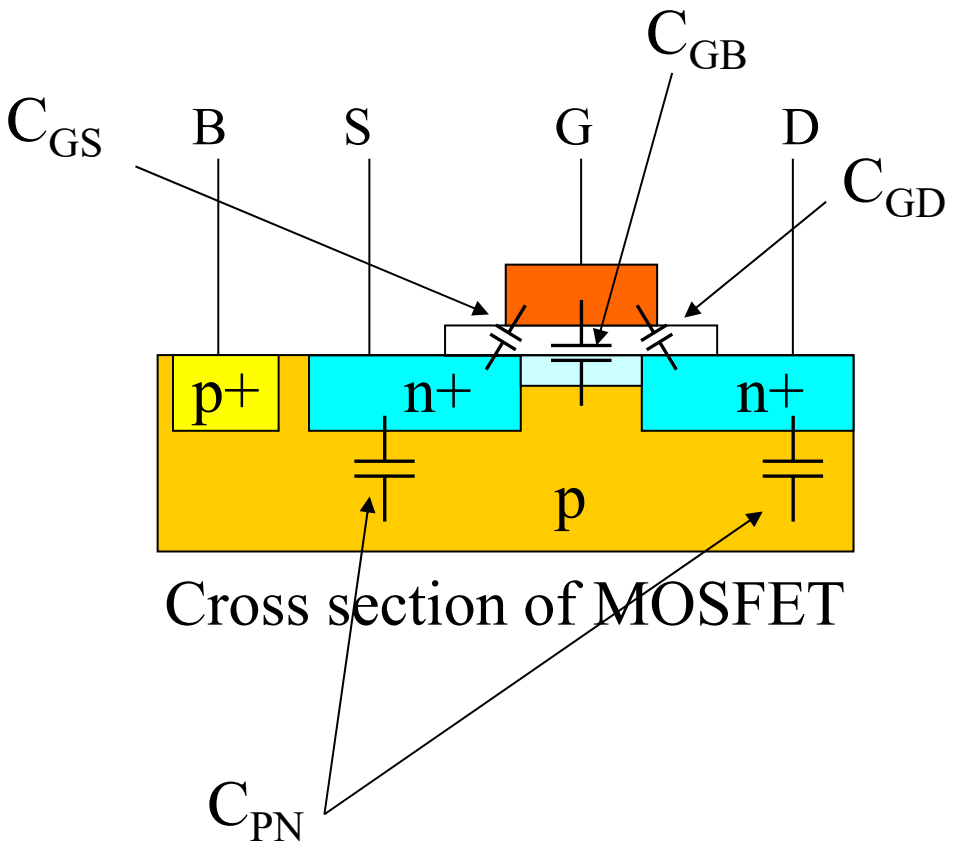
4.2 C-V characteristics of MOSFET

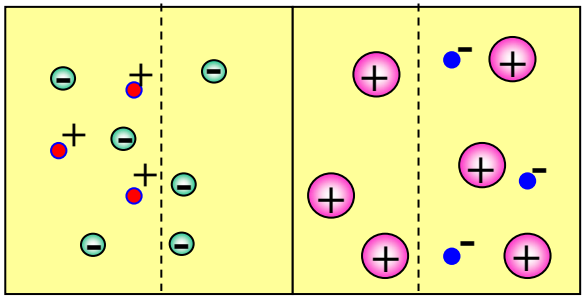
Charge in MOSFET

Parasitic capacitance of MOSFET



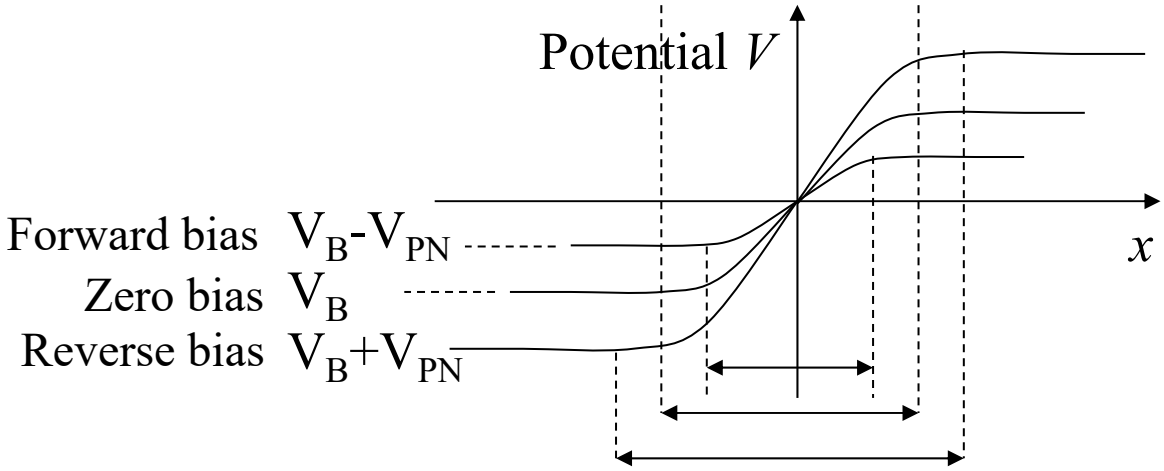
Cross section of MOSFET

C_{PN}-V_{PN} characteristic 1



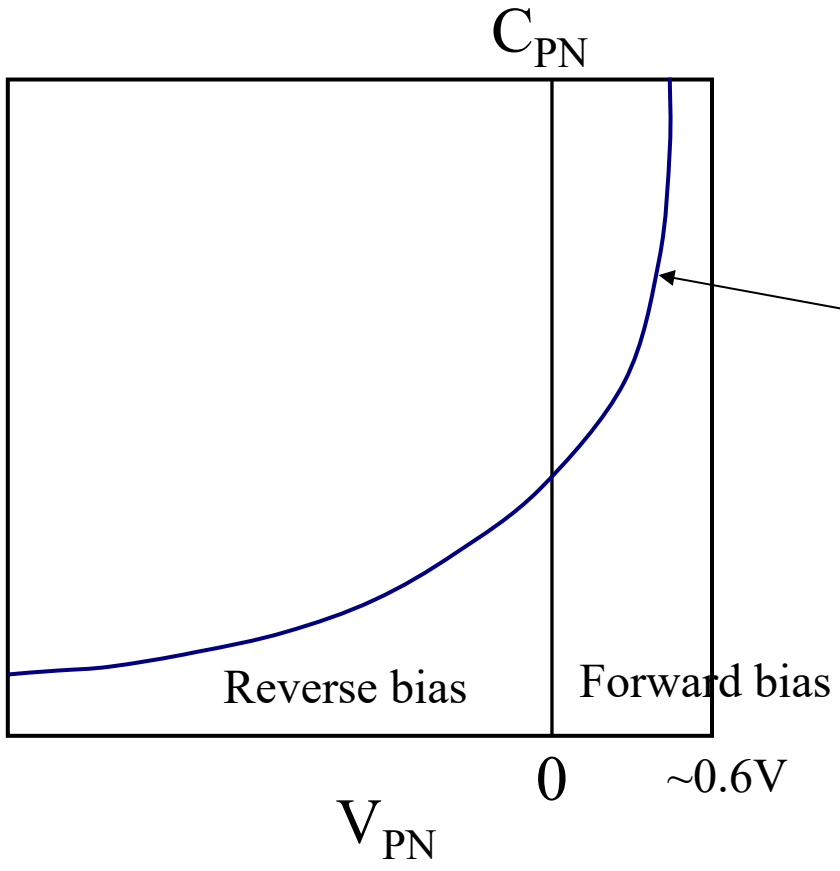
In a depletion layer,
+ charge of donor
- charge of acceptor
forms an electric double layer.

The electric double layer is equivalent to the changed capacitor.



The width of depletion layer depends on the bias voltage.

C_{PN}-V_{PN} characteristic 2



C-V model equation

$$C_{PN} = \varepsilon_0 \varepsilon_{Si} \frac{S}{d} = \frac{C_{PN}(0V)}{\sqrt{1 - \frac{V_{PN}}{V_B}}}$$

S: Junction area

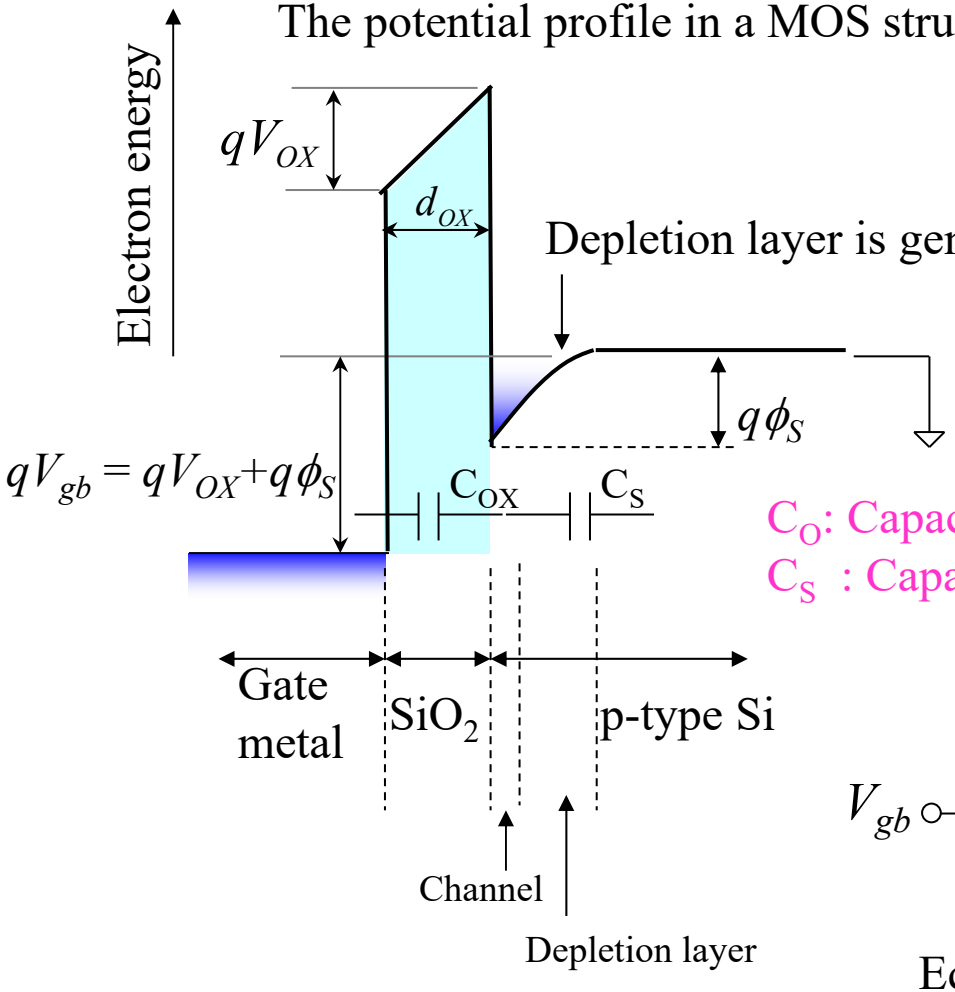
d: Width of depletion layer

V_B: Built-in Potential ~0.6〜0.9V

Note: This equation can be derived from a charge distribution of donors and acceptors. However, in a forward bias condition, a charge balance of carriers outside of a pn junction should be considered.

C_{GB}-V_{GB} characteristic 1

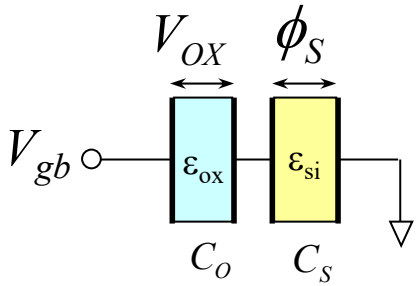
The potential profile in a MOS structure to which V_G is applied.



ϕ_S: Semiconductor surface potential

C_O: Capacitance of gate oxide (F/m^2)

C_S : Capacitance of depletion layer (F/m^2)



Equivalent circuit

$$V_{gb} = V_{OX} + \phi_S$$

$$\phi_S = \frac{C_O}{C_O + C_S} V_{gb}$$

C_{GB}-V_{GB} characteristic 2

Assumption: $V_{gb} < V_{tn0}$, and the free electron is not generated in the MOS interface.

Capacitance per area

Capacitance of a depletion layer $C_S = \frac{\varepsilon_0 \varepsilon_{Si}}{x_D}$

Capacitance of a gate oxide $C_O = \frac{\varepsilon_0 \varepsilon_{SiO_2}}{t_{OX}}$

Width of a depletion layer x_D

$$x_D = \sqrt{\frac{2\varepsilon_0 \varepsilon_{Si} \phi_S}{qN_A}} = \sqrt{\frac{2\varepsilon_0 \varepsilon_{Si}}{qN_A} \frac{C_O}{C_O + C_S} V_{gb}}$$

(See the appendix.)

$$\phi_S = \frac{C_O}{C_O + C_S} V_{gb}$$

(See the previous slide.)

Total capacitance of MOS structure

$$C_{GB}(V_{gb}) = \frac{1}{\frac{1}{C_O} + \frac{1}{C_S(V_{gb})}}$$

Capacitance of MOS structure

A C-V characteristic of a MOS structure