

# 微电子器件物理

## MOS结构

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# 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

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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

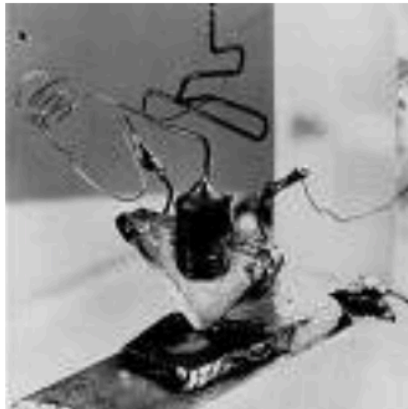
# MOSFET的尺寸缩小

真空管



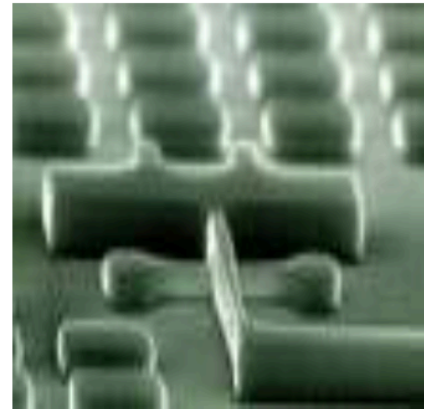
1906-1950s

三极管



1947-1980s

MOSFET



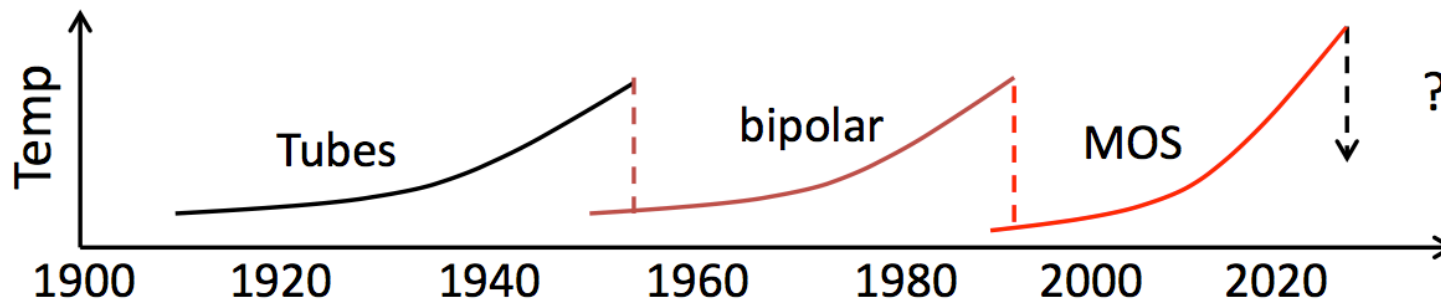
1960-until now

Now ??

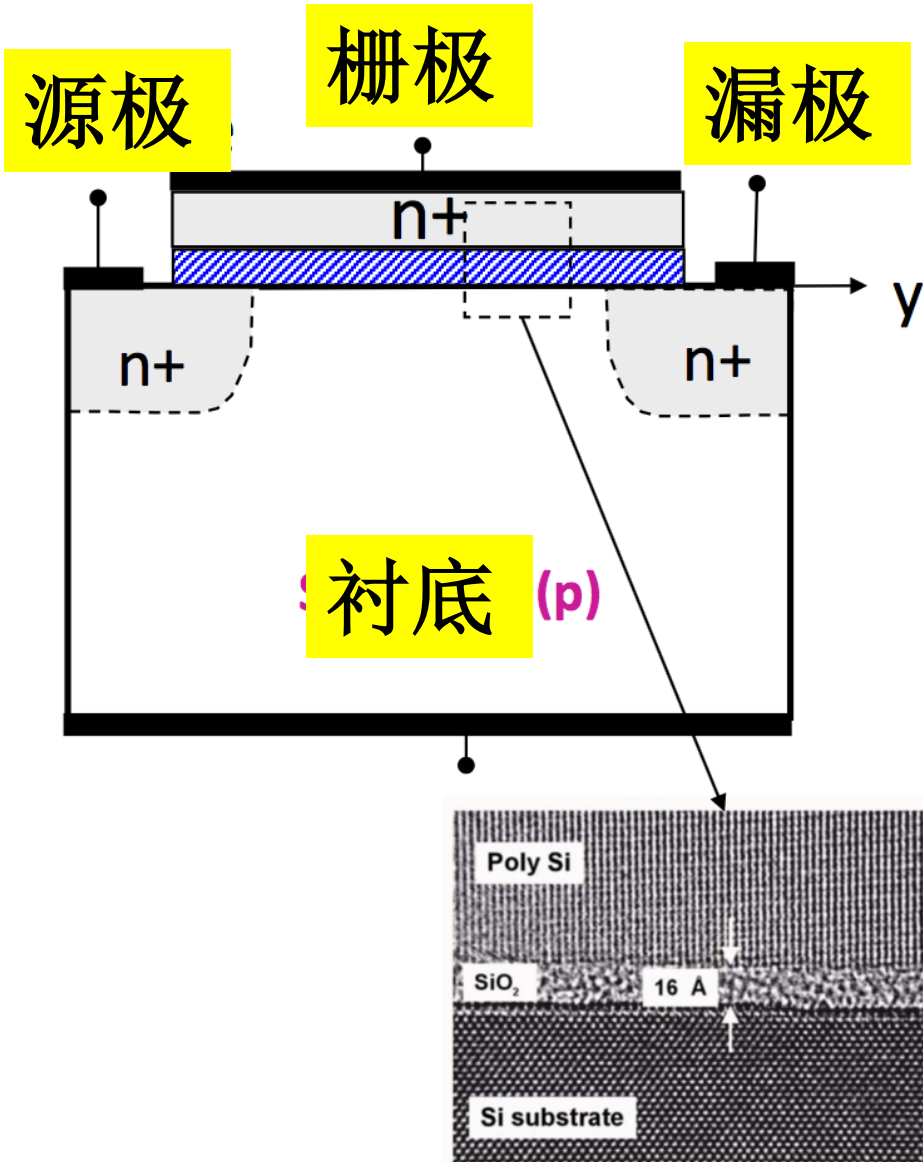
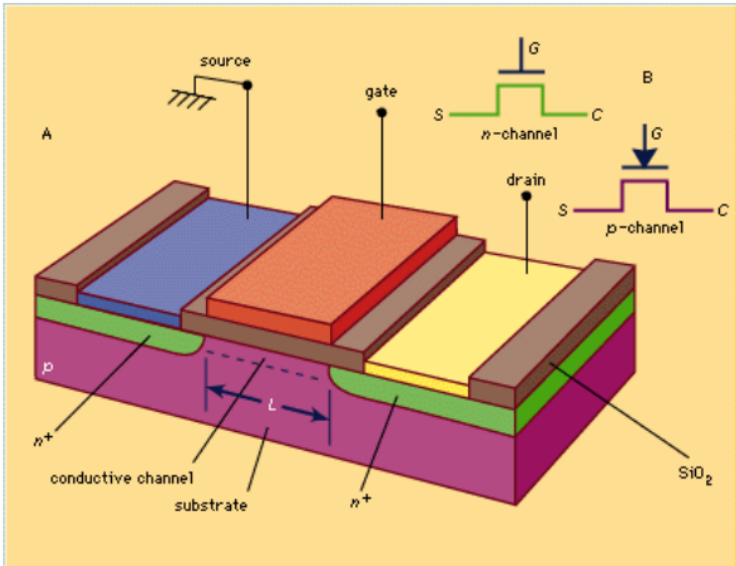
Spintronics

Bio Sensors

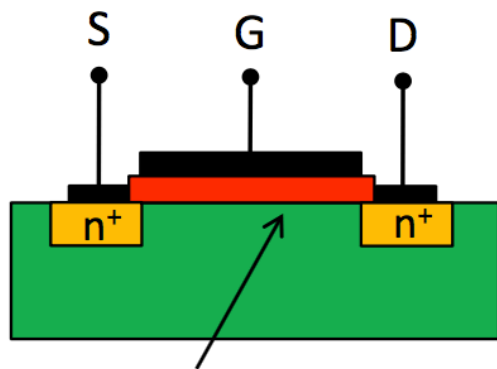
Displays ....



# MOSFET的基本结构

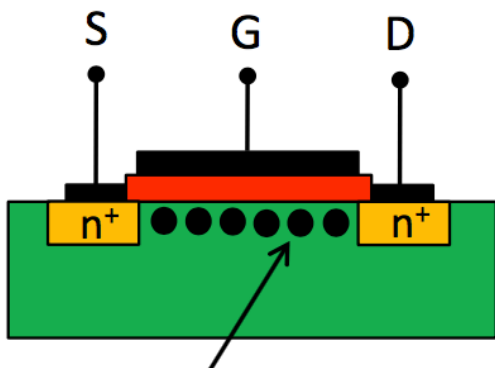
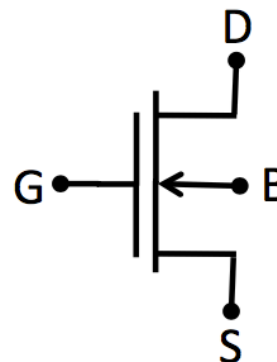


# MOSFET的电路符号



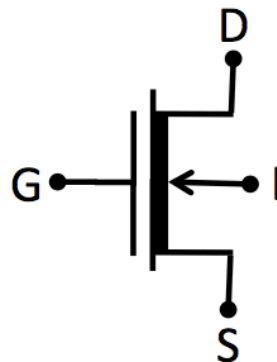
**No channel**  
when  $V_G = 0$

增强型



**Channel**  
when  $V_G = 0$

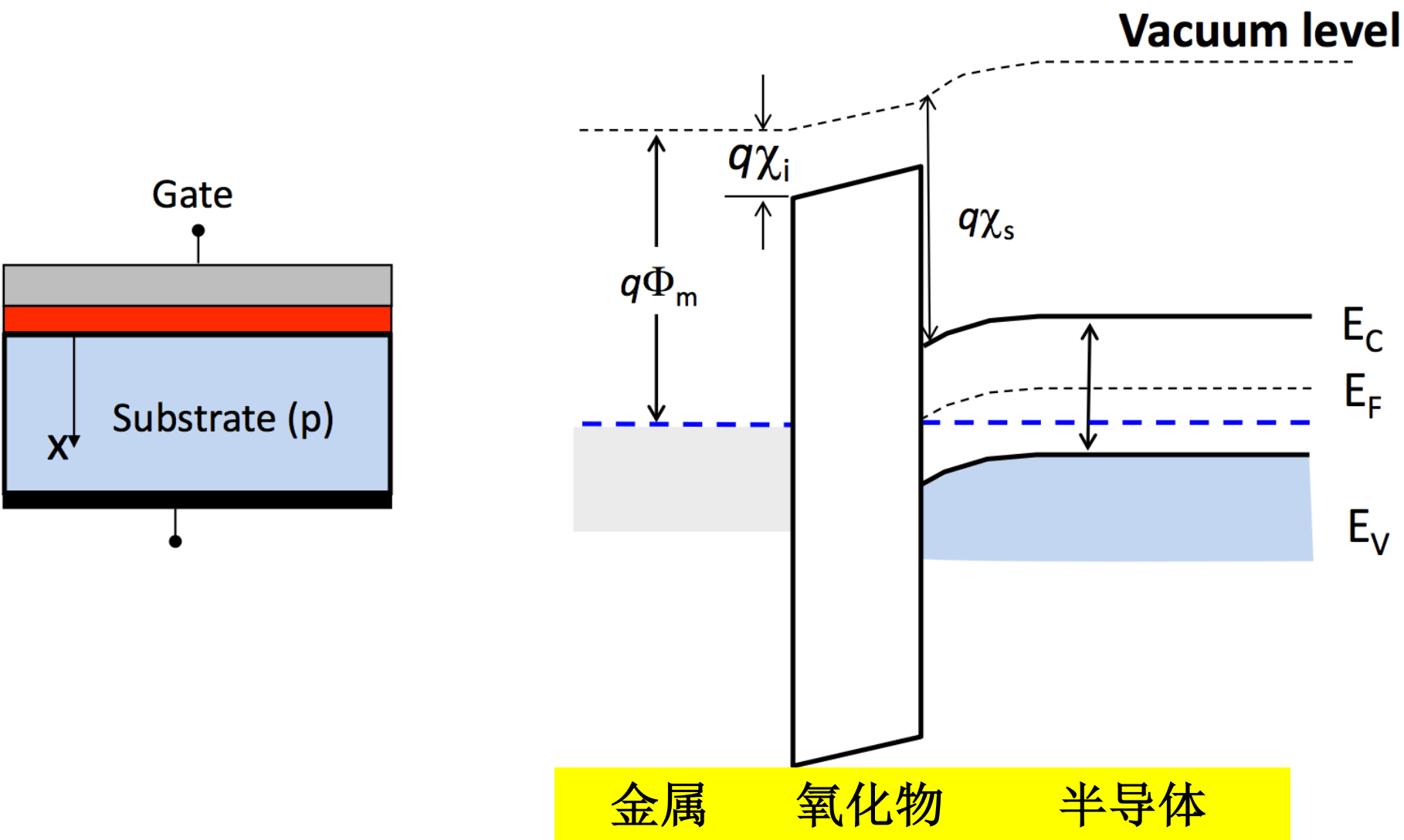
耗尽型



# 本节课提纲

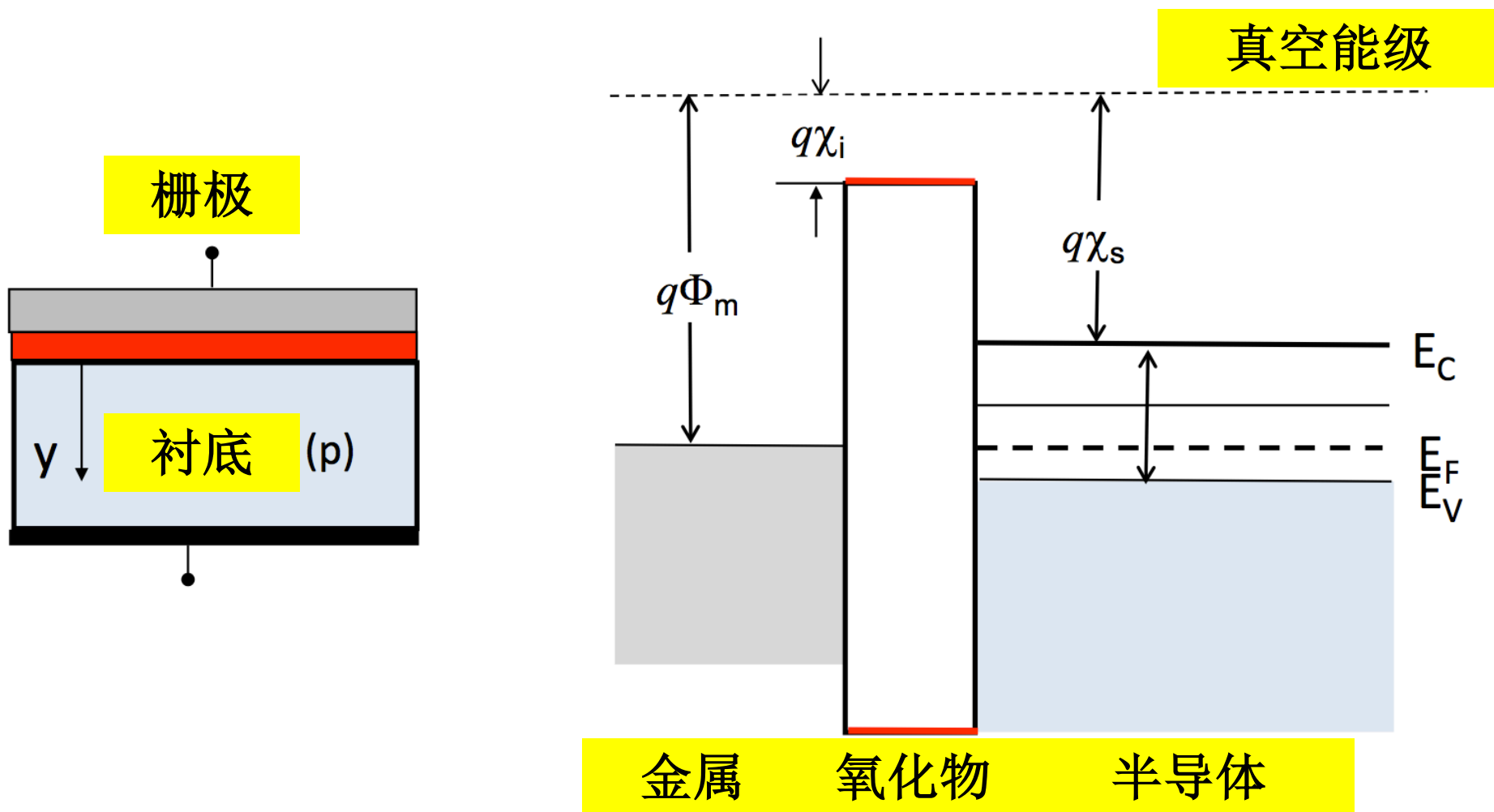
1. 背景
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# MOS结构的平衡态能带图

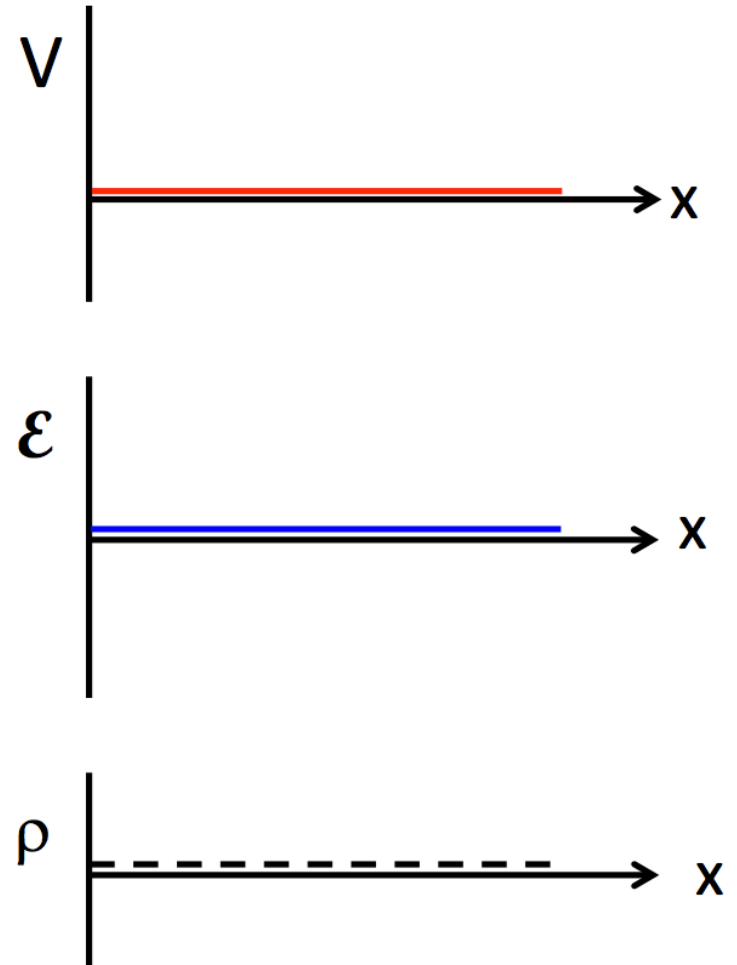
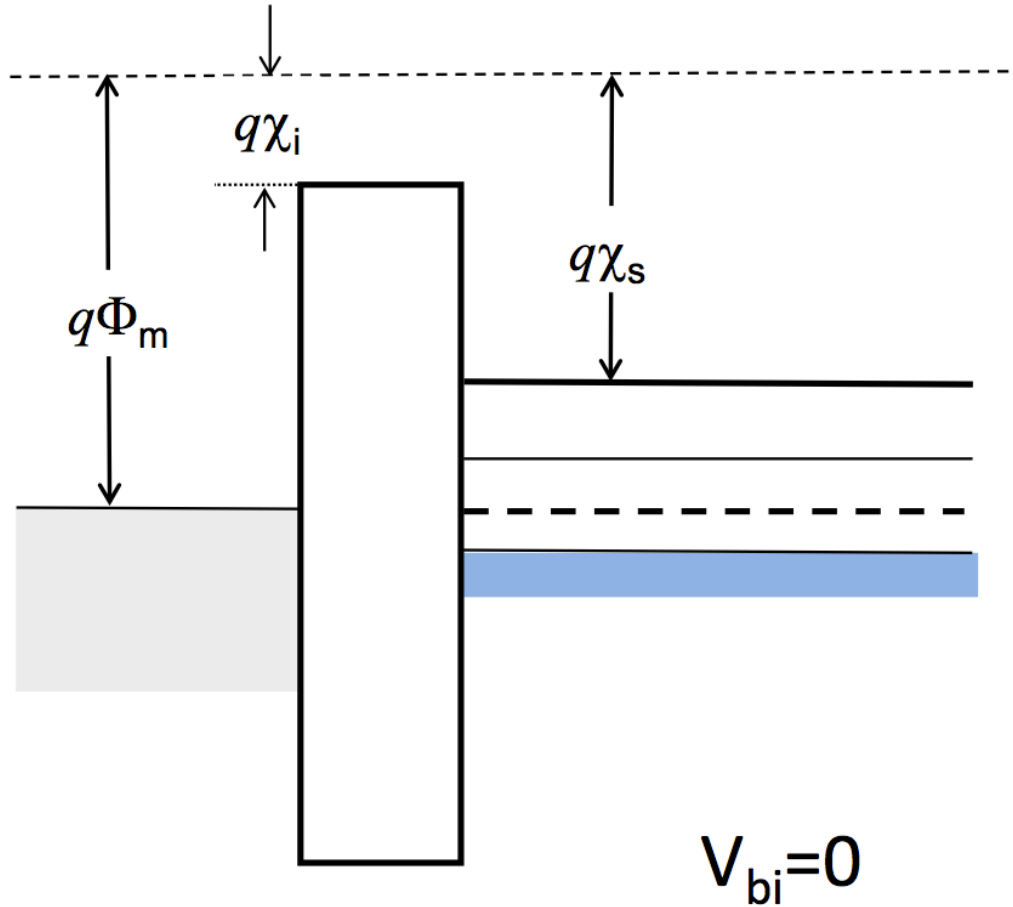




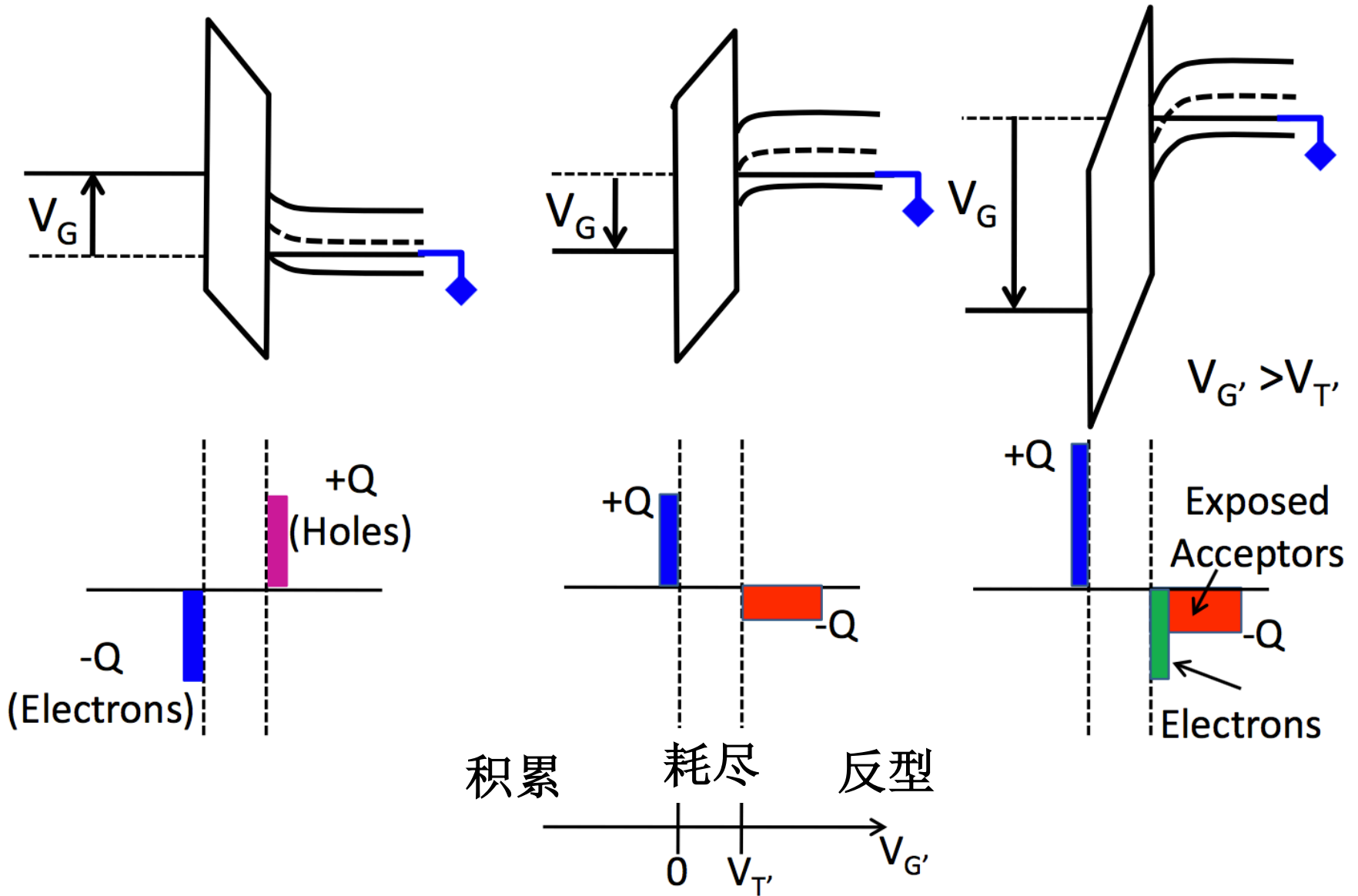
# 理想MOS电容



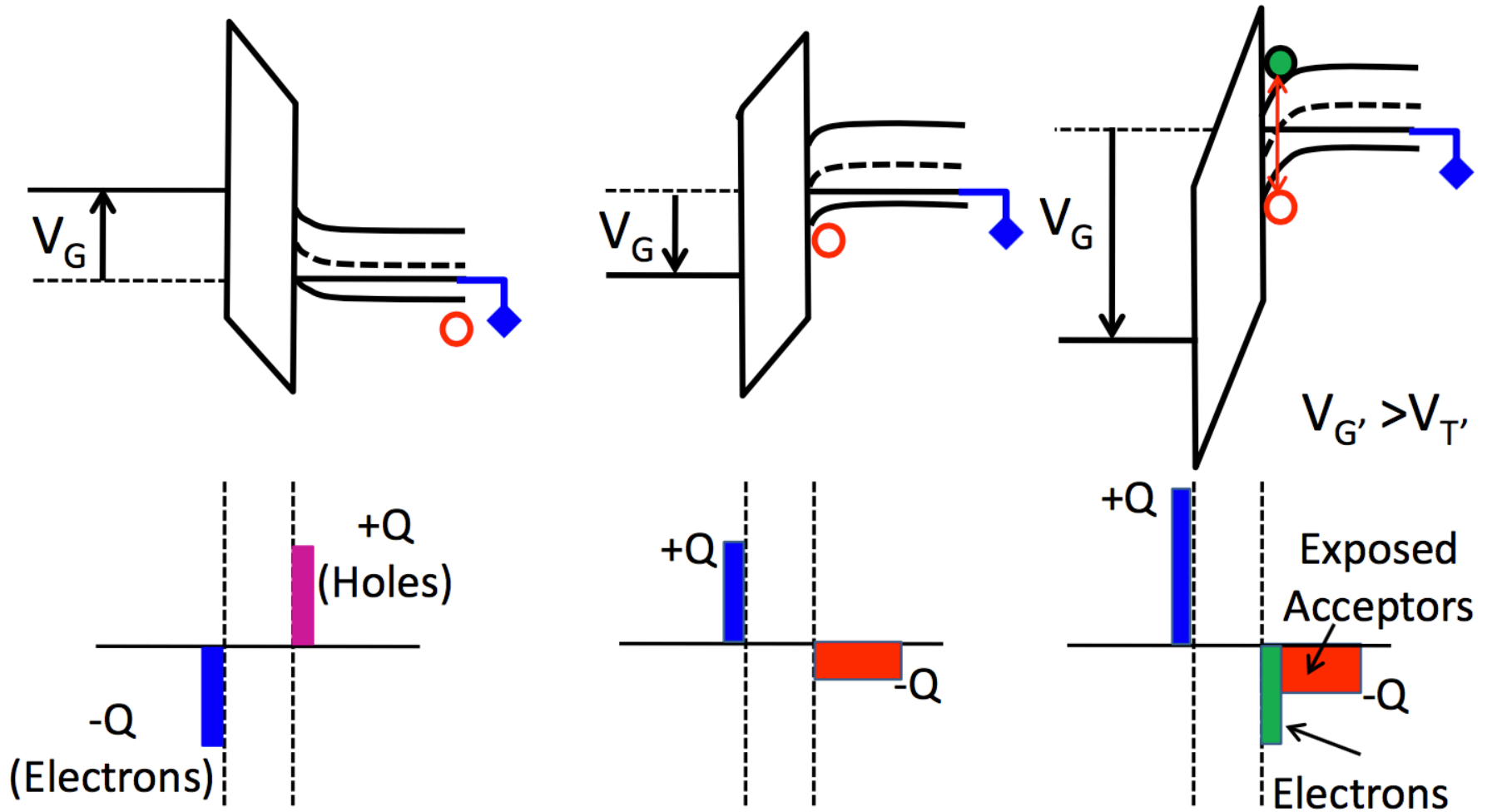
# 理想MOS电容



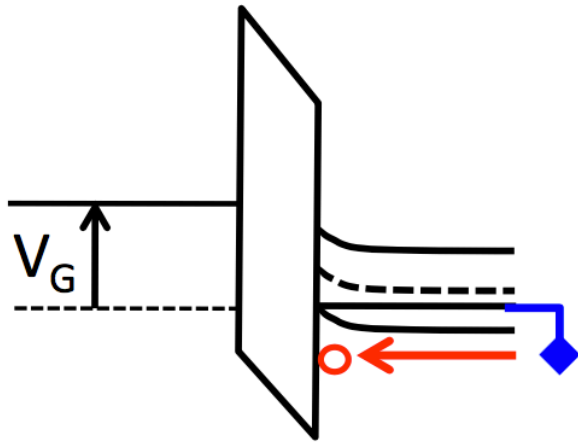
# 加偏置的MOS电容



# 电子和空穴从哪里来？

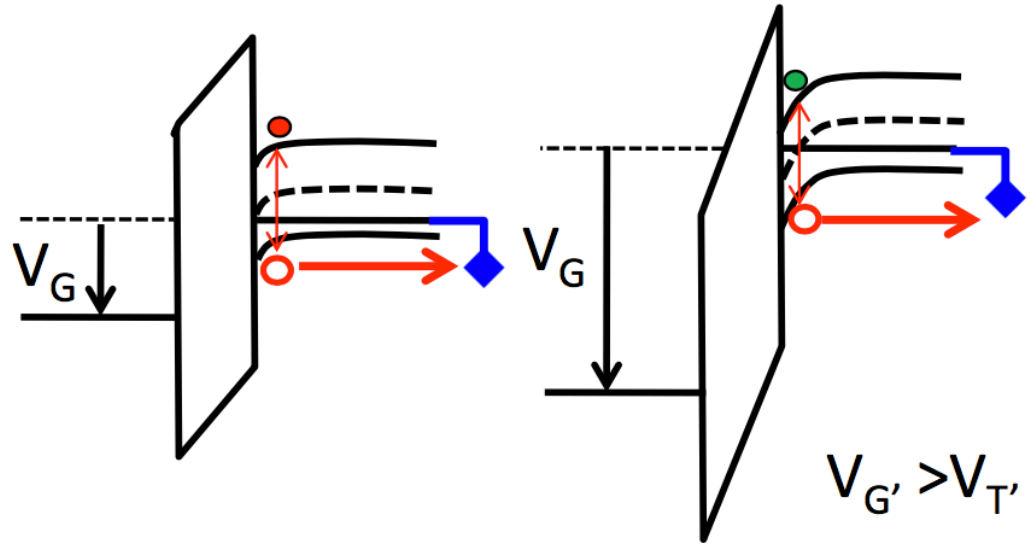


# 响应时间



多数载流子

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



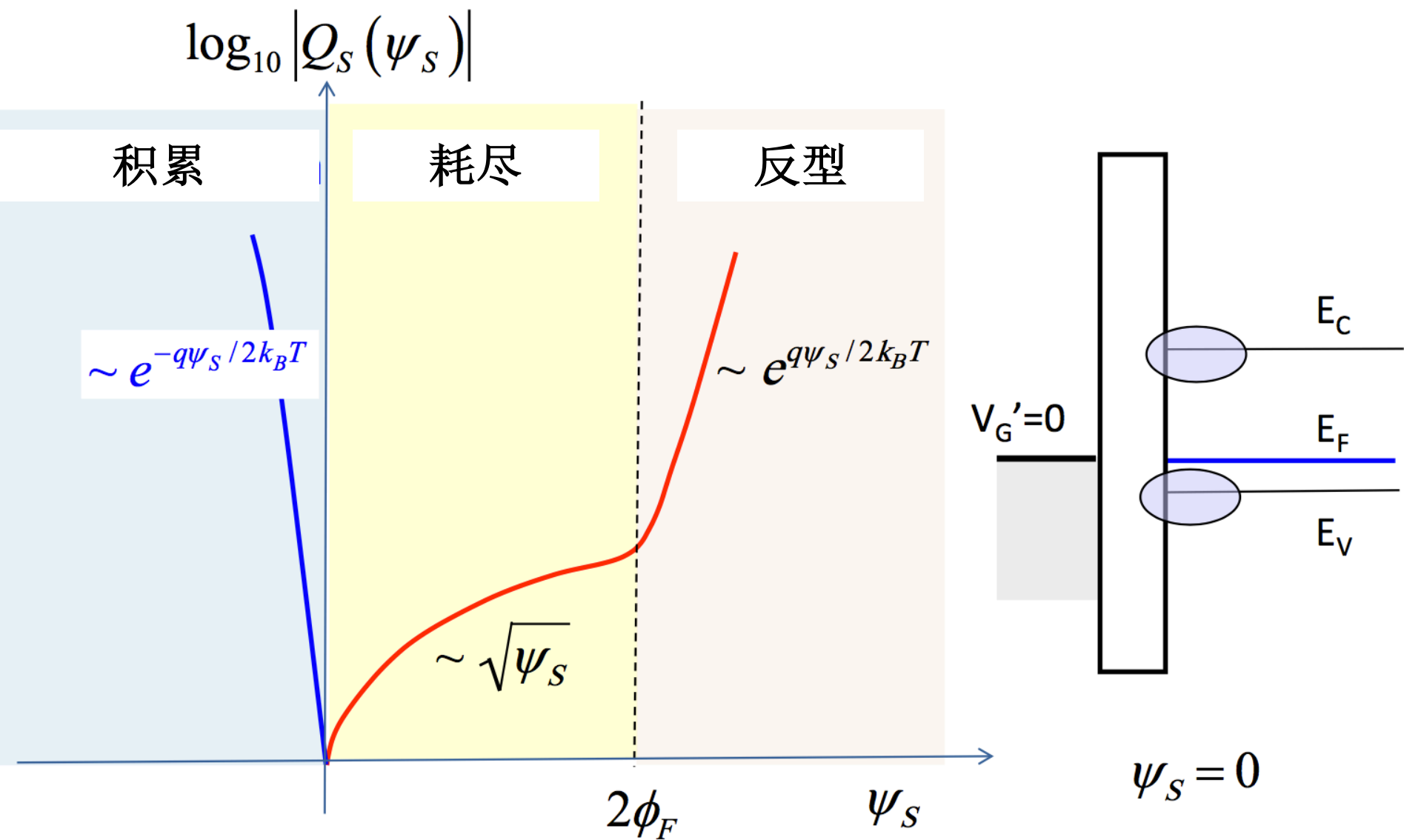
少数载流子 (SRH)

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

# 本节课提纲

1. 背景
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3. **MOS结构的电荷-电压关系**

# 电荷与表面势



# 电荷与表面势

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

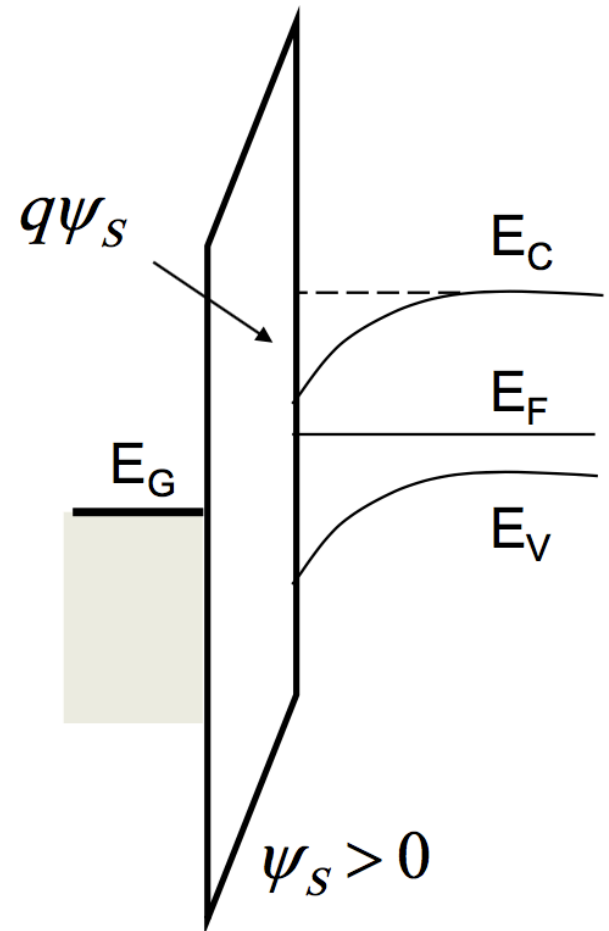
$$\nabla \cdot (\vec{J}_n / -q) = (G - R)$$

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

泊松方程

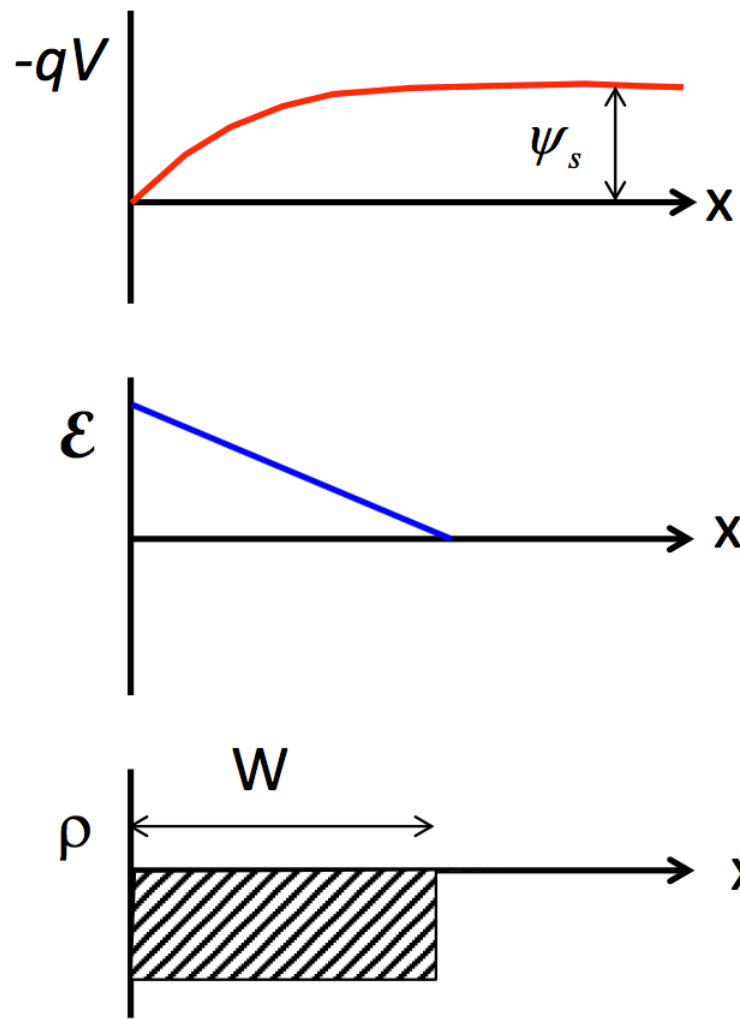
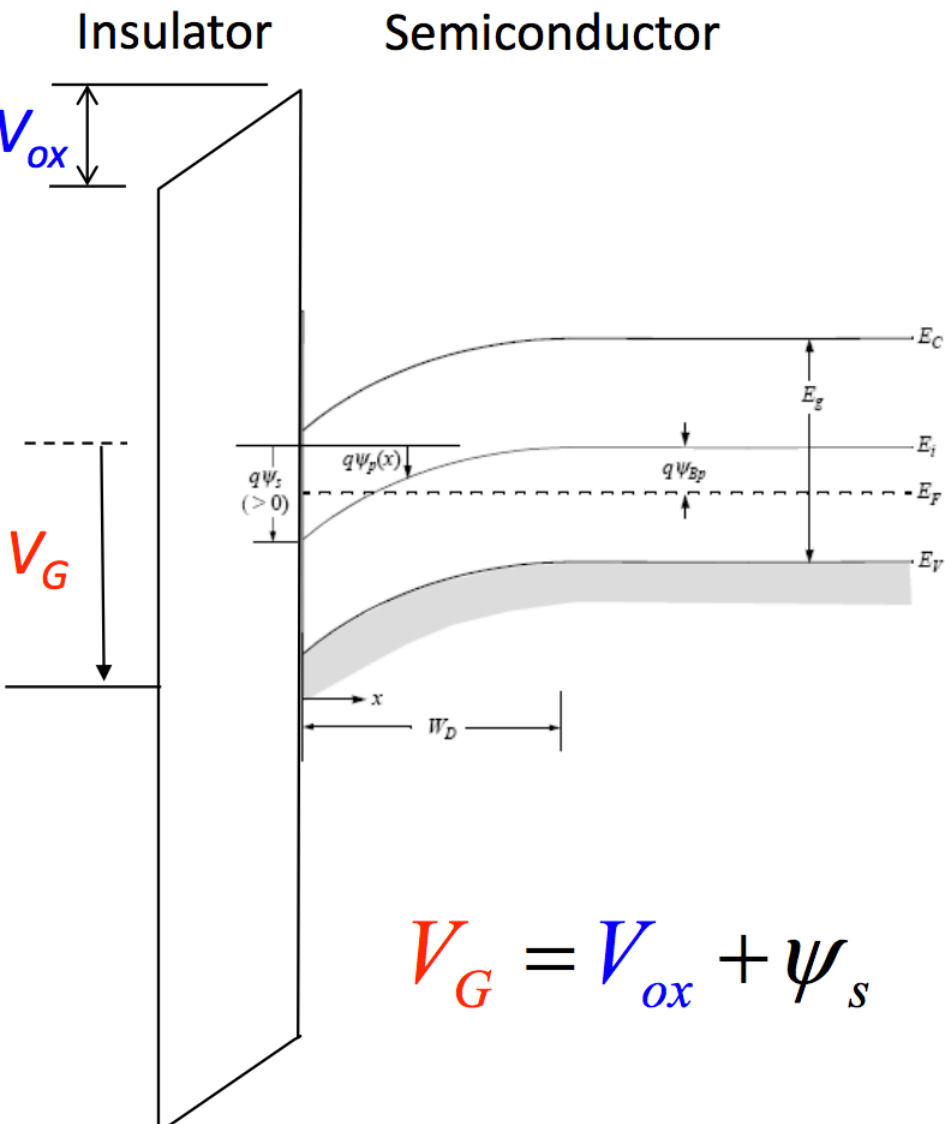


$$\frac{d^2\psi}{dx^2} = \frac{-q}{\kappa_{Si}\epsilon_0} [p_0(x) - n_0(x) + N_D^+ - N_A^-]$$





# 电荷与表面势：耗尽



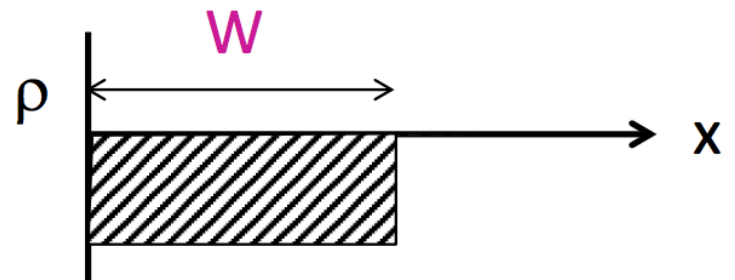
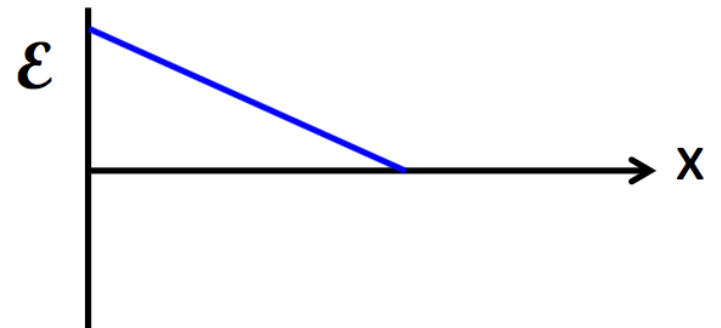
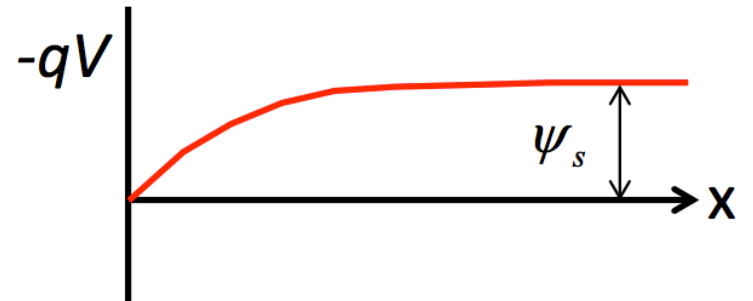
# 电荷与表面势：耗尽

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

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

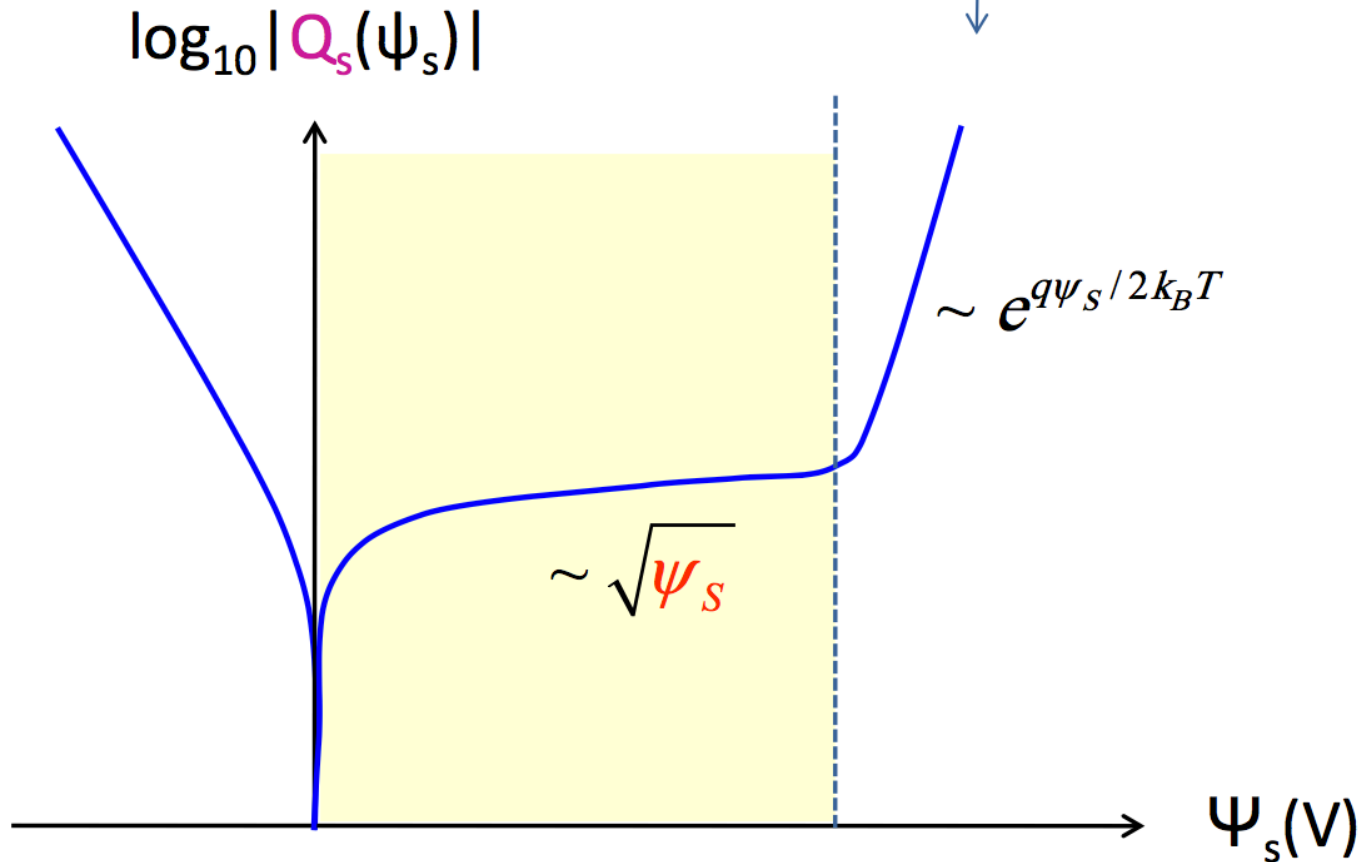
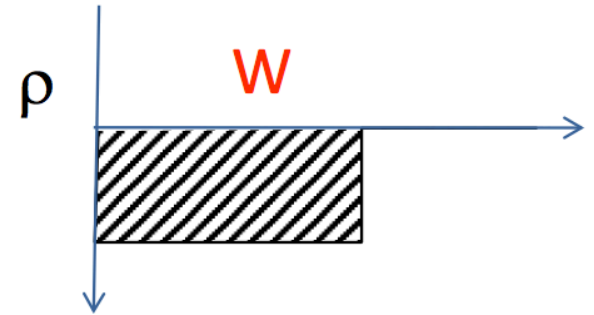
$$(1) \quad \mathcal{E}(0^+) = -\frac{qN_A W}{\kappa_s \epsilon_0}$$

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



# 电荷与表面势：耗尽

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



**Thanks!**  
**Q&A**