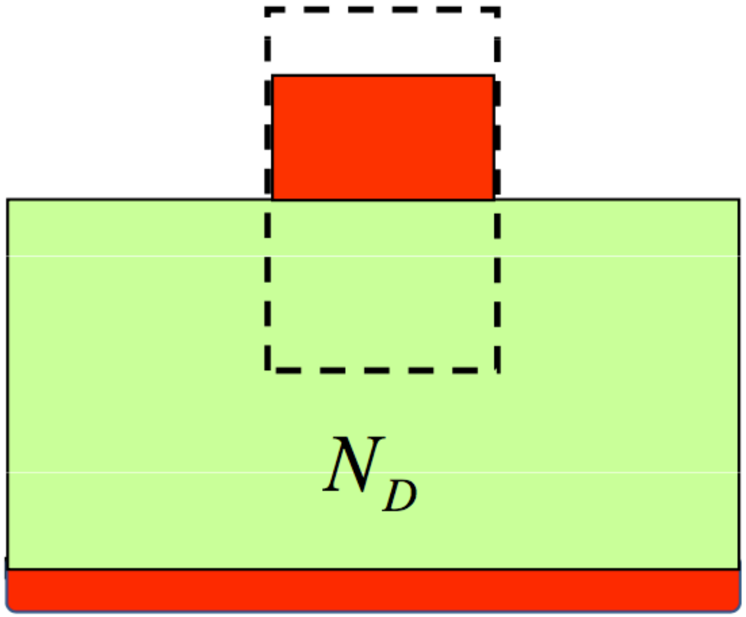
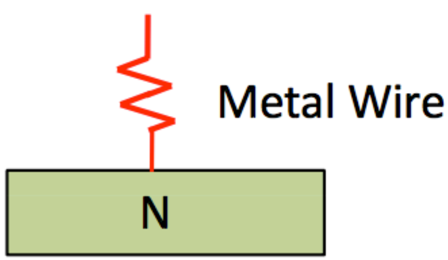
微电子器件物理
肖特基二极管

曾琅

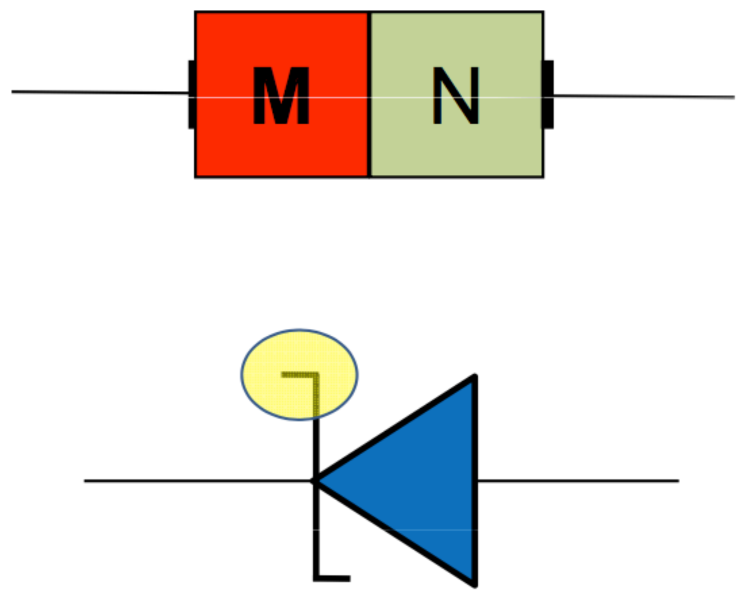
2020/09/25

金属半导体二极管

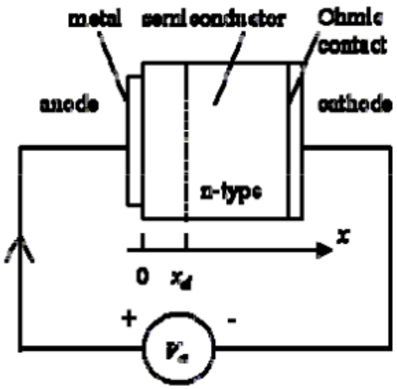




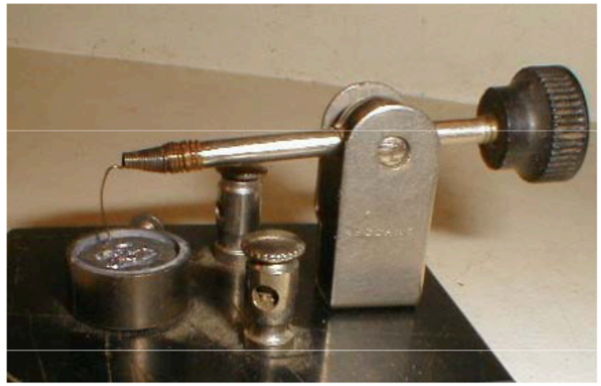
Symbols



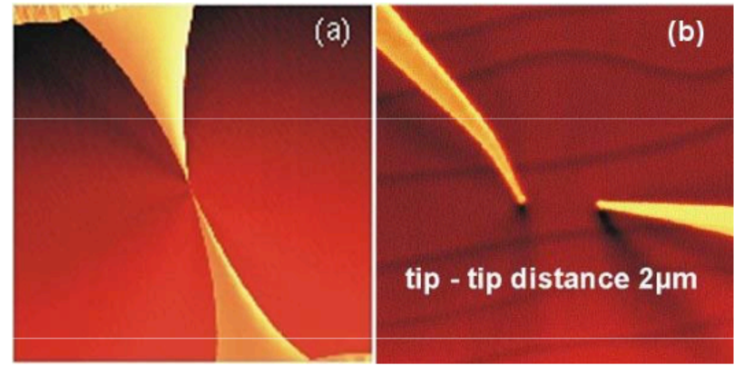
肖特基二极管的应用



矿石收音机



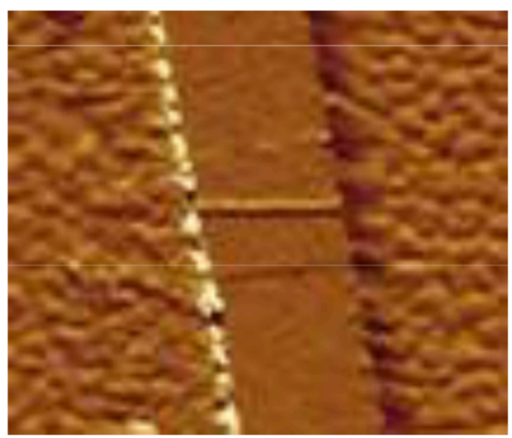
扫描隧道显微镜

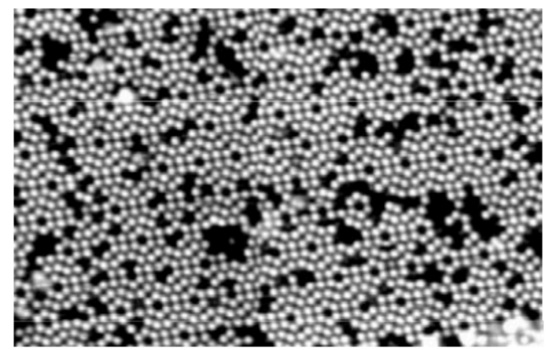


www.fz-juelich.de/ibn/index.php?index=674

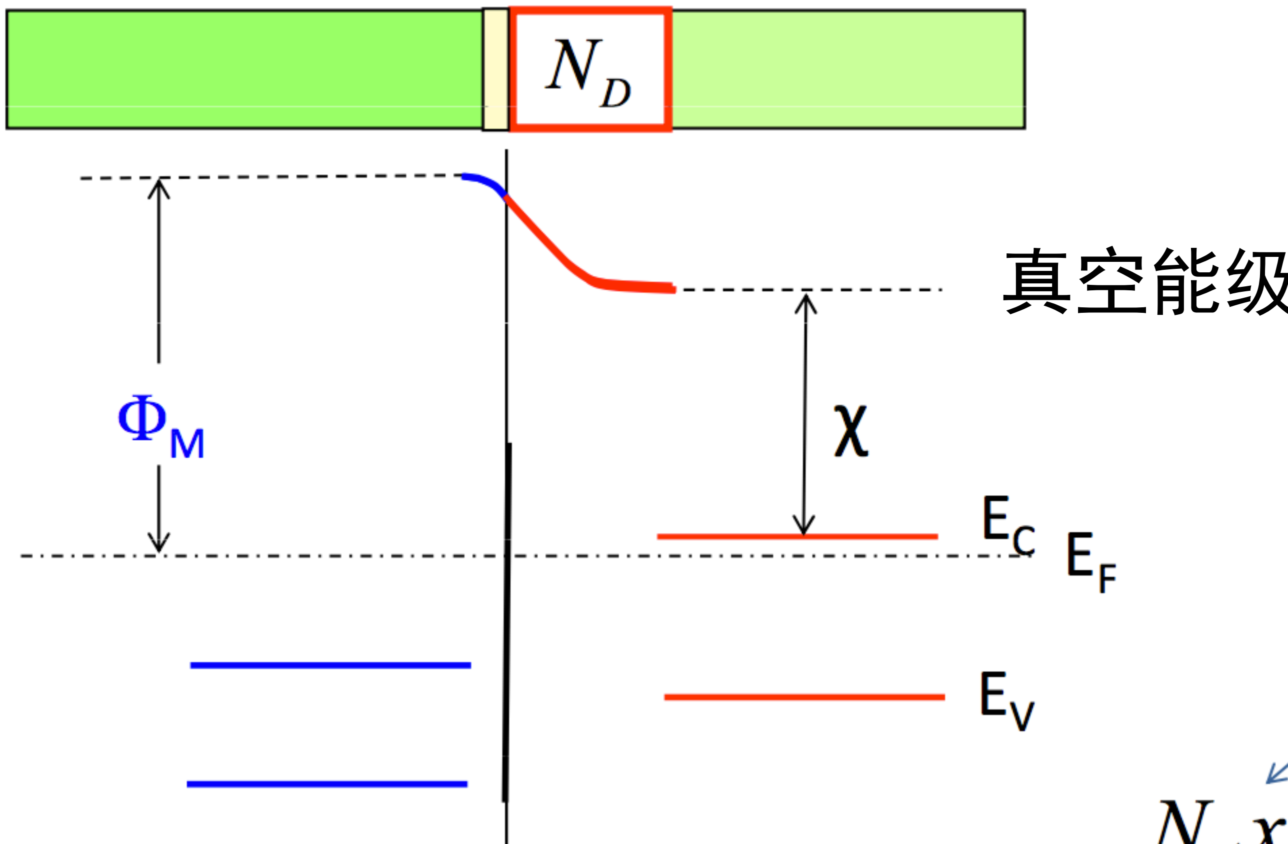
第一个晶体管

碳纳米管



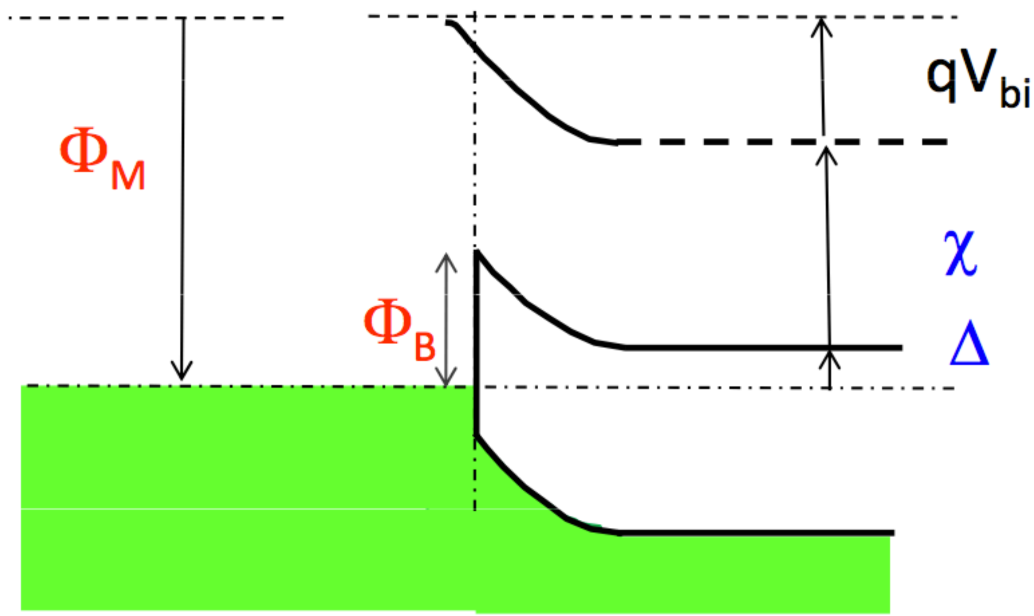


肖特基二极管的能带图



$$N_A x_p = N_D x_n$$

肖特基二极管的能带图



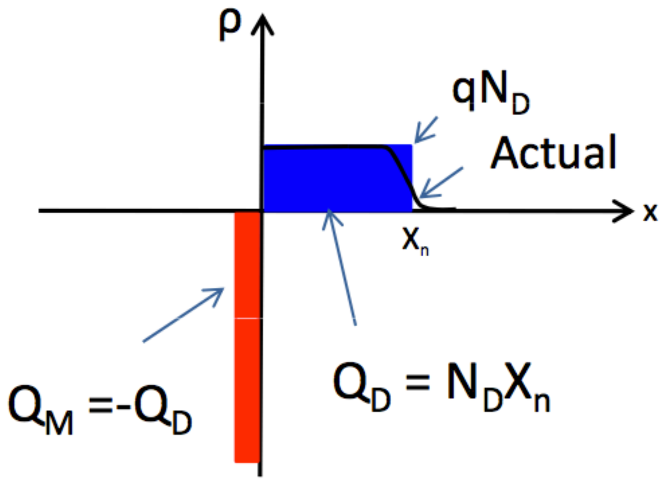
$$\Delta + \chi + qV_{bi} = \Phi_M$$

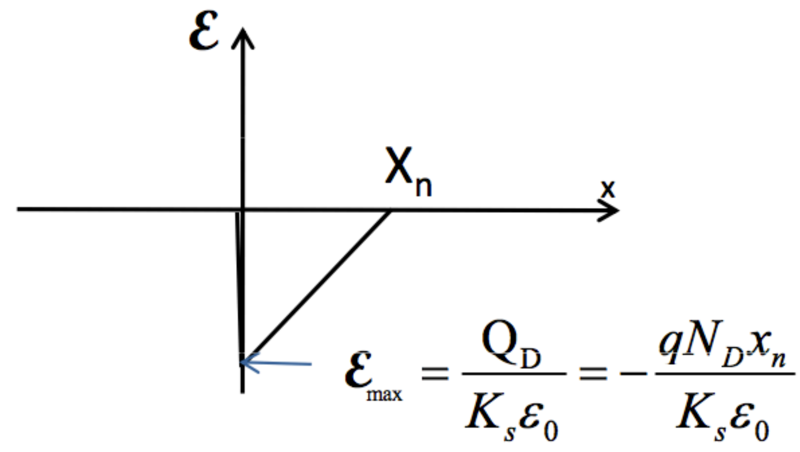
$$qV_{bi} = (\Phi_M - \chi) - \Delta \equiv \Phi_B - \Delta$$

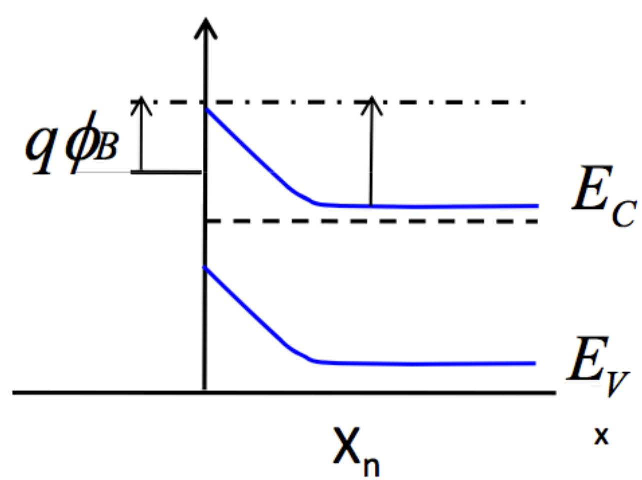
$$= \Phi_B - k_B T \ln \frac{N_D}{N_C}$$

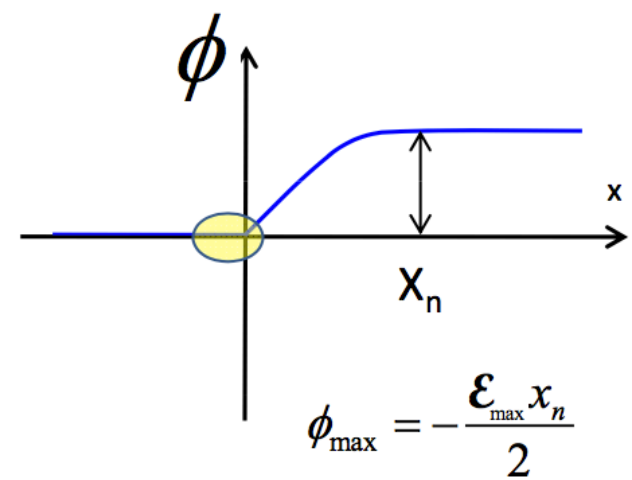
肖特基二极管的能带图

Depletion Approximation

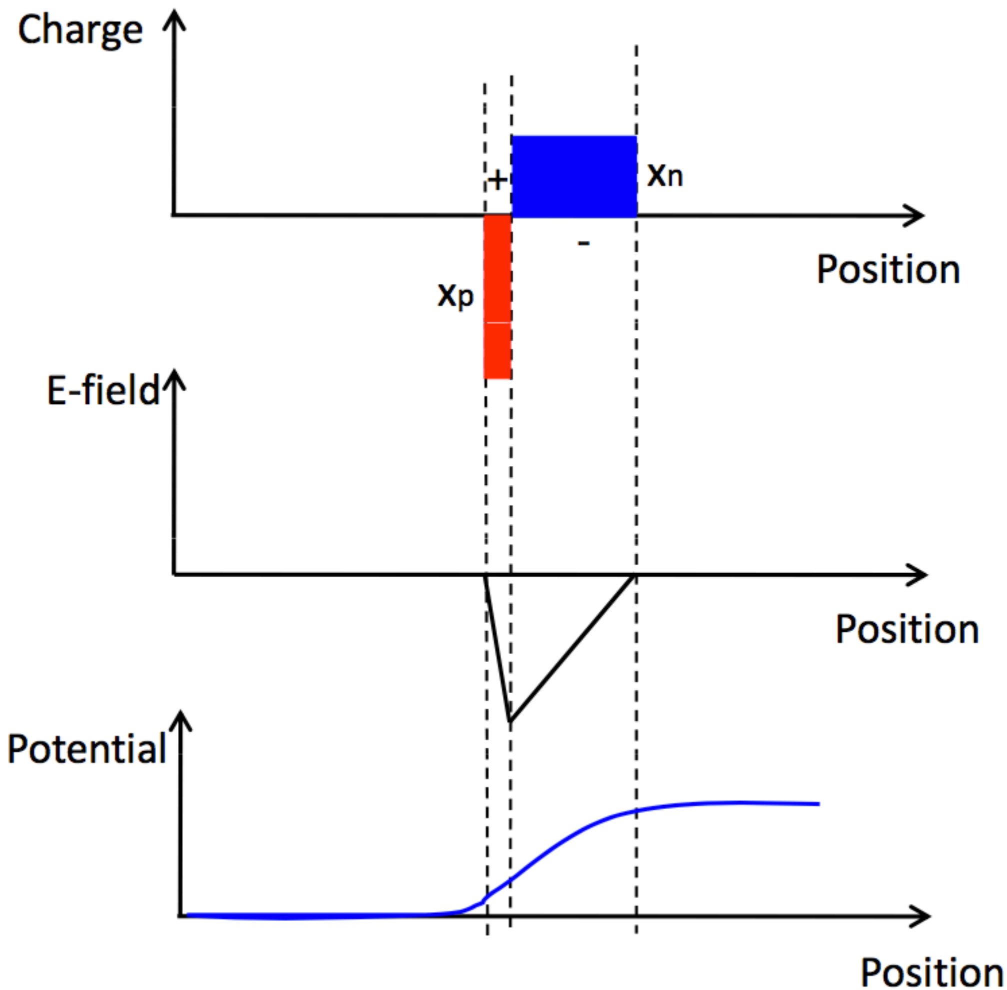








肖特基二极管的能带图



$$\mathcal{E}(0^{+}) = \frac{qN_D x_n}{k_s \varepsilon_0}$$

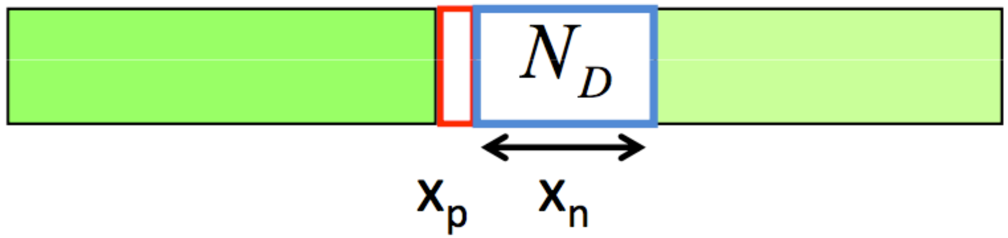
$$\mathcal{E}(0^{-}) = \frac{qN_M x_p}{k_s \varepsilon_0} \; ?$$

$$\Rightarrow N_D x_n = N_M x_p$$

$$qV_{bi} = \frac{\mathcal{E}(0^{-})x_n}{2} + \frac{\mathcal{E}(0^{+})x_p}{2}$$

$$= \frac{qN_D x_n^{\;2}}{2k_s\varepsilon_0} + \frac{qN_M x_p^{\;2}}{2k_s\varepsilon_0}$$

耗尽区



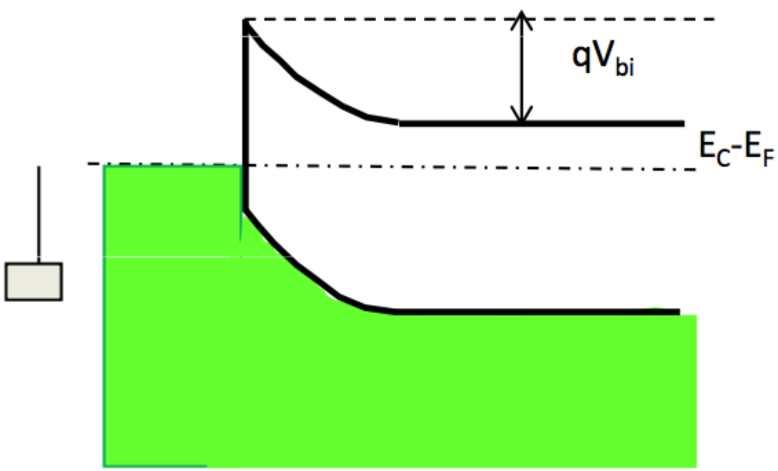
$$N_D x_n = N_M x_p$$

$$qV_{bi} = \frac{qN_D x_n^{\ 2}}{2k_s\varepsilon_0} + \frac{qN_M x_p^{\ 2}}{2k_s\varepsilon_0}$$

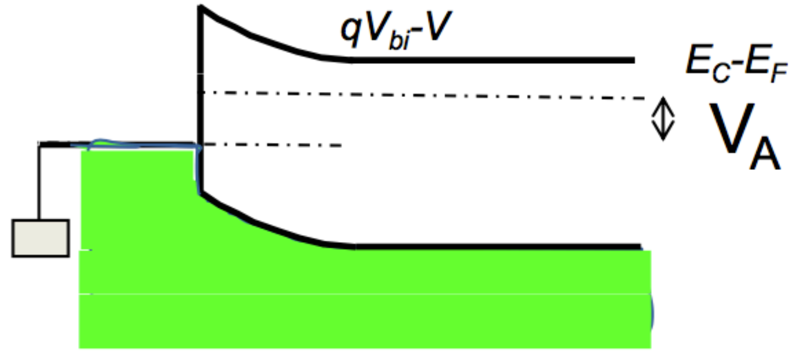
$$x_n = \sqrt{\frac{2k_s\varepsilon_0}{q}\frac{N_M}{N_D\left(N_M + N_D\right)}V_{bi}} \rightarrow \sqrt{\frac{2k_s\varepsilon_0}{q}\frac{1}{N_D}V_{bi}}$$

$$x_p = \sqrt{\frac{2k_s\varepsilon_0}{q}\frac{N_D}{N_M\left(N_M + N_D\right)}V_{bi}} \rightarrow 0$$

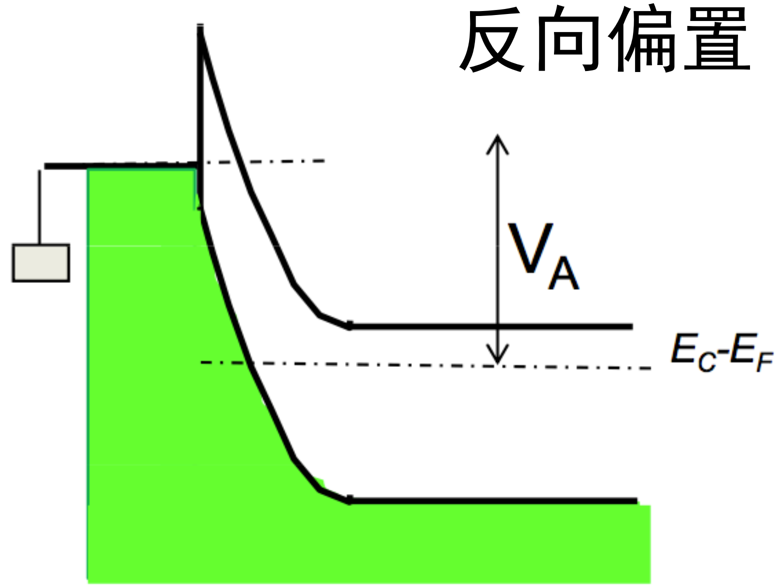
正向偏置与反向偏置



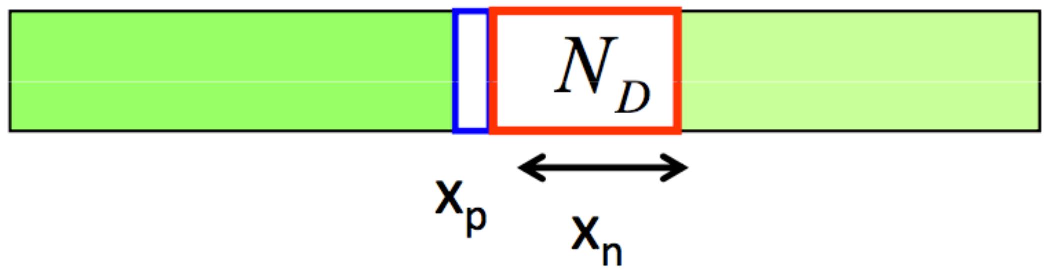
正向偏置



反向偏置



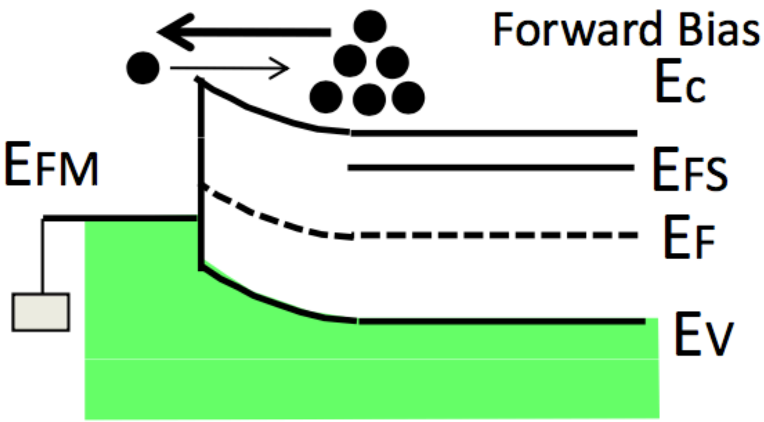
偏置下的耗尽区



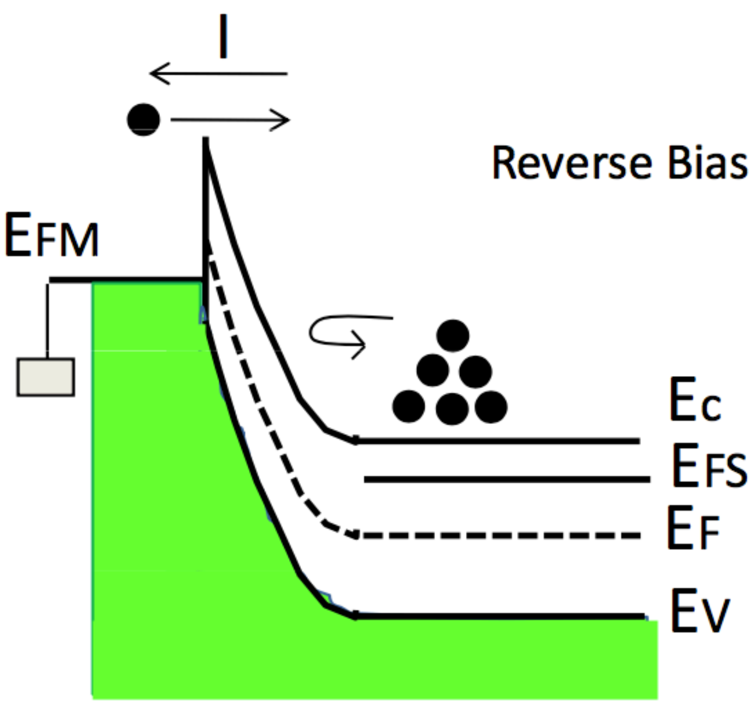
$$x_n = \sqrt{\frac{2k_s\varepsilon_0}{q}\frac{N_M}{N_D\left(N_M + N_D\right)}V_{bi}} \rightarrow \sqrt{\frac{2k_s\varepsilon_0}{q}\frac{1}{N_D}\left(V_{bi} - V_A\right)}$$

$$x_p = \sqrt{\frac{2k_s\varepsilon_0}{q}\frac{N_D}{N_M\left(N_M + N_D\right)}V_{bi}} \rightarrow 0$$

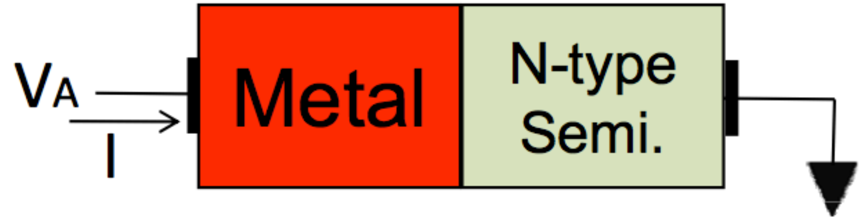
电流特性



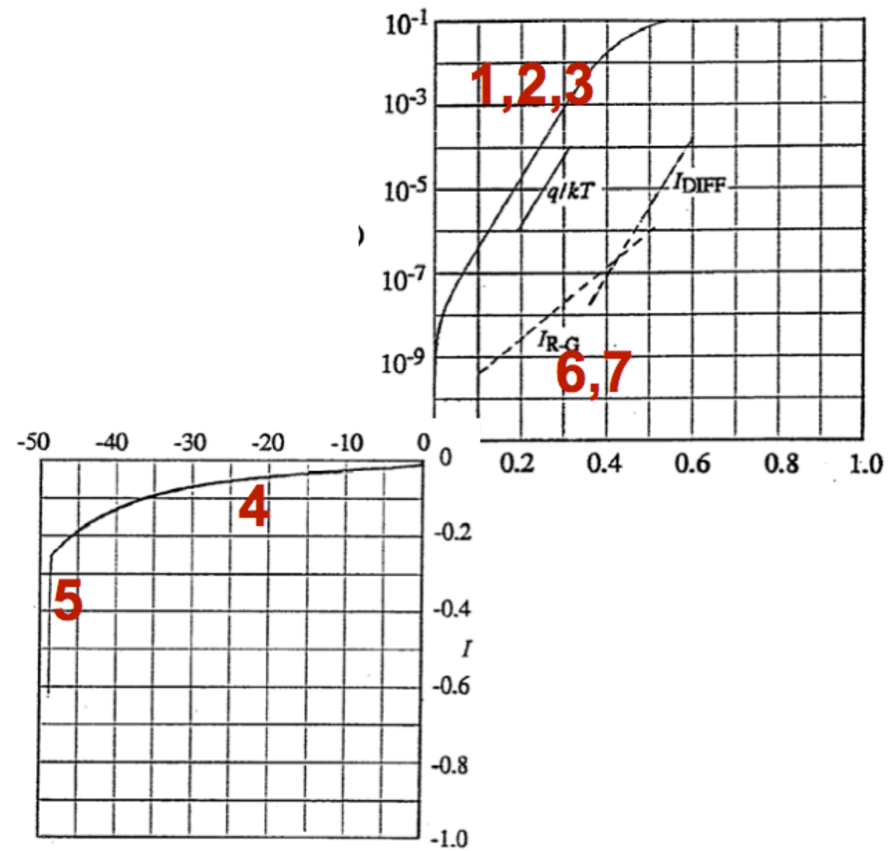
Forward Bias
Ec
EFM
EFS
EF
Ev



I
Reverse Bias
EFM
Ec
EFS
EF
Ev

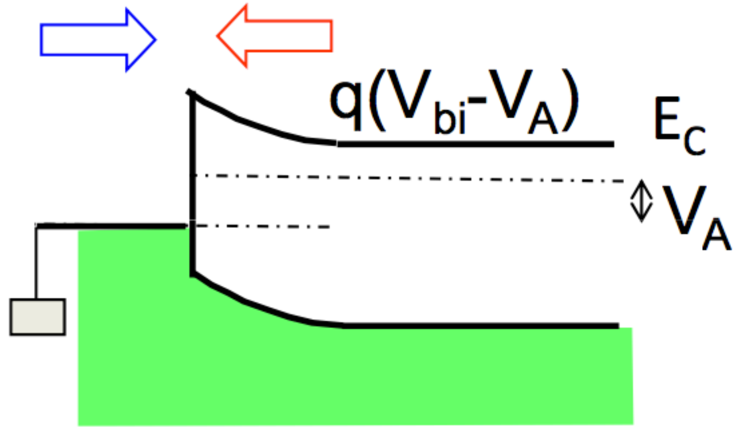


VA
I
Metal
N-type
Semi.



10-1
10-3
10-5
10-7
10-9
1,2,3
q/kT
IDIFF
IR-G
6,7
0
0.2
0.4
0.6
0.8
1.0
-50
-40
-30
-20
-10
0
4
5
-0.2
-0.4
I
-0.6
-0.8
-1.0

电流是如何流动的



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

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

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

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

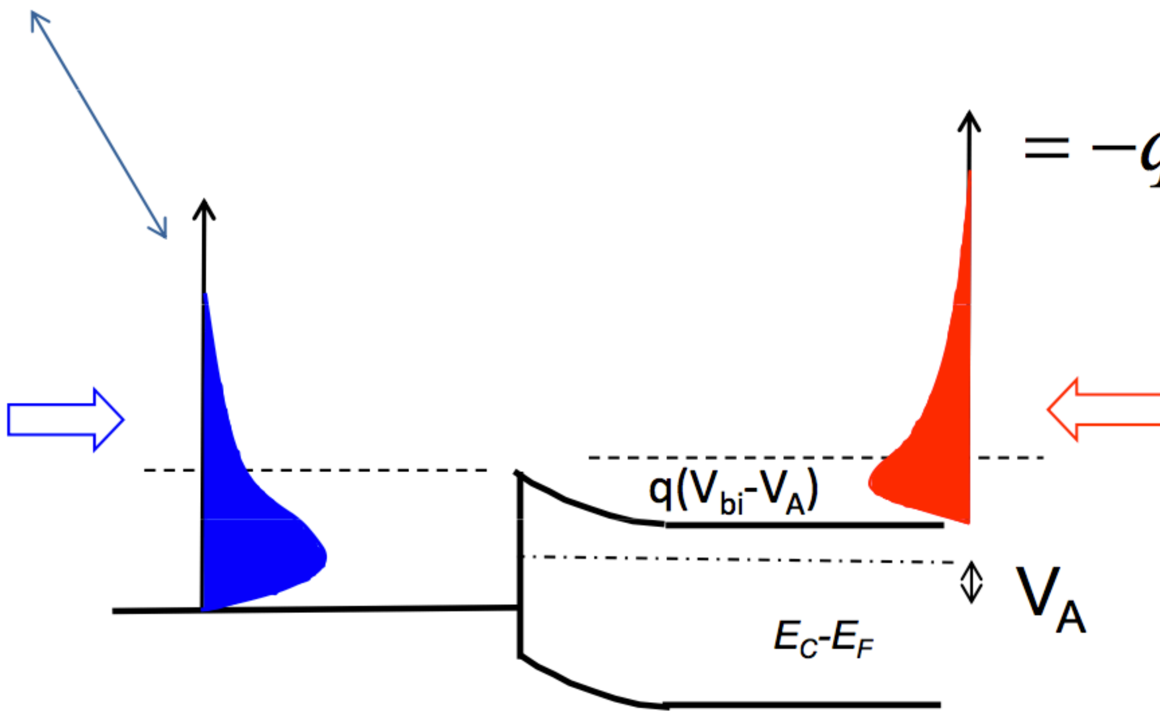
半导体到金属的电流

$$J_{m\to s}(V_A) = -q\frac{n_m}{2}e^{-\frac{q\Phi_B}{kT}}\upsilon_{th}$$

$$J_{s\to m}(V_A) = -q\frac{n_s}{2}e^{-q\frac{V_{bi}-V_A}{kT}}\upsilon_{th}$$

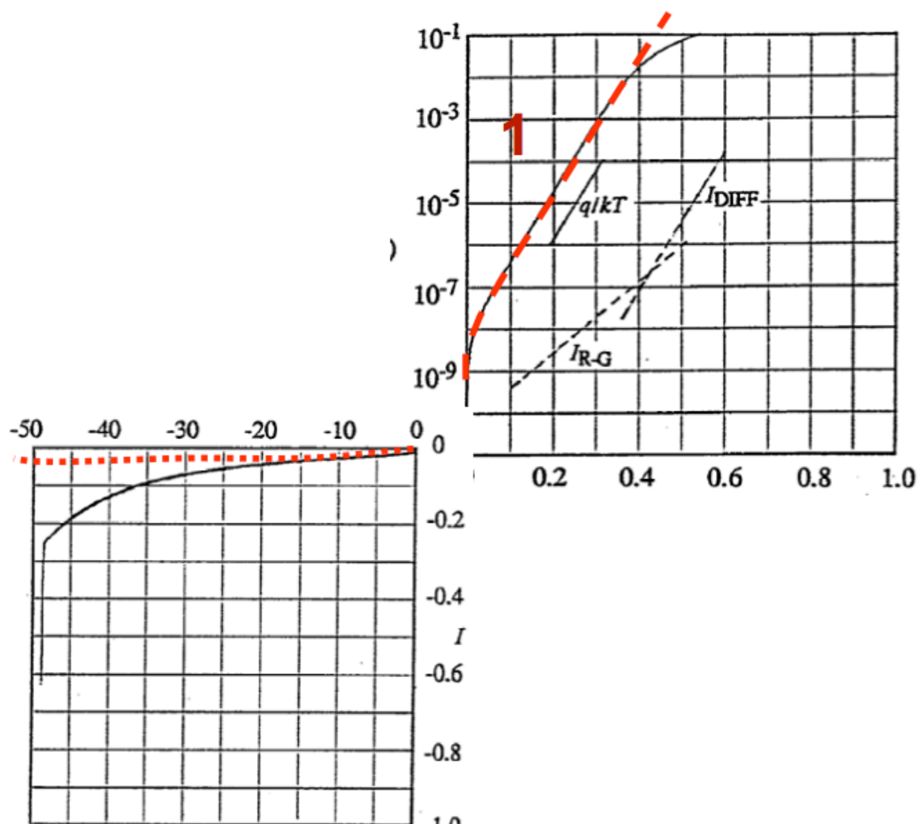
$$= -q\frac{n_s\upsilon_{th}}{2}e^{-\frac{qV_{bi}}{kT}}\times e^{\frac{qV_A}{kT}}$$

$$= -q\frac{n_m\upsilon_{th}}{2}e^{-\frac{q\Phi_B}{kT}}e^{\frac{qV_A}{kT}}$$

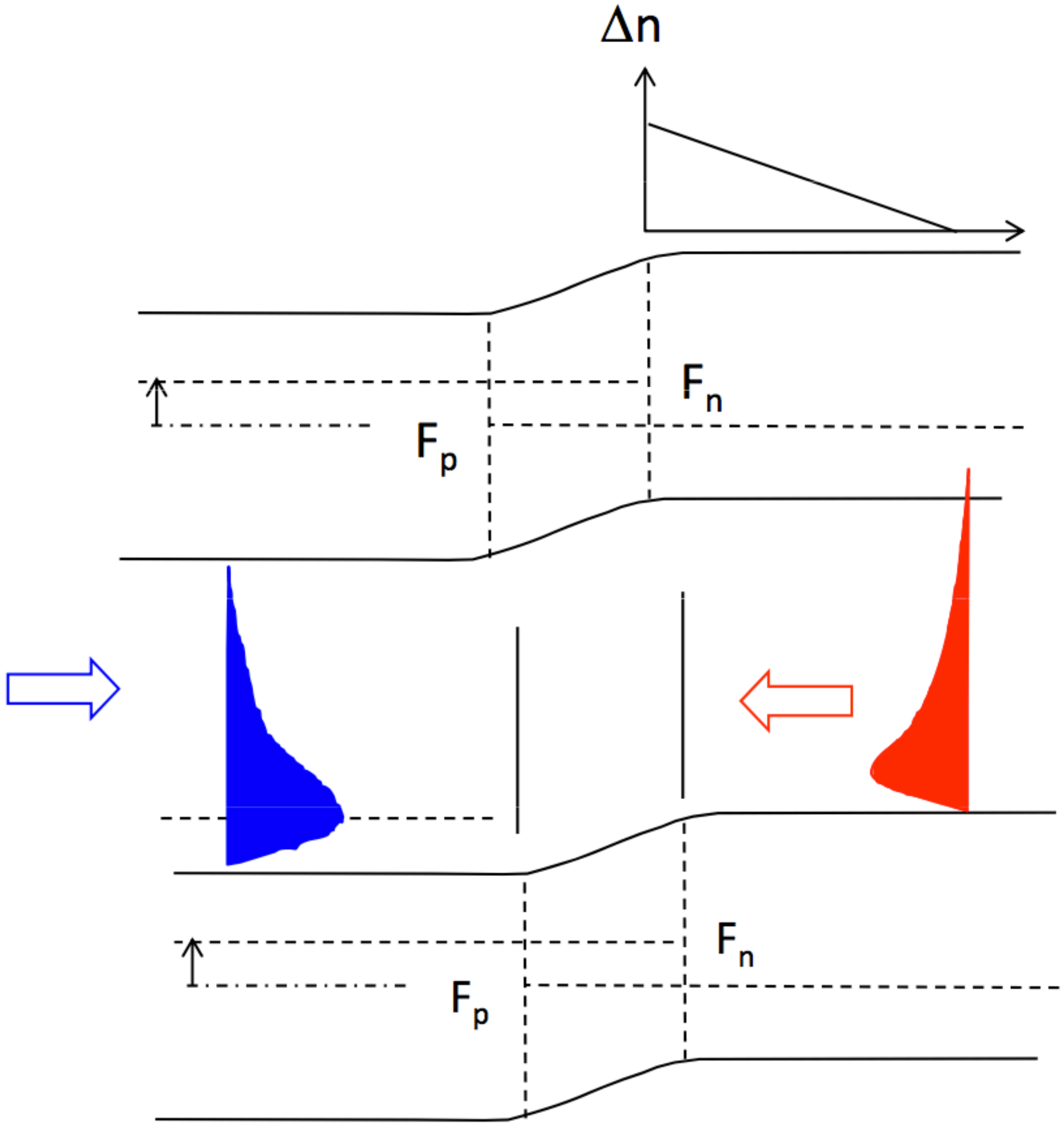


总电流

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

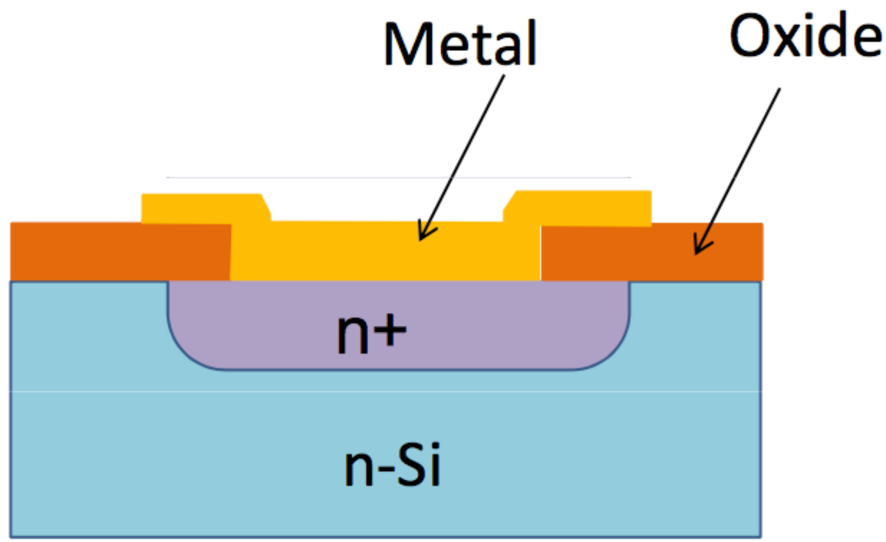


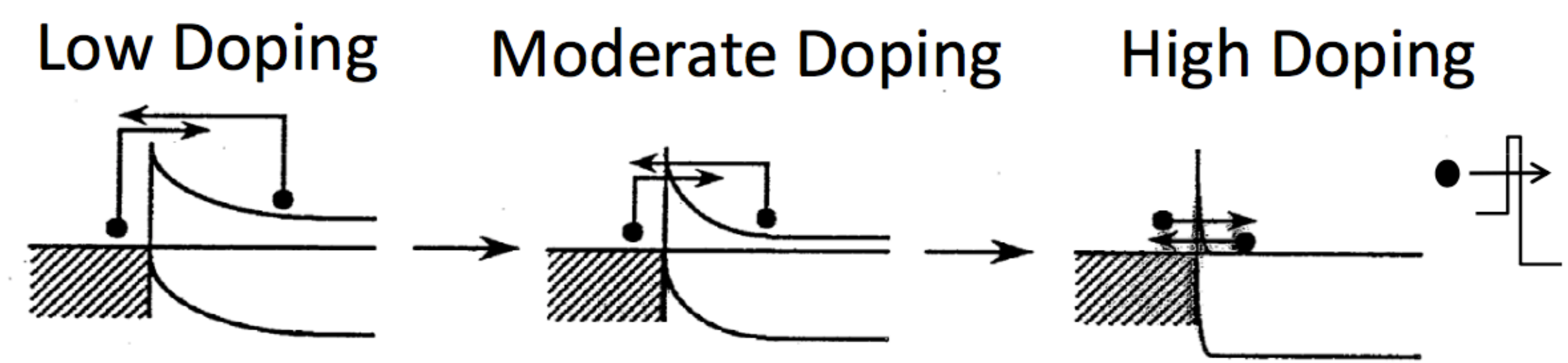
扩散电流 vs 热发射电流



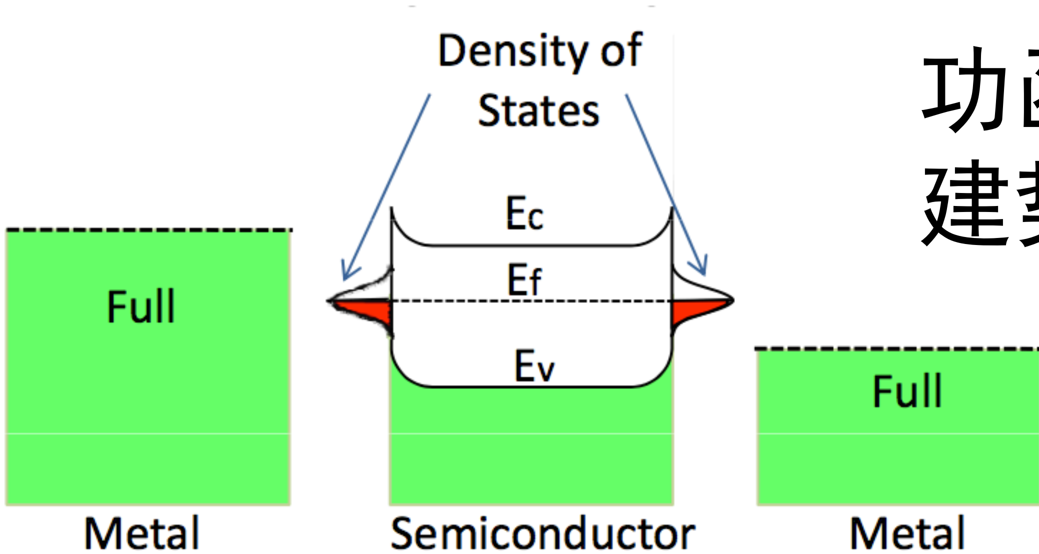
两者的电流特性非常相似

欧姆接触与肖特基接触

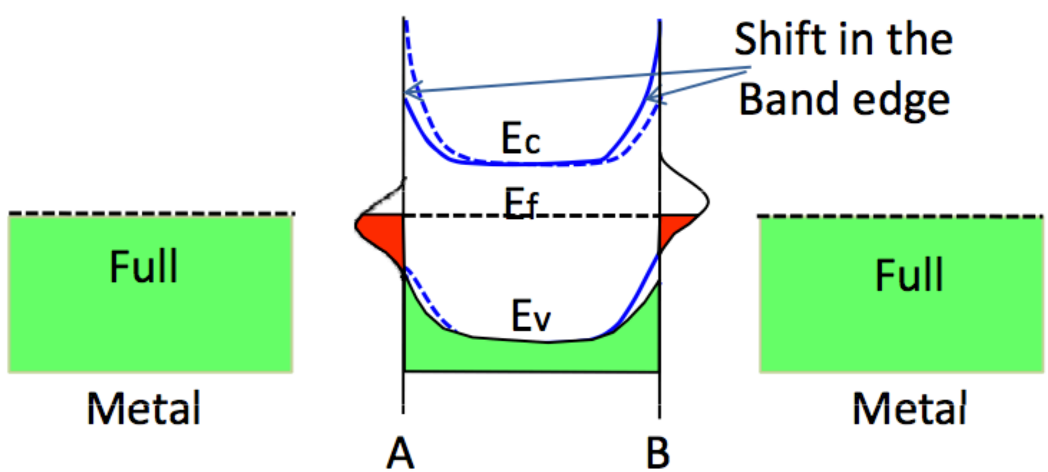




费米钉扎效应



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