

微电子器件物理 MOS结构

曾琅

2020/10/09

本节课提纲

1. 背景
2. 平衡态和加偏置时的能带图
3. MOS结构的电荷-电压关系

本节课提纲

1. 背景
2. 平衡态和加偏置时的能带图
3. MOS结构的电荷-电压关系

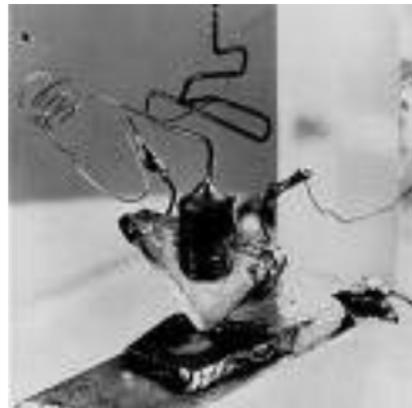
MOSFET的尺寸缩小

真空管



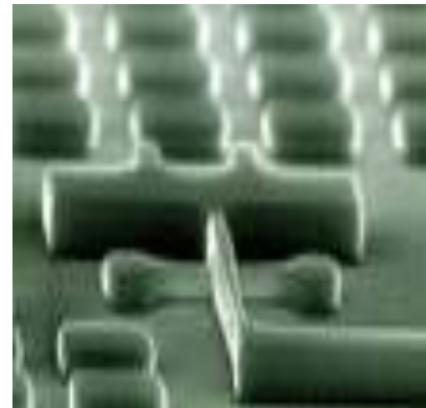
1906-1950s

三极管



1947-1980s

MOSFET



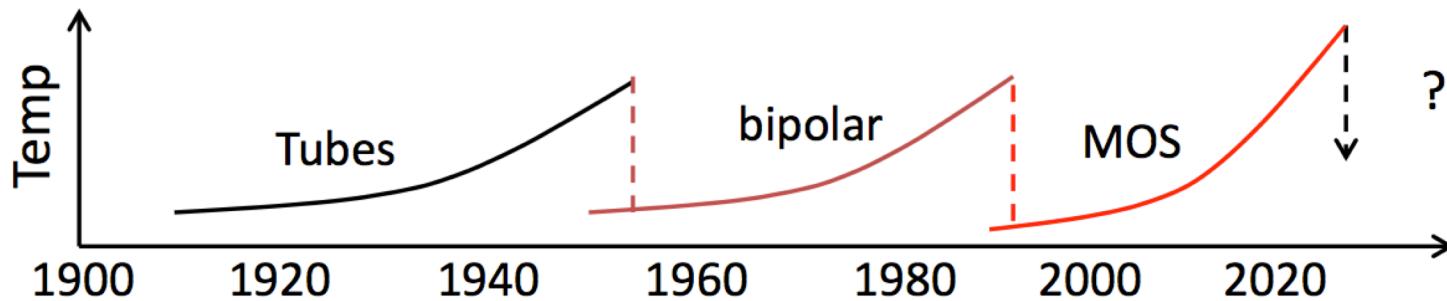
1960-until now

Now ??

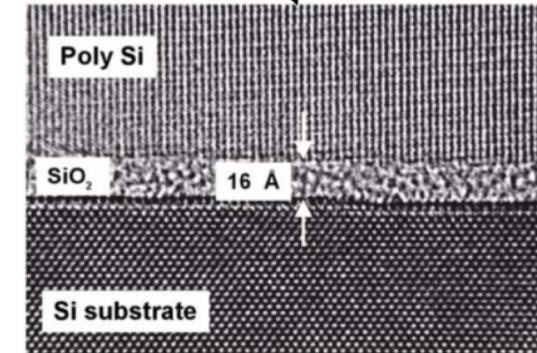
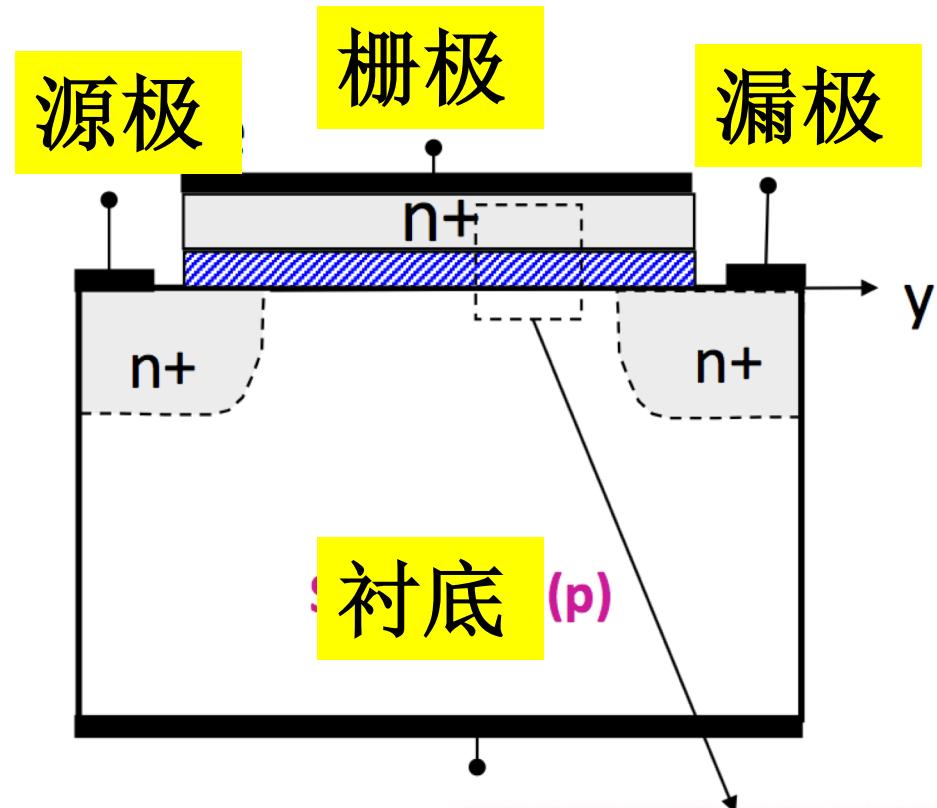
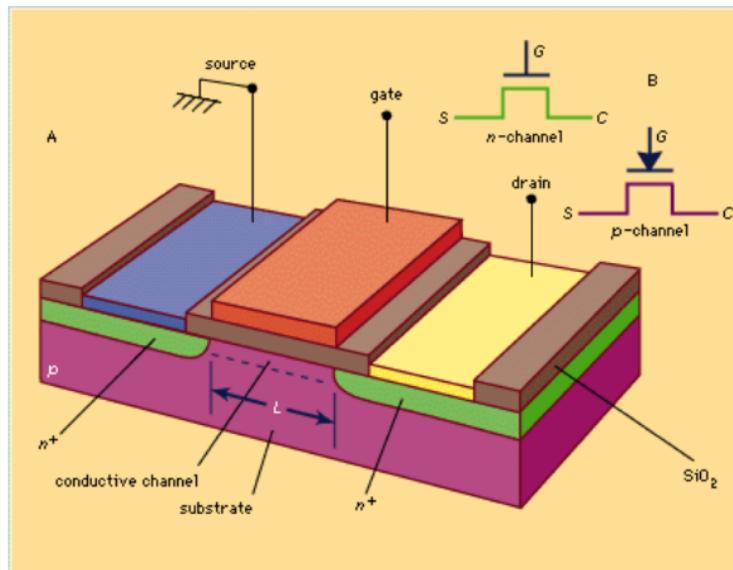
Spintronics

Bio Sensors

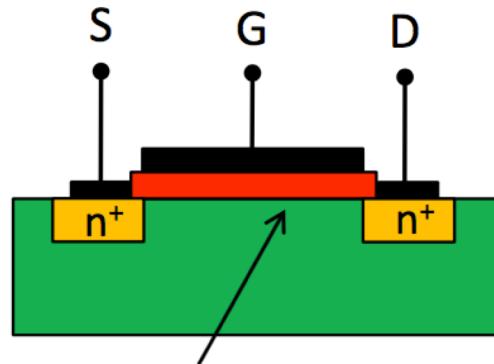
Displays



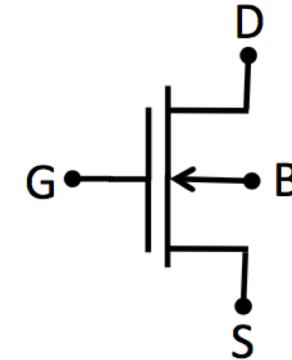
MOSFET的基本结构



MOSFET的电路符号

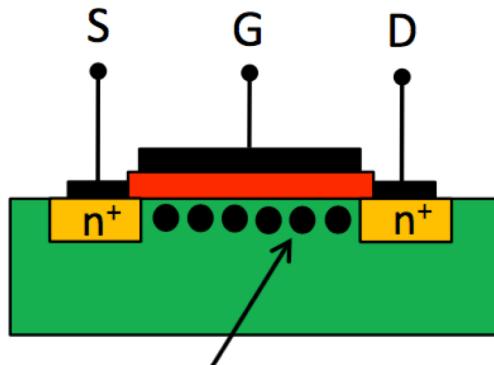


增强型

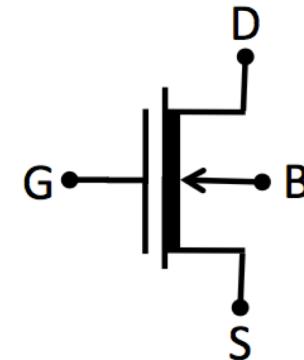


No channel

when $V_G = 0$



耗尽型

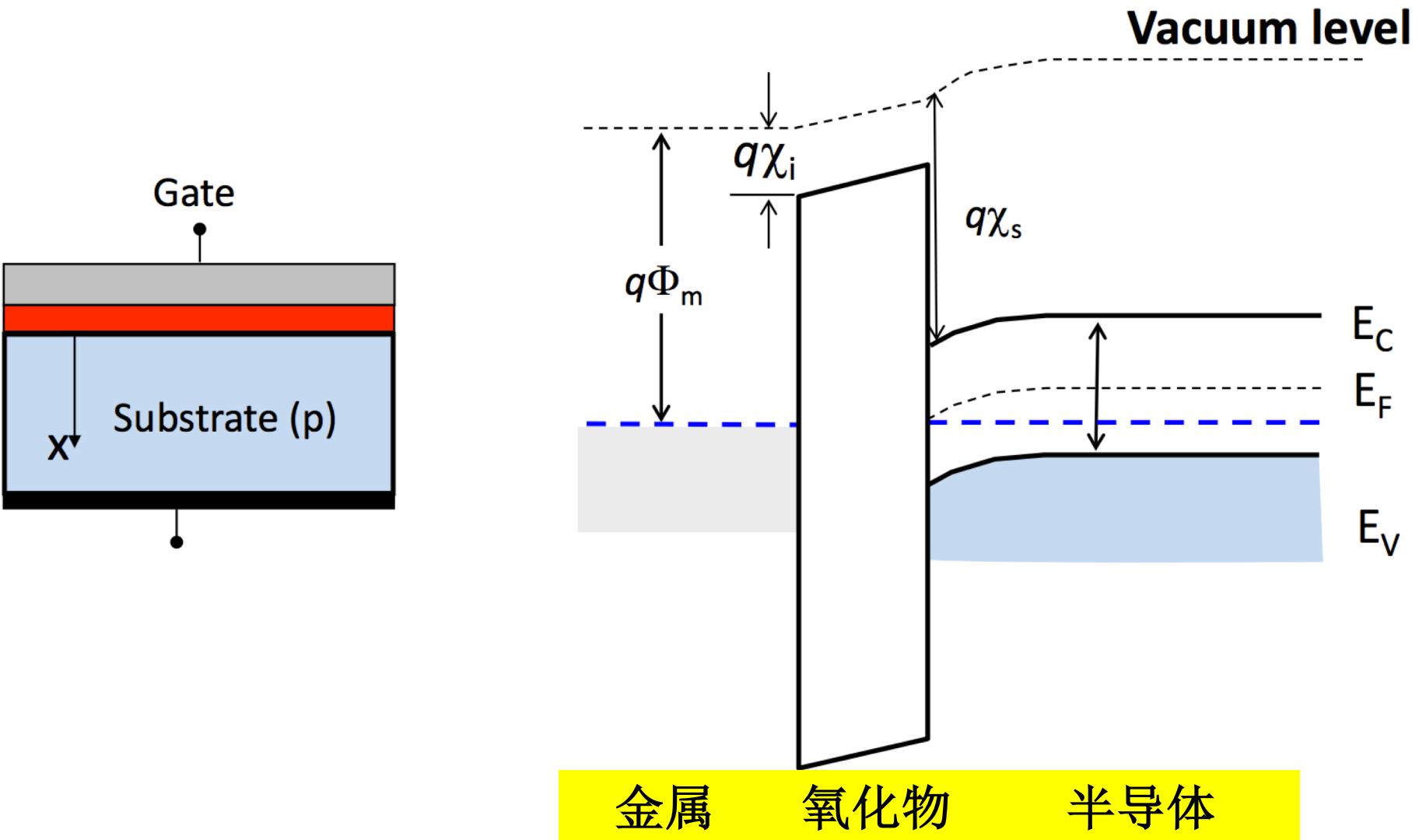


Channel
when $V_G = 0$

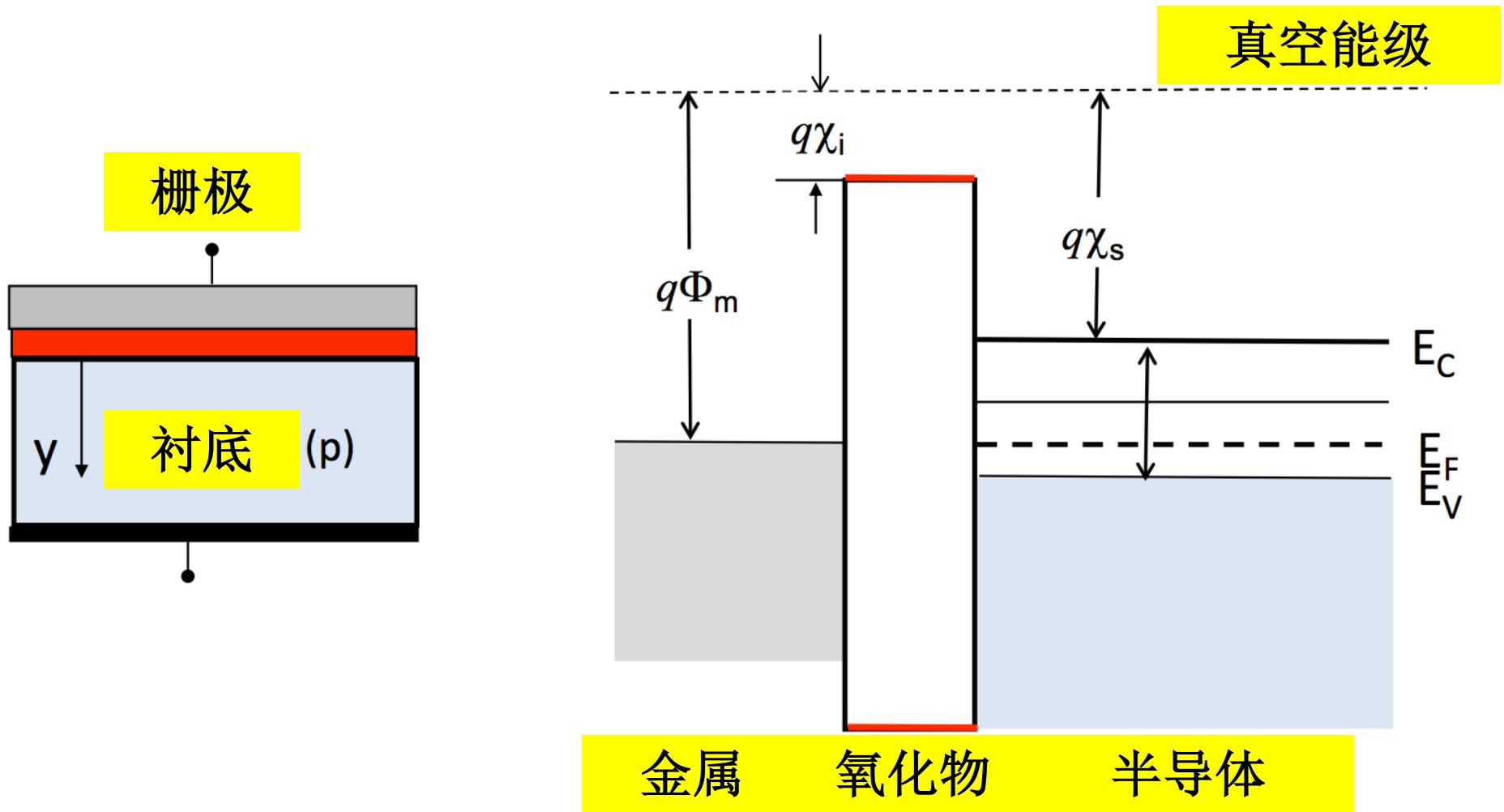
本节课提纲

1. 背景
2. 平衡态和加偏置时的能带图
3. MOS结构的电荷-电压关系

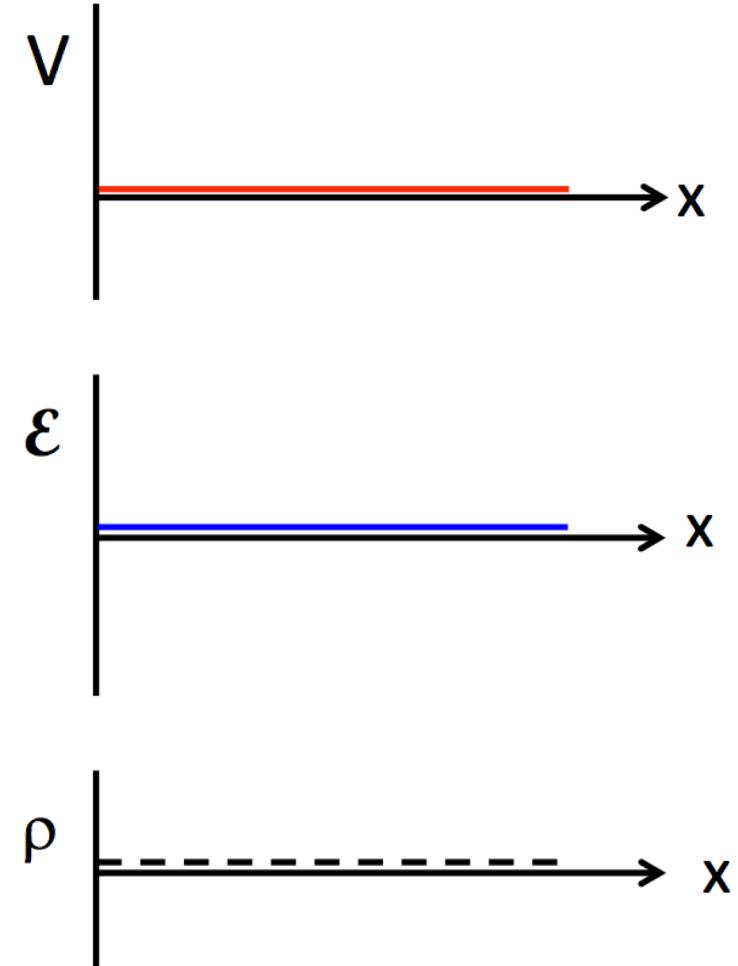
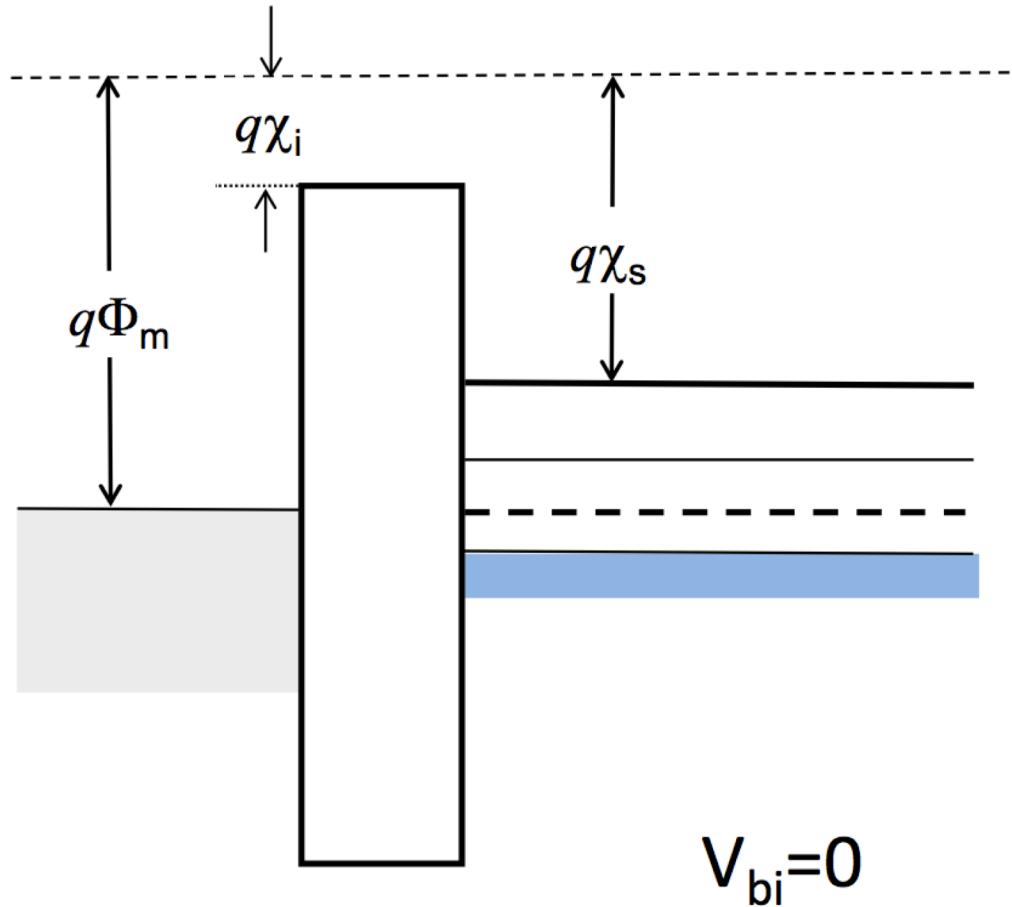
MOS结构的平衡态能带图



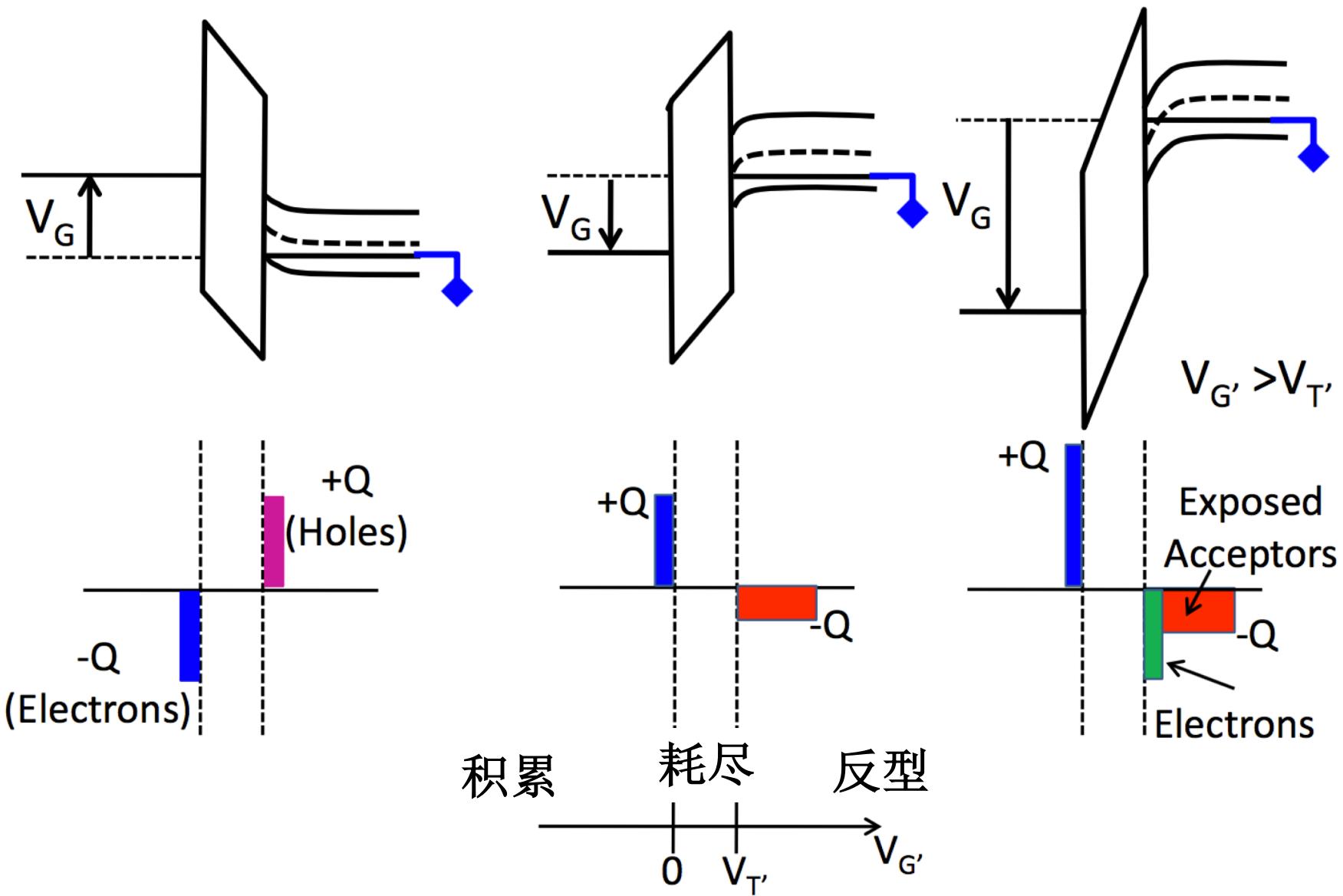
理想MOS电容



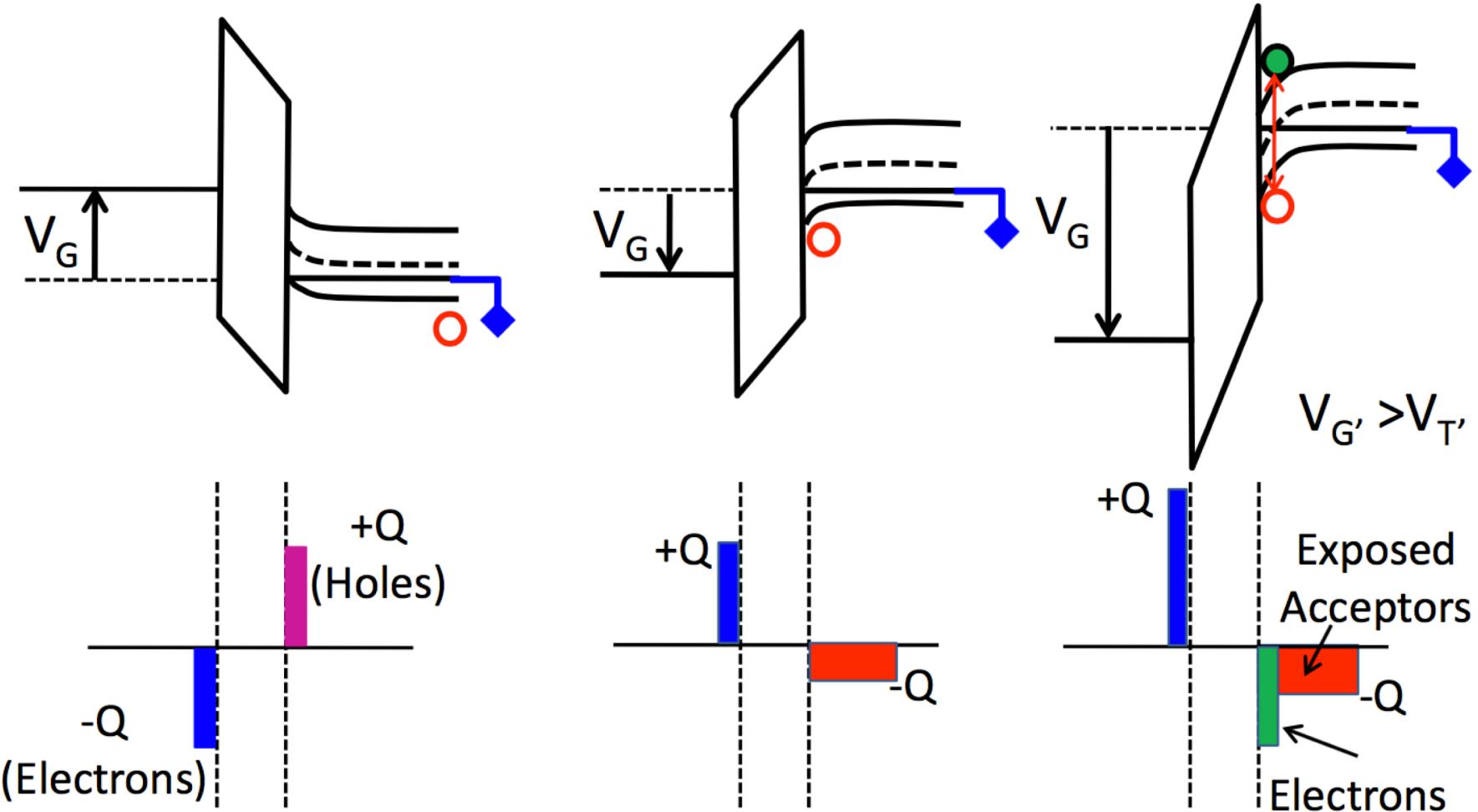
理想MOS电容



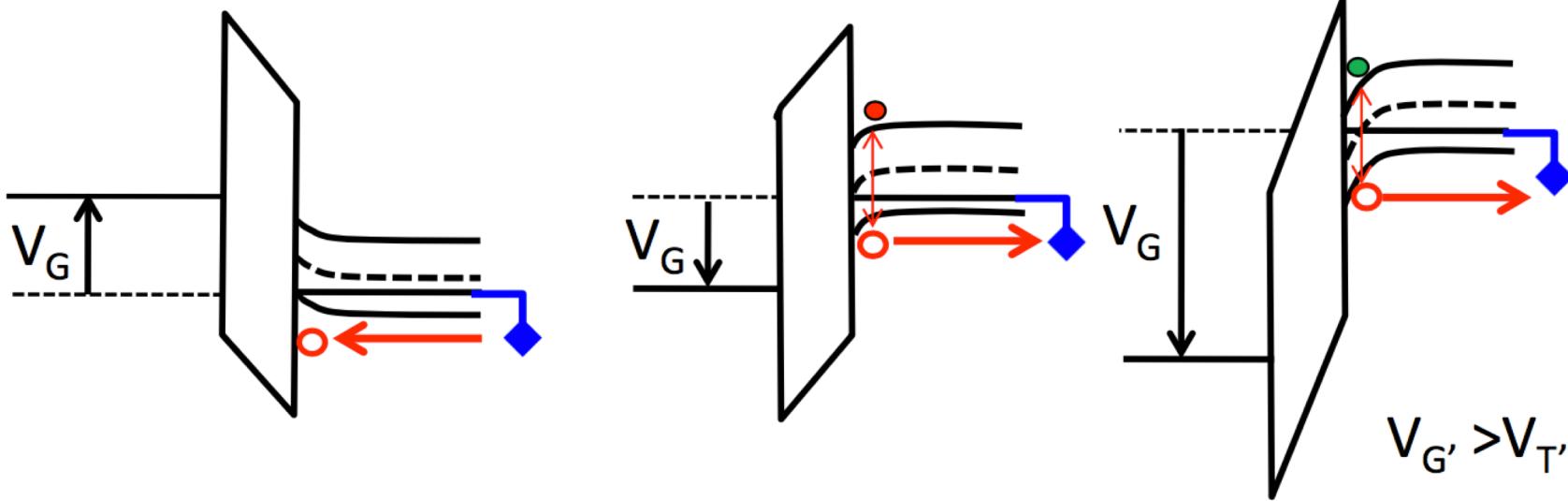
加偏置的MOS电容



电子和空穴从哪里来？



响应时间



多数载流子

$$\tau = \frac{\sigma}{\kappa_s \epsilon_0}$$

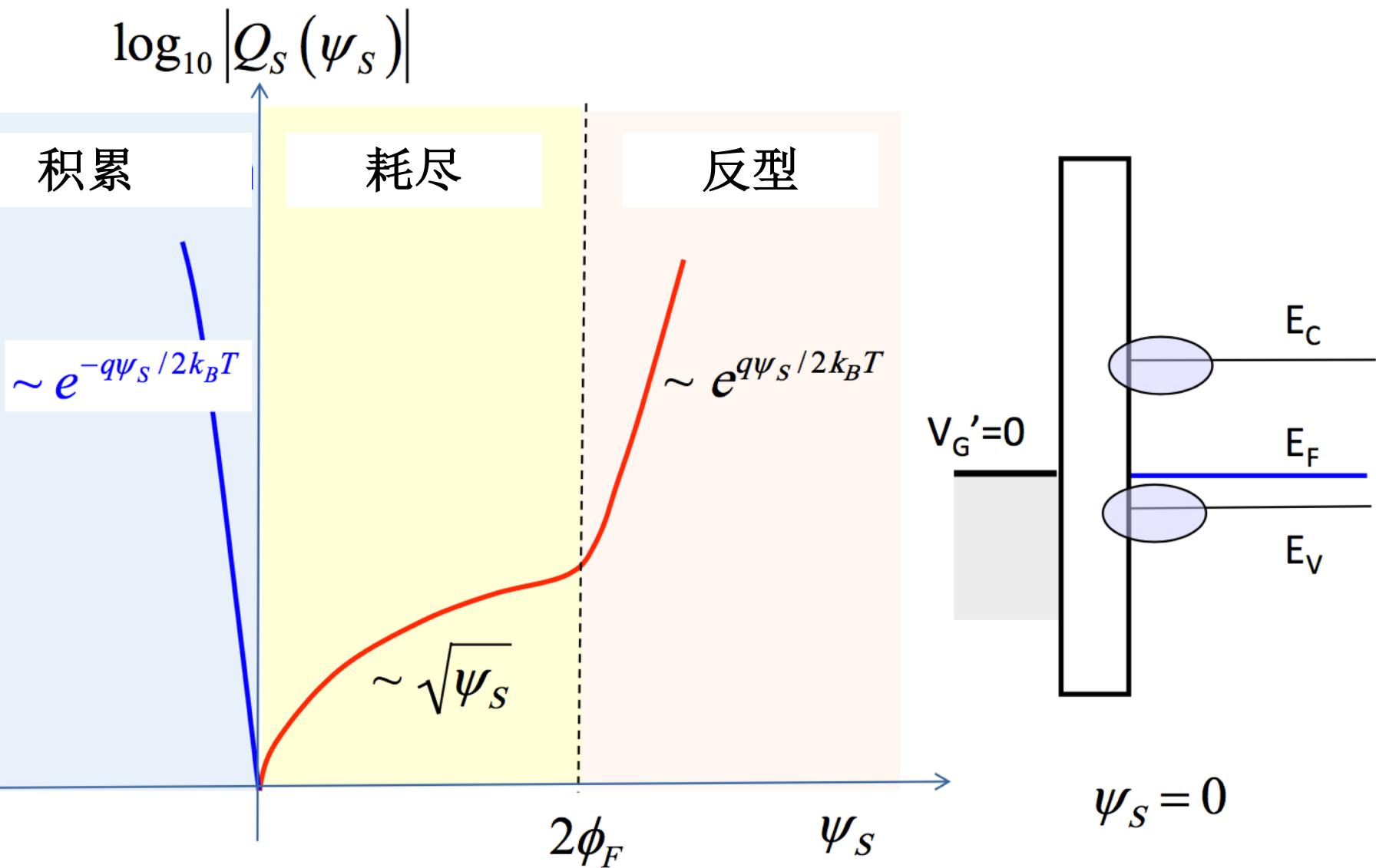
少数载流子 (SRH)

$$R = \frac{np - n_i^2}{\tau_n(p + p_1) + \tau_p(n + n_1)} \rightarrow \frac{-n_i}{\tau_n + \tau_p}$$

本节课提纲

1. 背景
2. 平衡态和加偏置时的能带图
3. MOS结构的电荷-电压关系

电荷与表面势



电荷与表面势

$$\nabla \bullet \vec{D} = \rho$$

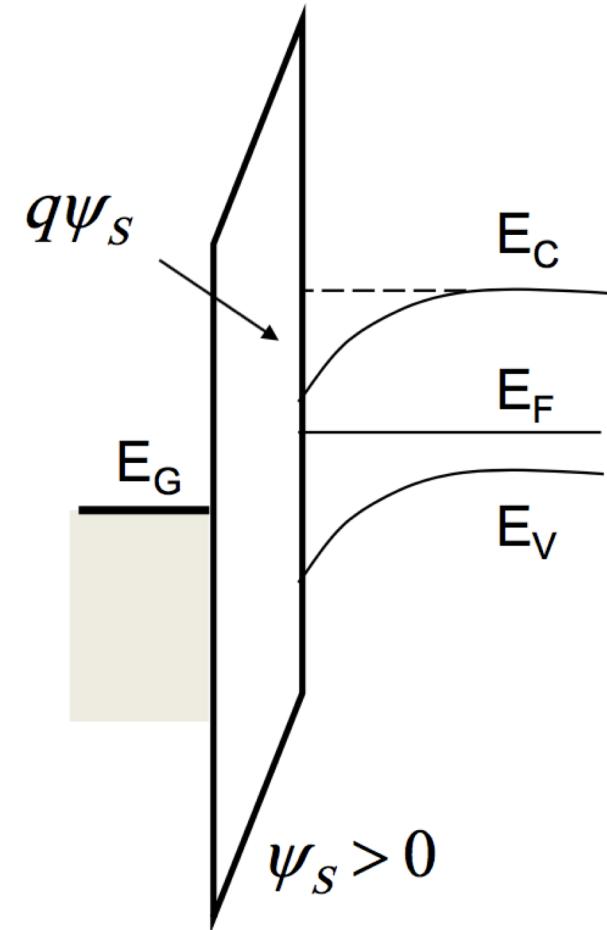
$$\nabla \bullet (\vec{J}_n / -q) = (G - R)$$

$$\nabla \bullet (\vec{J}_p / q) = (G - R)$$

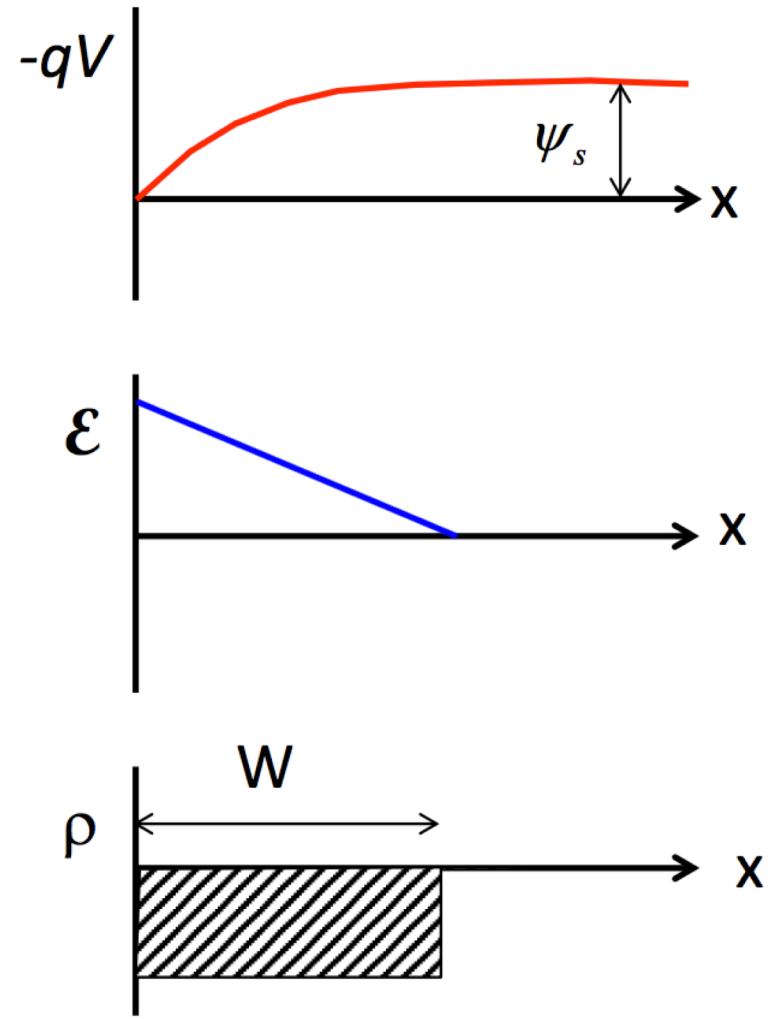
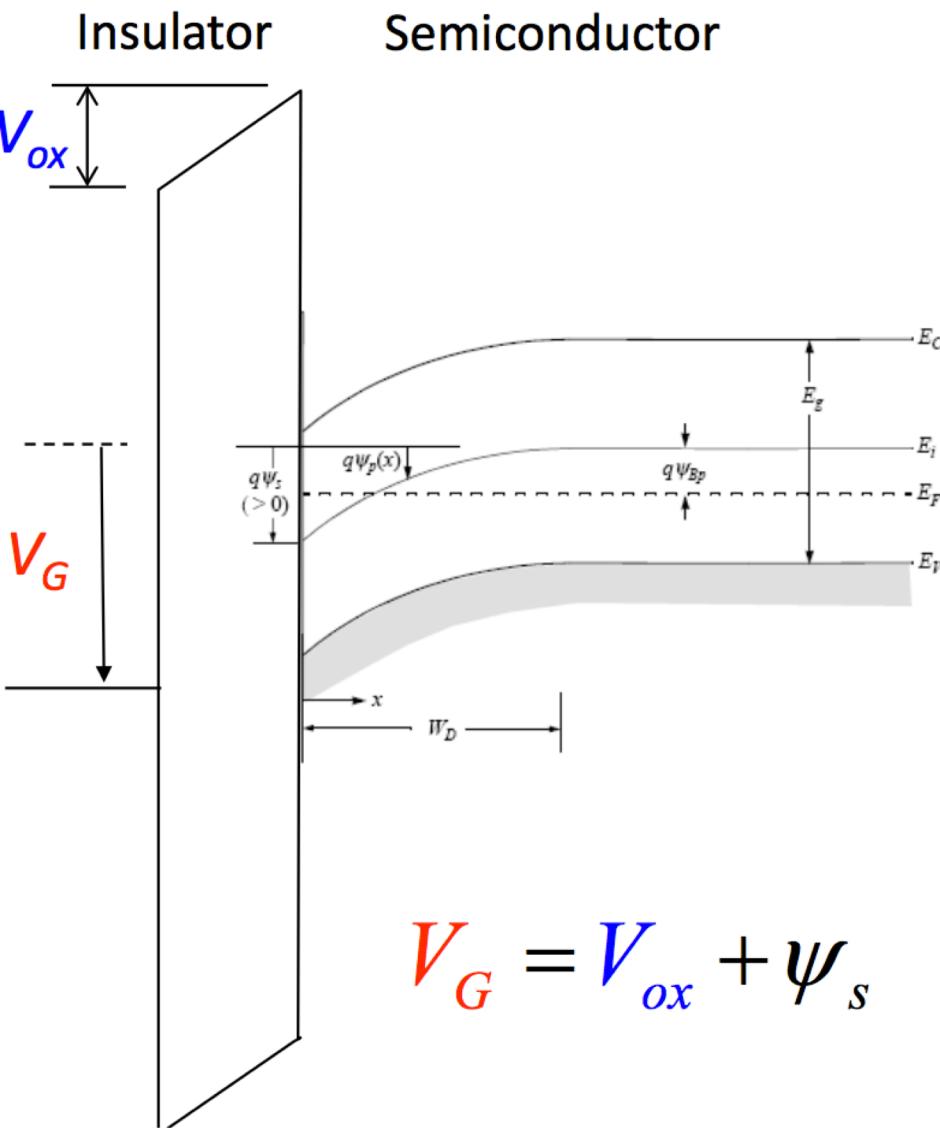
泊松方程



$$\frac{d^2\psi}{dx^2} = \frac{-q}{\kappa_{Si}\epsilon_0} [p_0(x) - n_0(x) + N_D^+ - N_A^-]$$



电荷与表面势：耗尽



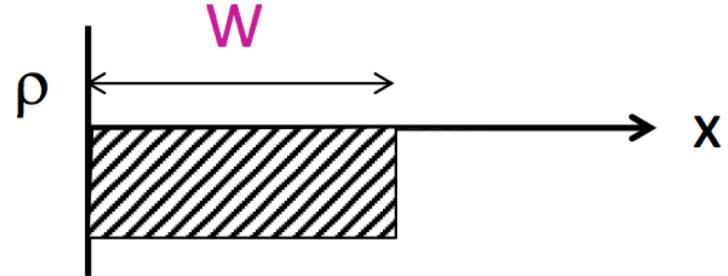
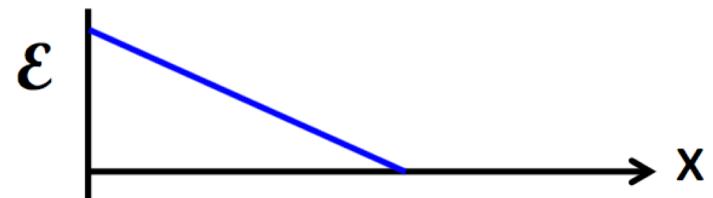
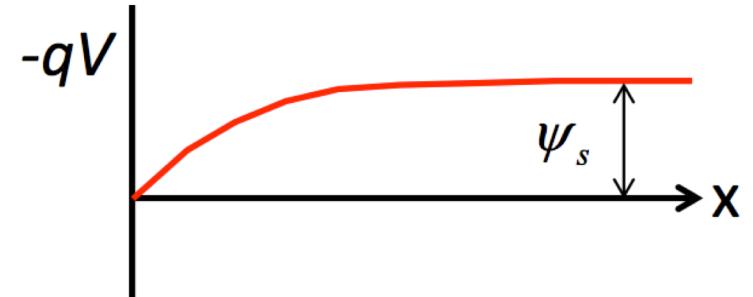
电荷与表面势：耗尽

$$(2) \psi_s = \frac{1}{2} \left(\frac{qN_A W}{\kappa_s \epsilon_0} \right) W = \left(\frac{qN_A W^2}{2\kappa_s \epsilon_0} \right)$$

$$(3) W = \sqrt{\frac{2\kappa_s \epsilon_0 \psi_s}{qN_A}}$$

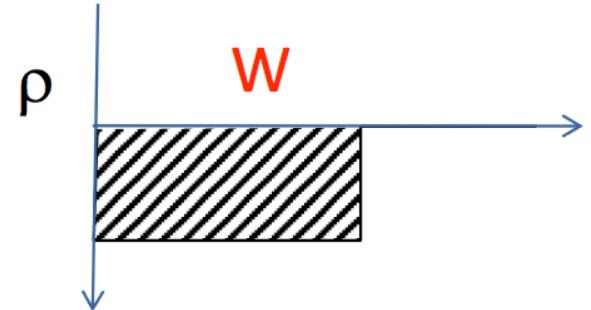
$$(1) \mathcal{E}(0^+) = -\frac{qN_A W}{\kappa_s \epsilon_0}$$

$$(4) V_G = V_{ox} + \psi_s$$

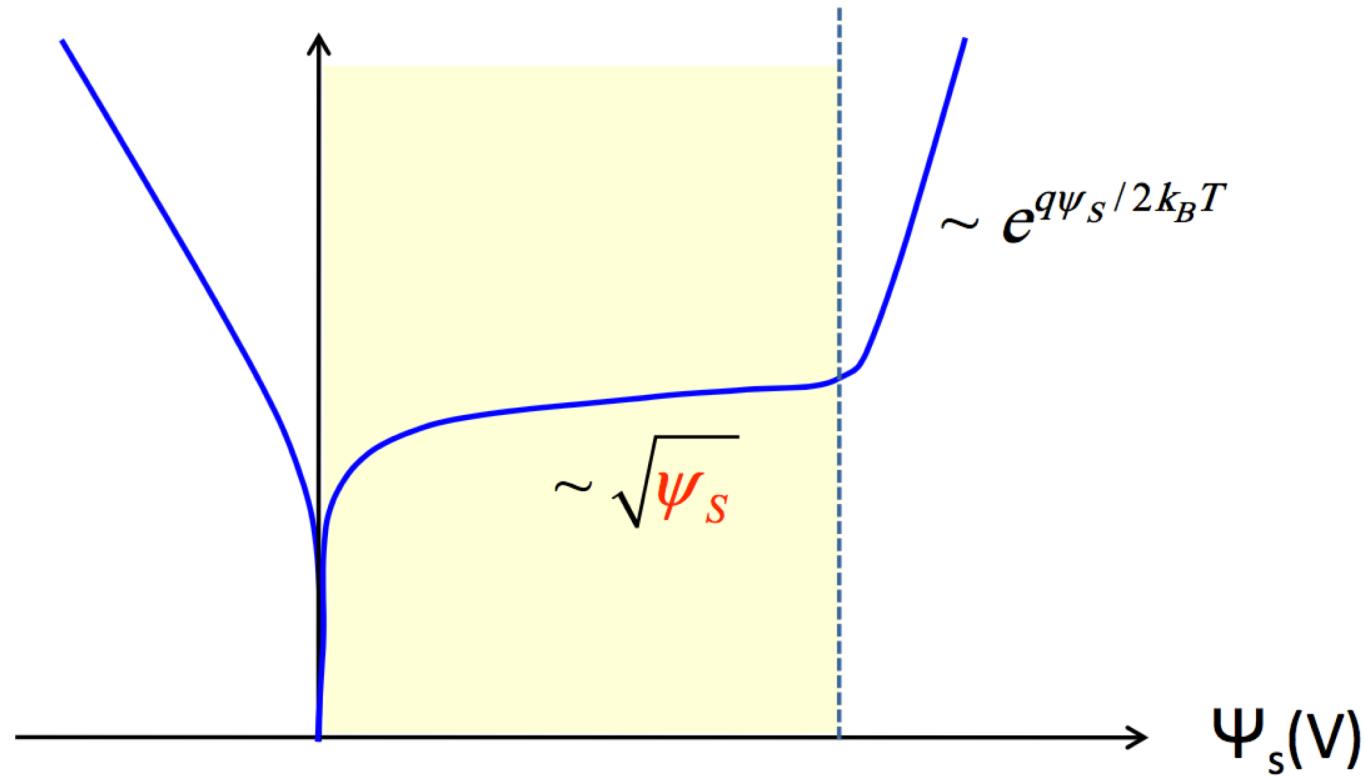


电荷与表面势：耗尽

$$Q_s(\psi_s) = -qN_A W = \sqrt{2qN_A K_{Si} \epsilon_0 \psi_s}$$



$$\log_{10} |Q_s(\psi_s)|$$



Thanks!
Q&A