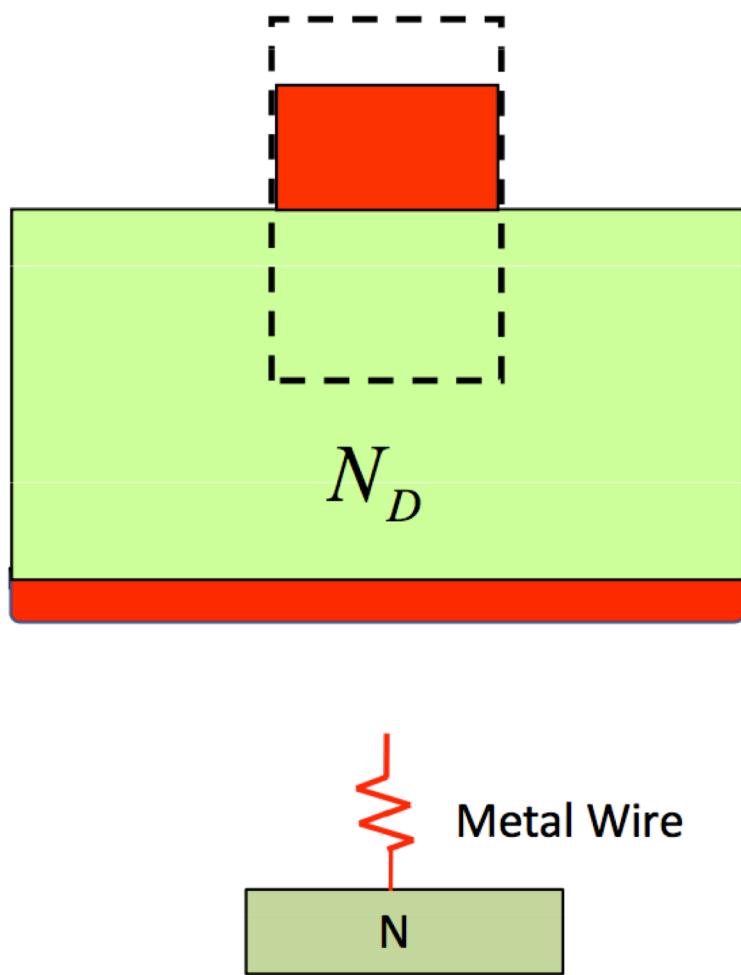


微电子器件物理 肖特基二极管

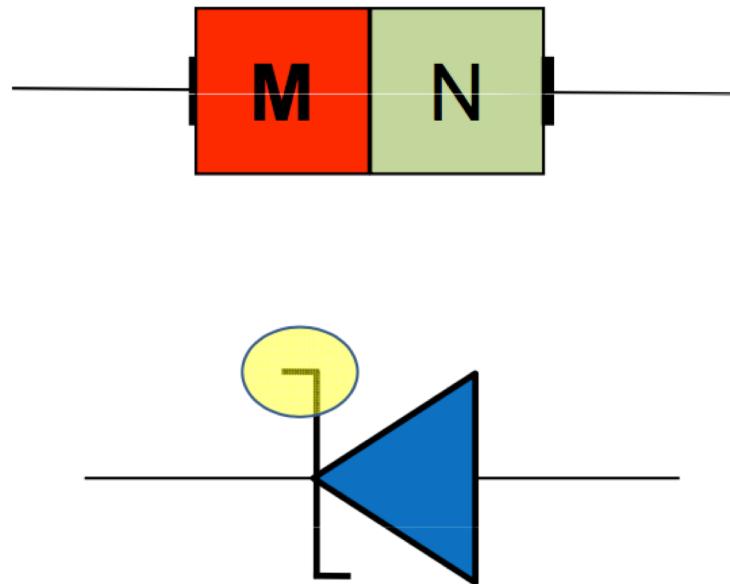
曾琅

2020/09/25

金属半导体二极管

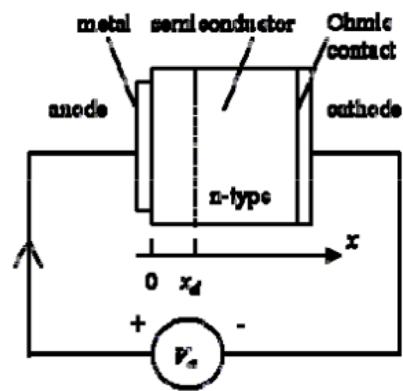


Symbols

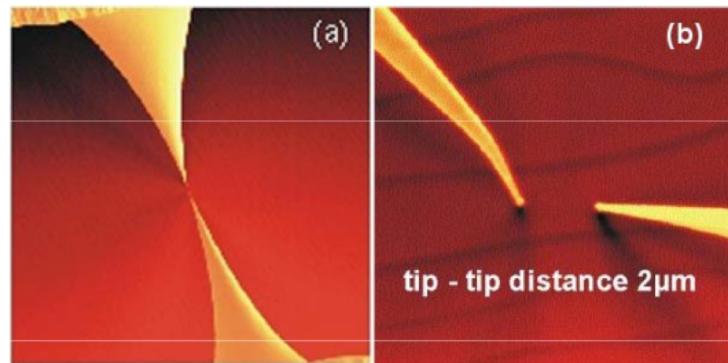


肖特基二极管的应用

矿石收音机



扫描隧道显微镜

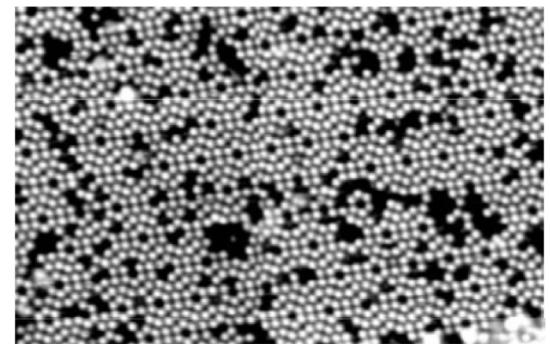
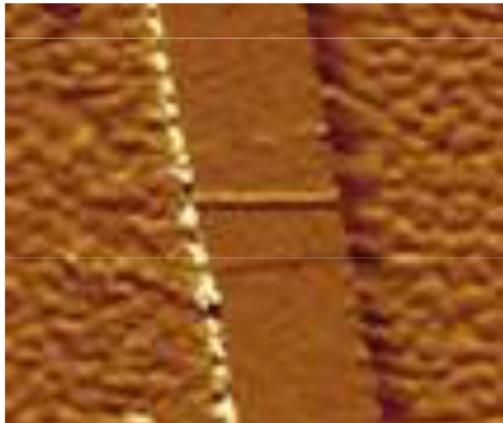


www.fz-juelich.de/ibn/index.php?index=674

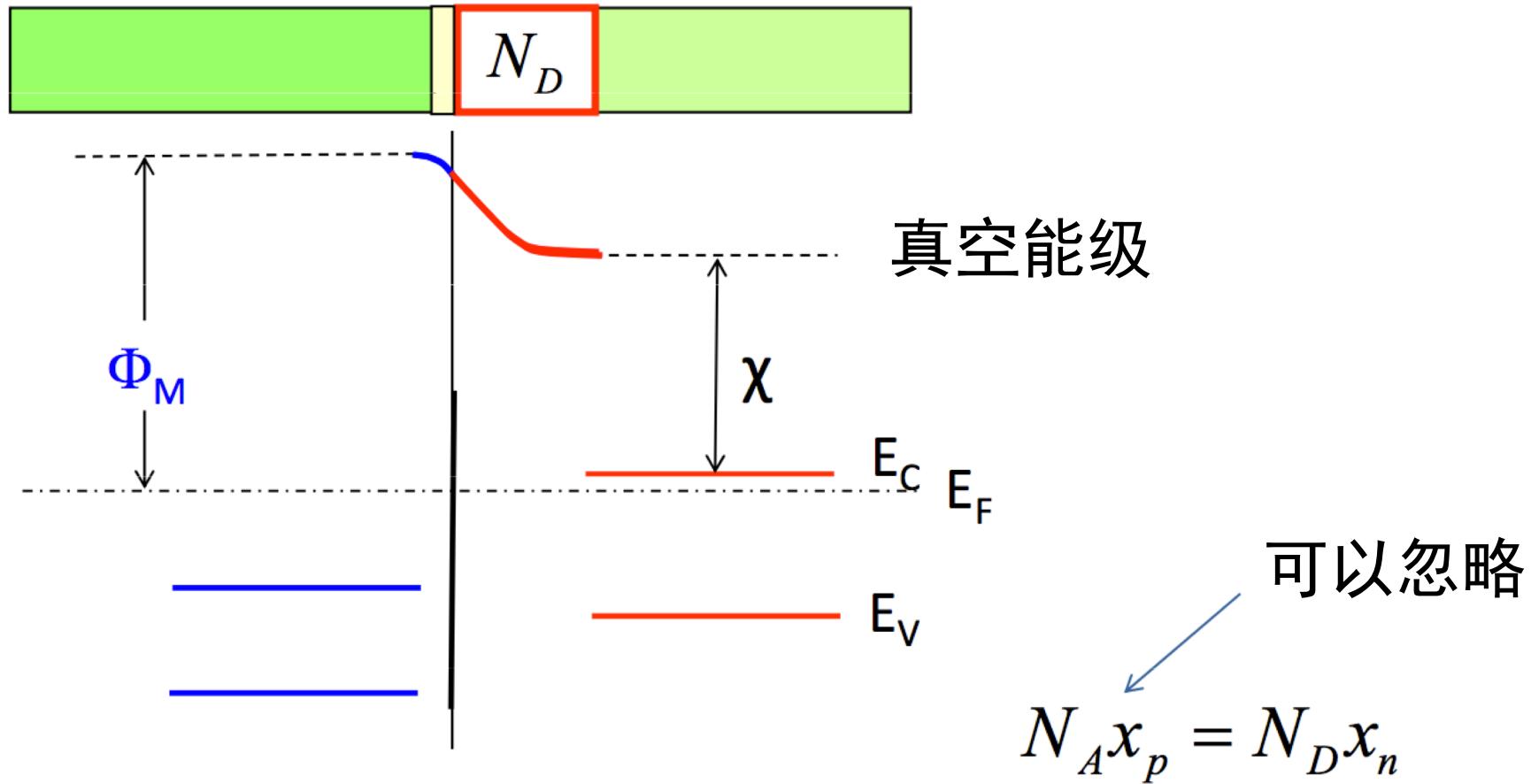
第一个晶体管



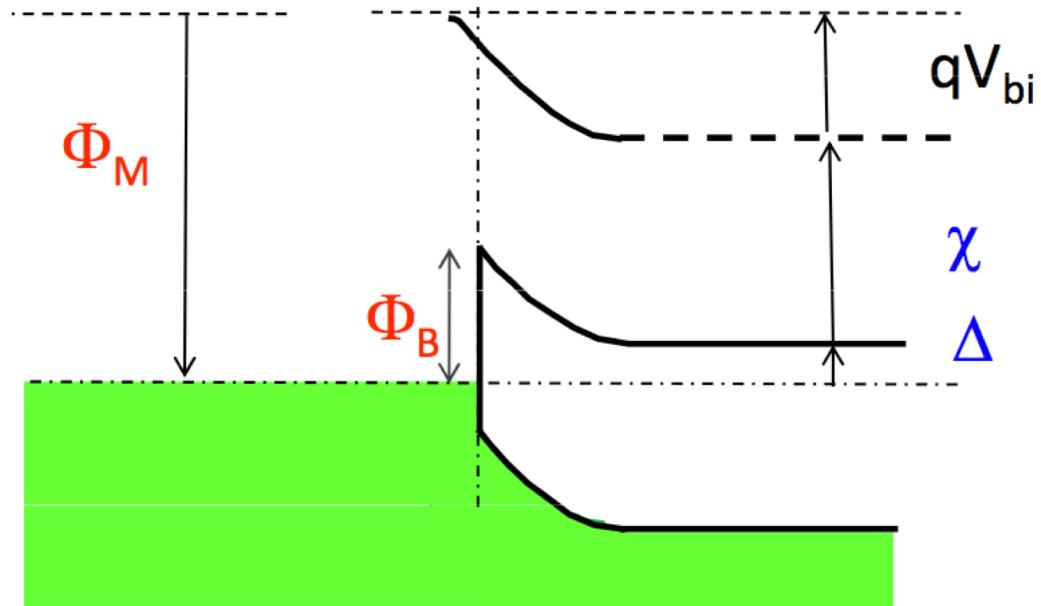
碳纳米管



肖特基二极管的能带图



肖特基二极管的能带图



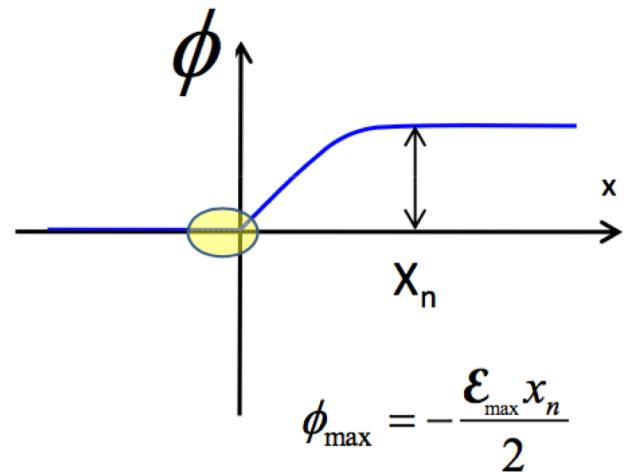
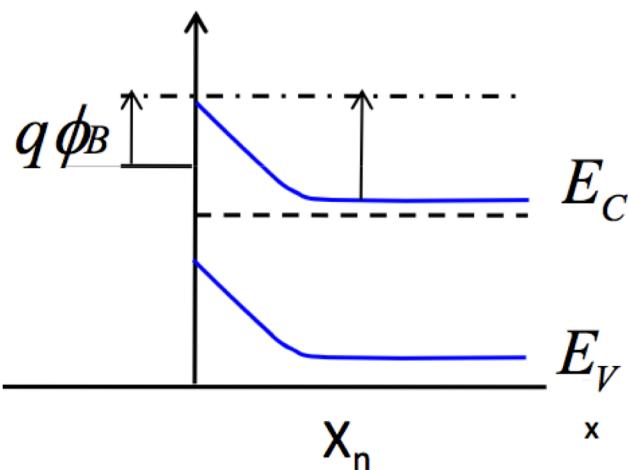
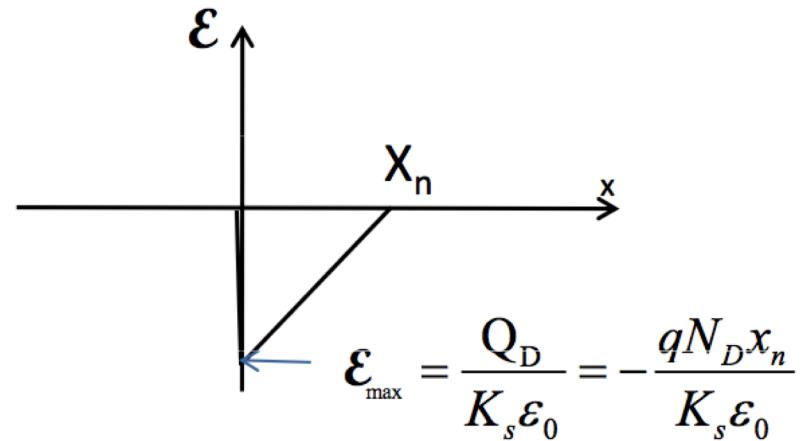
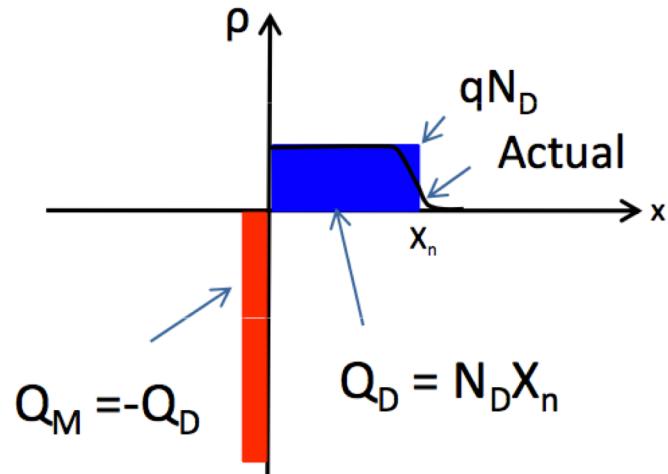
$$\Delta + \chi + qV_{bi} = \Phi_M$$

$$qV_{bi} = (\Phi_M - \chi) - \Delta \equiv \Phi_B - \Delta$$

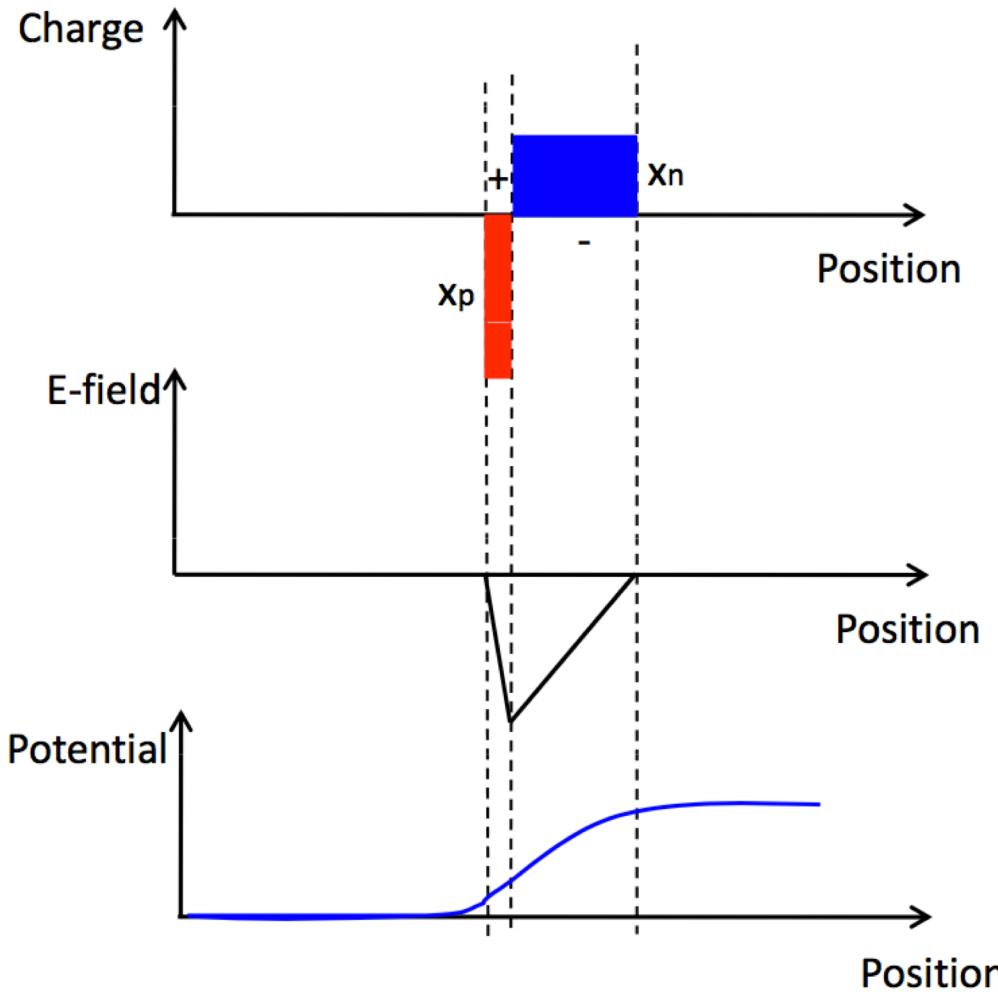
$$= \Phi_B - k_B T \ln \frac{N_D}{N_C}$$

肖特基二极管的能带图

Depletion Approximation



肖特基二极管的能带图



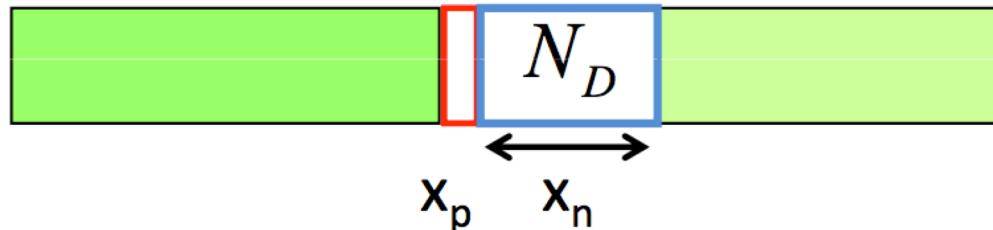
$$\mathcal{E}(0^+) = \frac{qN_D x_n}{k_s \epsilon_0}$$

$$\mathcal{E}(0^-) = \frac{qN_M x_p}{k_s \epsilon_0} ?$$

$$\Rightarrow N_D x_n = N_M x_p$$

$$\begin{aligned} qV_{bi} &= \frac{\mathcal{E}(0^-) x_n}{2} + \frac{\mathcal{E}(0^+) x_p}{2} \\ &= \frac{qN_D x_n^2}{2k_s \epsilon_0} + \frac{qN_M x_p^2}{2k_s \epsilon_0} \end{aligned}$$

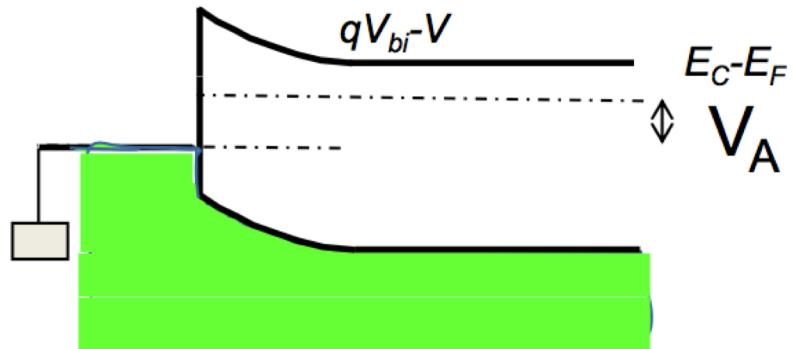
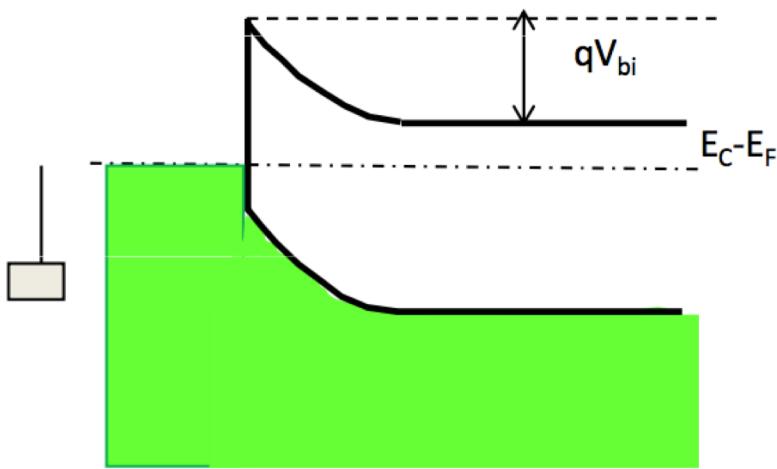
耗尽区



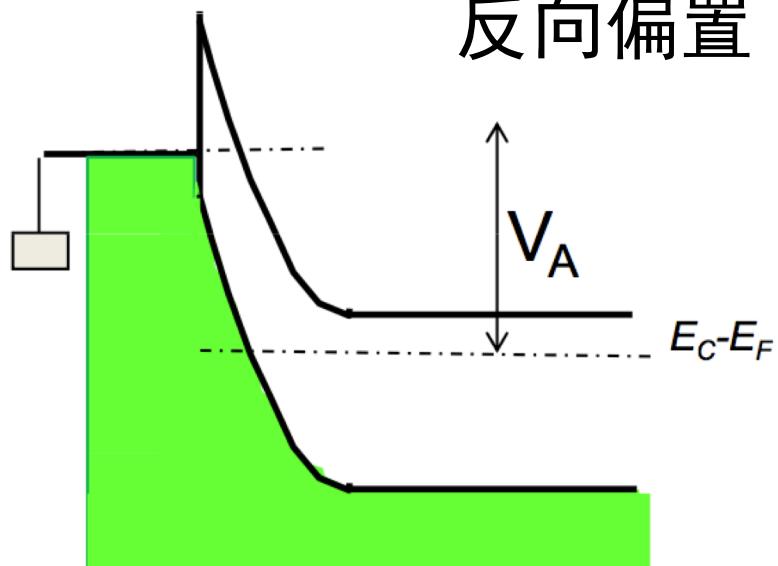
$$\left. \begin{aligned} N_D x_n &= N_M x_p \\ qV_{bi} &= \frac{qN_D x_n^2}{2k_s \epsilon_0} + \frac{qN_M x_p^2}{2k_s \epsilon_0} \end{aligned} \right\} \quad \begin{aligned} x_n &= \sqrt{\frac{2k_s \epsilon_0}{q} \frac{N_M}{N_D(N_M + N_D)} V_{bi}} \rightarrow \sqrt{\frac{2k_s \epsilon_0}{q} \frac{1}{N_D} V_{bi}} \\ x_p &= \sqrt{\frac{2k_s \epsilon_0}{q} \frac{N_D}{N_M(N_M + N_D)} V_{bi}} \rightarrow 0 \end{aligned}$$

正向偏置与反向偏置

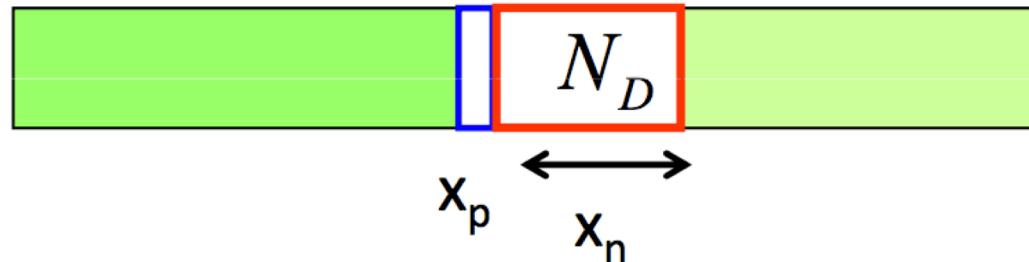
正向偏置



反向偏置



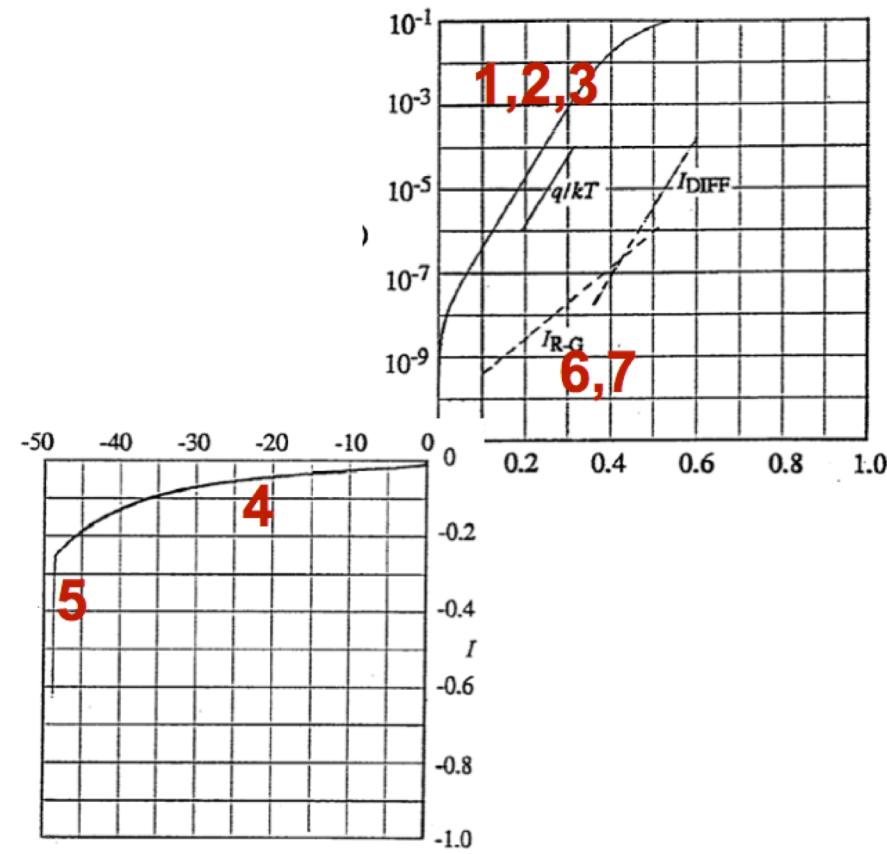
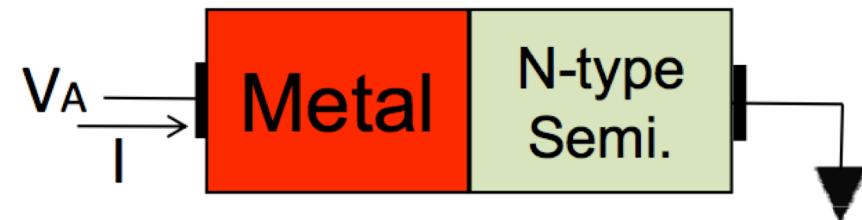
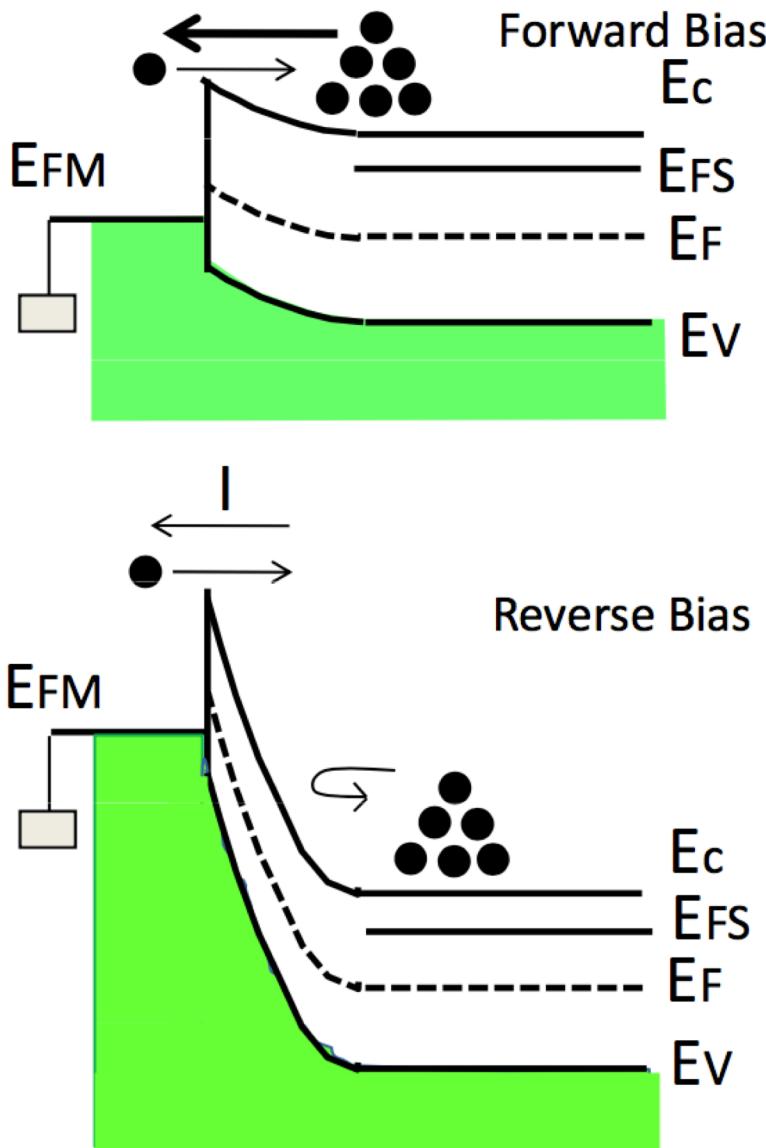
偏置下的耗尽区



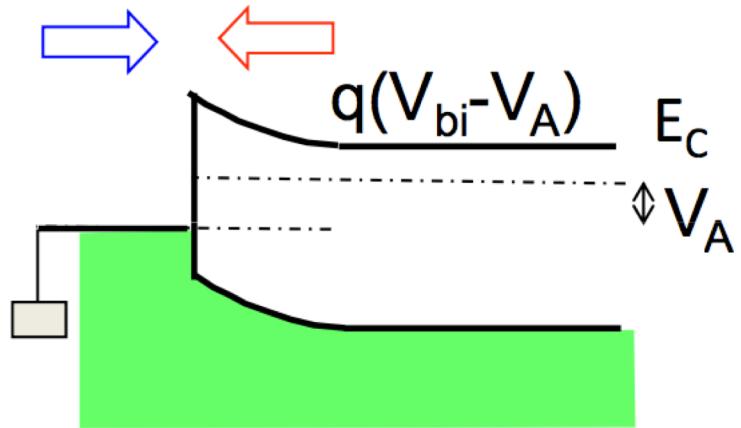
$$x_n = \sqrt{\frac{2k_s \epsilon_0}{q} \frac{N_M}{N_D(N_M + N_D)} V_{bi}} \rightarrow \sqrt{\frac{2k_s \epsilon_0}{q} \frac{1}{N_D} (V_{bi} - V_A)}$$

$$x_p = \sqrt{\frac{2k_s \epsilon_0}{q} \frac{N_D}{N_M(N_M + N_D)} V_{bi}} \rightarrow 0$$

电流特性



电流是如何流动的



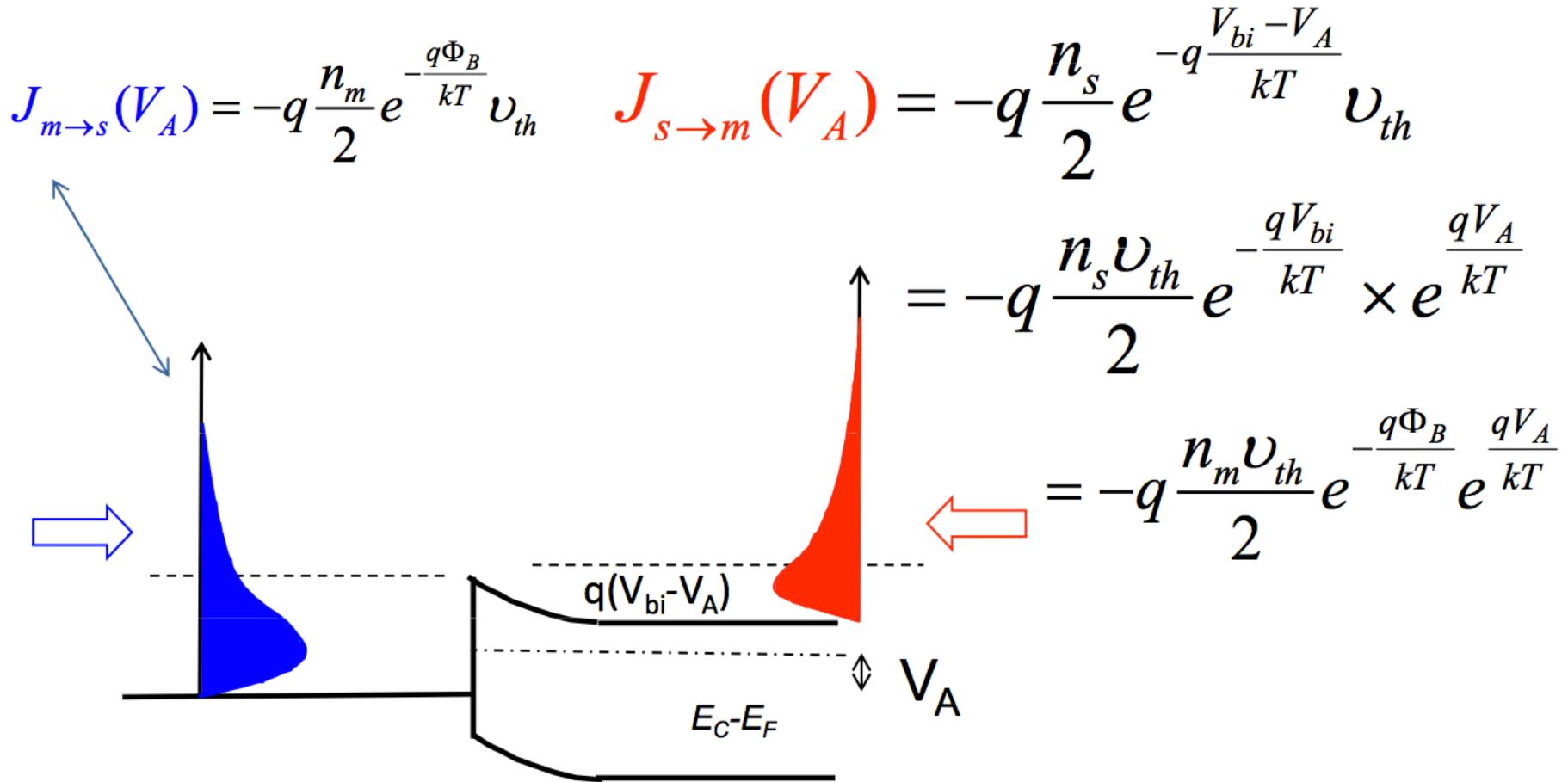
$$\begin{aligned} J_T(V_A) &= J_{m \rightarrow s}(V_A) - J_{s \rightarrow m}(V_A) \\ &= J_{m \rightarrow s}(0) - J_{s \rightarrow m}(V_A) \end{aligned}$$

$$J_T(V_A = 0) = 0 = J_{m \rightarrow s}(0) - J_{s \rightarrow m}(0) \quad \text{动态平衡}$$

$$\Rightarrow J_{m \rightarrow s}(0) = J_{s \rightarrow m}(0)$$

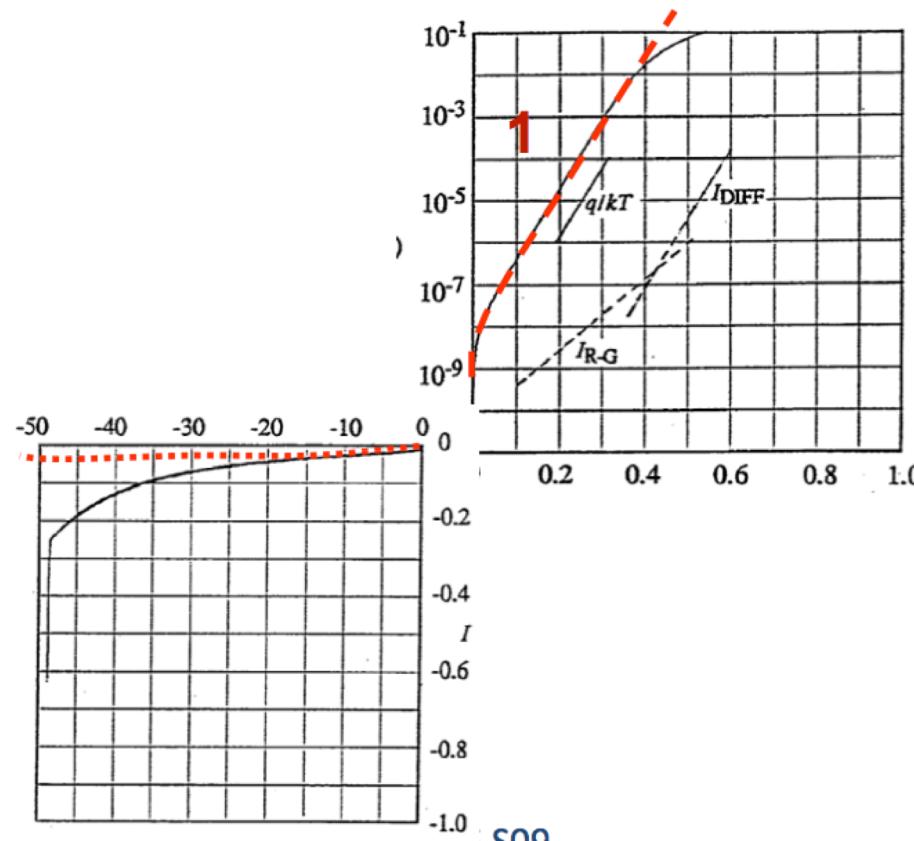
$$J_T(V_A) = J_{s \rightarrow m}(0) - J_{s \rightarrow m}(V_A)$$

半导体到金属的电流

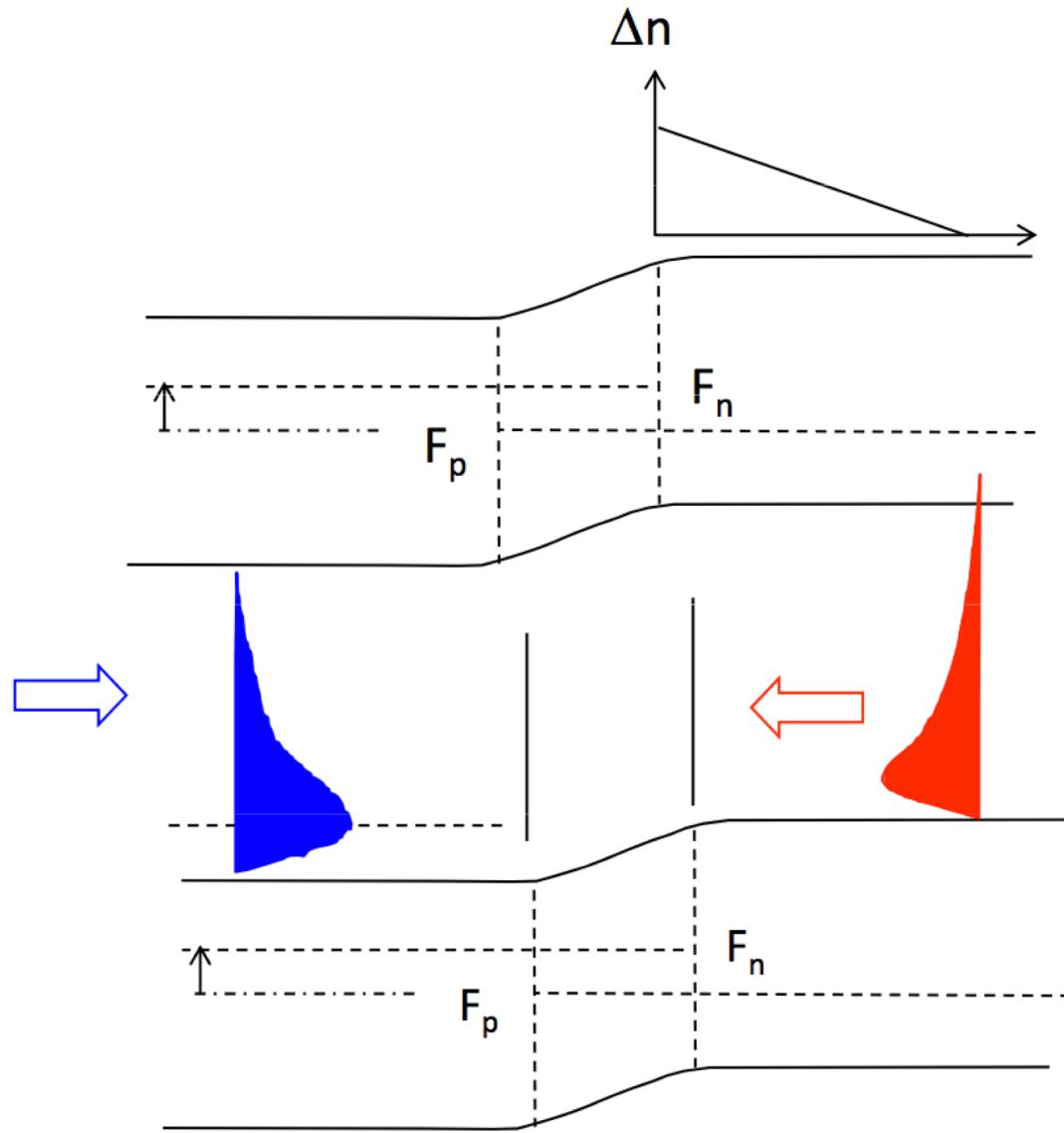


总电流

$$J_T = J_{s \rightarrow m}(0) - J_{s \rightarrow m}(V_A) = \frac{qn_m v_{th}}{2} e^{\frac{-q\Phi_m}{kT}} \left[e^{\frac{qV_A}{kT}} - 1 \right]$$

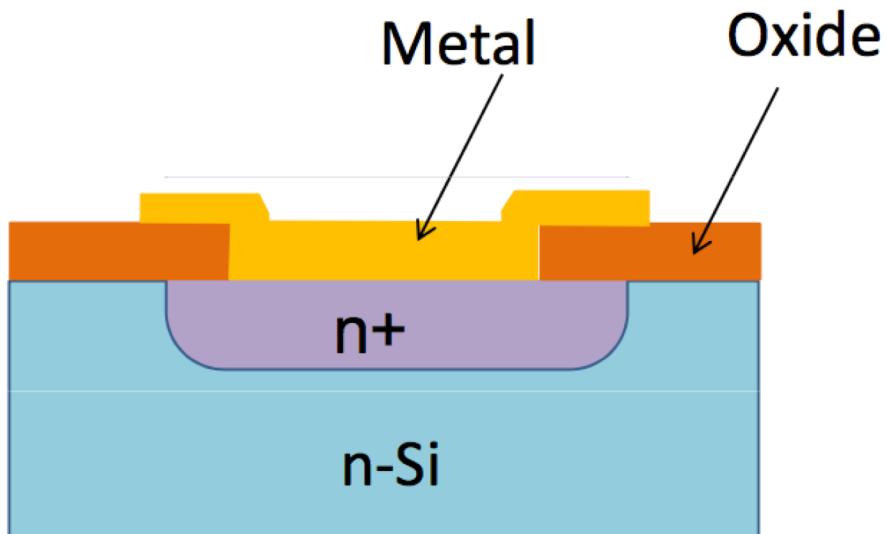


扩散电流 vs 热发射电流

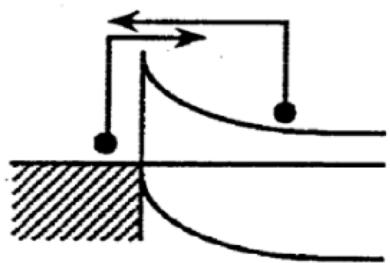


两者的电流特性
非常相似

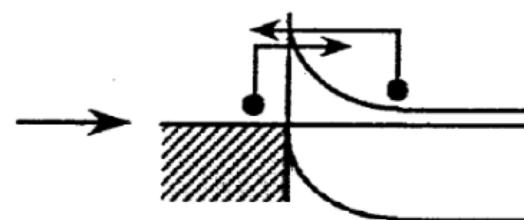
欧姆接触与肖特基接触



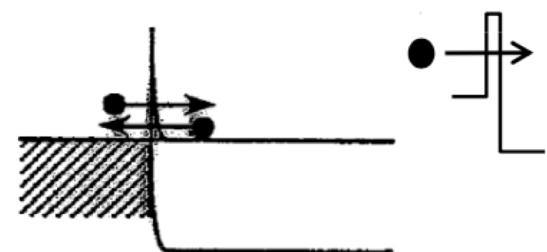
Low Doping



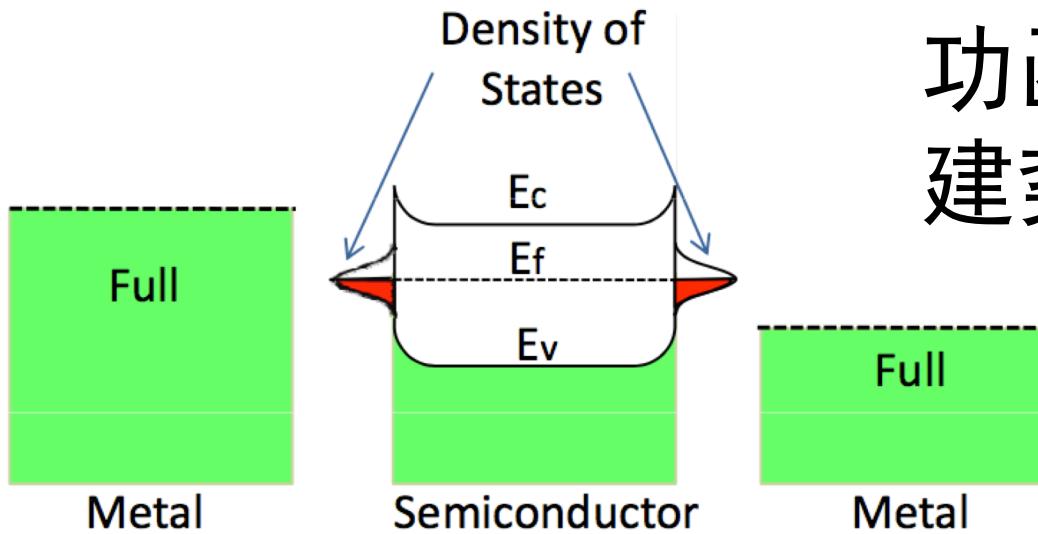
Moderate Doping



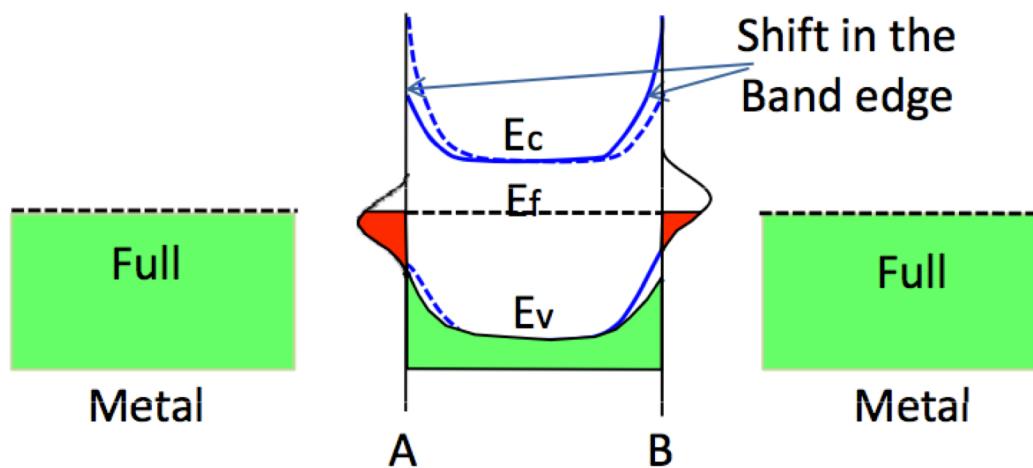
High Doping



费米钉扎效应



功函数无法调节内
建势



作业

- 《现代集成电路半导体器件》习题：4.1、
4.3、4.4、4.12、4.19

Thanks!
Q&A