半导体器件物理

The Physics of Semiconductor Devices

西安电子科技大学　微电子学院

Microelectronics Institute,

Xidian University

Ch4 power characteristics of BJT

- Resistance in series of base ⇨
- **emitter current crowding**
- **Breakdown and the epi**
- **SOA**

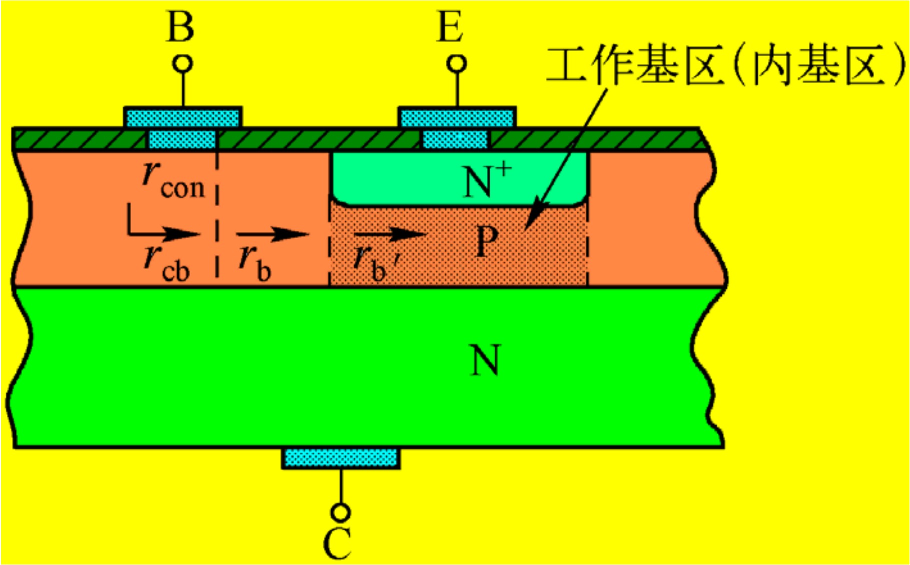
contruction

influence

calculation

design

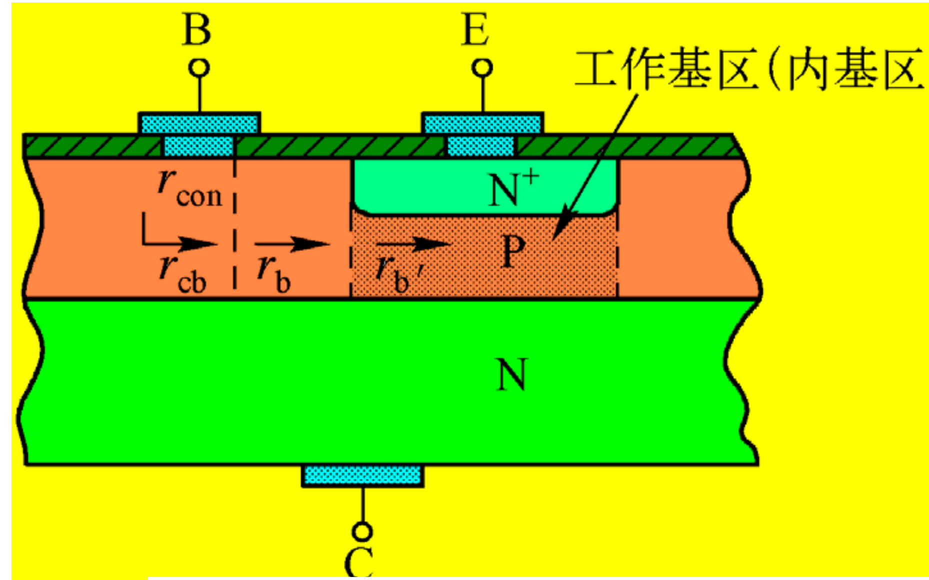
1、 contruction

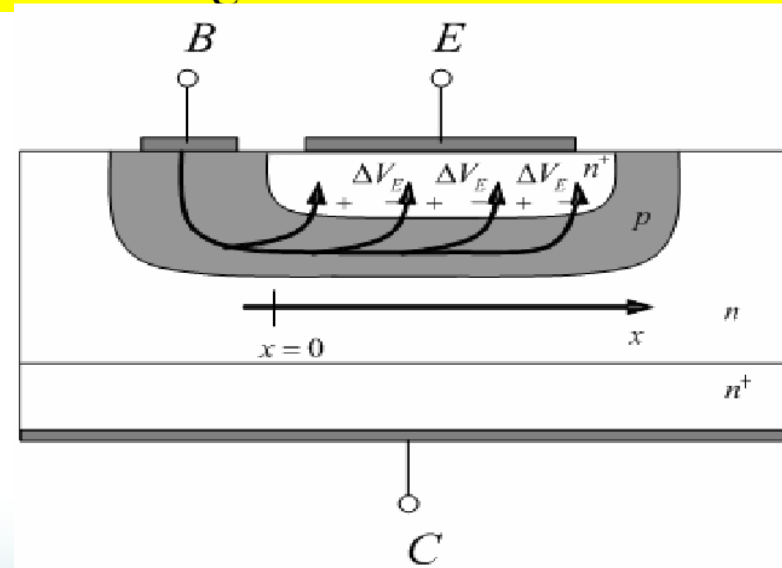


Large area bipolar transistors can have a very non-uniform current distribution due to the resistance of the base layer. Since the base current is applied through the thin base layer, there can be a significant series resistance in large devices.

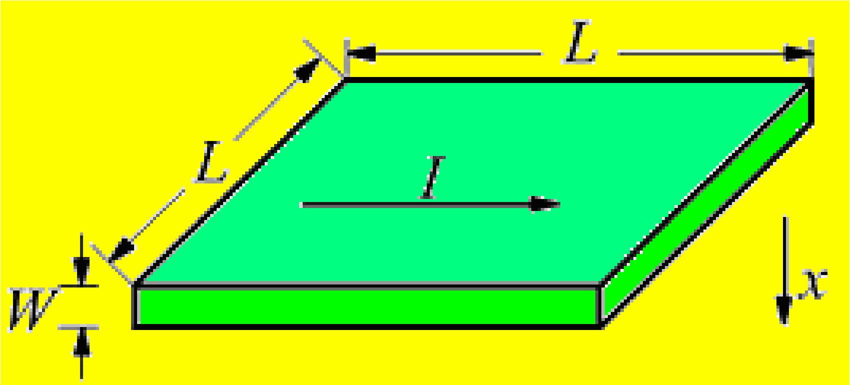
2、Influence

The base resistance causes a voltage variation across the base region. This voltage variation then causes a variation of the emitter current density, especially since the emitter current density depends exponentially on the local base-emitter voltage. This effect is minimal in the center of the emitter-base diode and strongly increases toward the edges.





3、Calculation



For semiconductor with uniform doping，

$$R_{\square} = \rho \frac{L}{LW} = \frac{\rho}{W} = \frac{1}{\sigma W} = \frac{1}{q\mu N W}$$

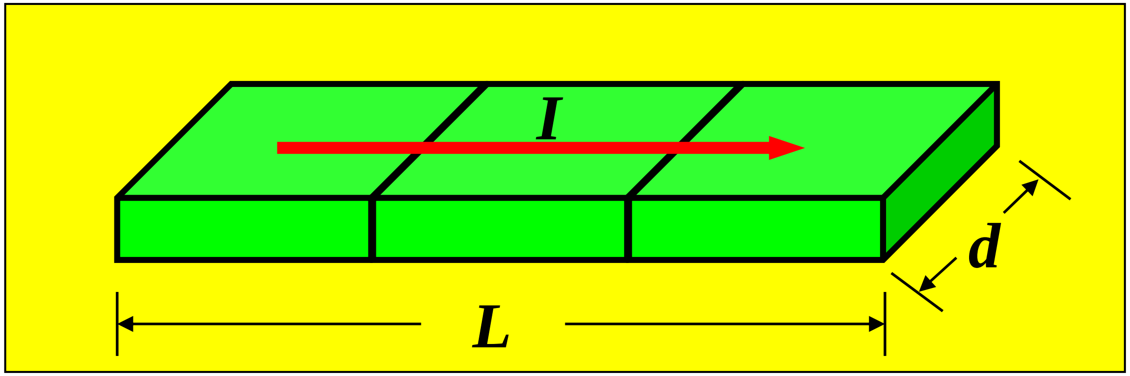
For semiconductor with uneven doping，

$$R_{\square} = \frac{1}{\int_0^W \sigma \, \mathrm{d}x} = \frac{1}{q\mu \int_0^W N \, \mathrm{d}x}$$

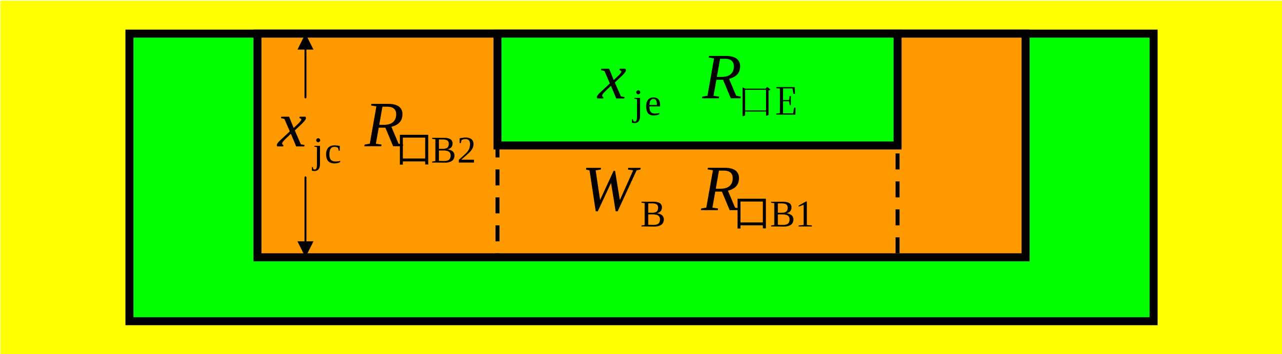
3、Calculation

Total resistance:

$$R = \rho \frac{L}{Wd} = \frac{L}{d} R_{\square} = (\text{方块个数}) \times R_{\square}$$



3、Calculation



发射区：

$$R_{□E} = \frac{1}{q\mu_n \int_0^{x_{je}} N_E \, dx}$$

工作基区：指正对着发射区下方的在 $W_B = x_{jc} - x_{je}$ 范围内的基区，也称为 有源基区 或 内基区 。

$$R_{□B1} = \frac{1}{q\mu_p \int_{x_{je}}^{x_{jc}} N_B \, dx}, \quad 或 \quad R_{□B1} = \frac{1}{q\mu_p \int_0^{W_B} N_B \, dx}$$

非工作基区：指在发射区下方以外从表面到 x_{jc} 处的基区，也称为 无源基区 或 外基区 。

$$R_{□B2} = \frac{1}{q\mu_p \int_0^{x_{jc}} N_B \, dx}$$

3、Calculation

（2）、r_{con} and r_b

$$r_{\text{con}} = \frac{C_{\Omega}}{A}$$

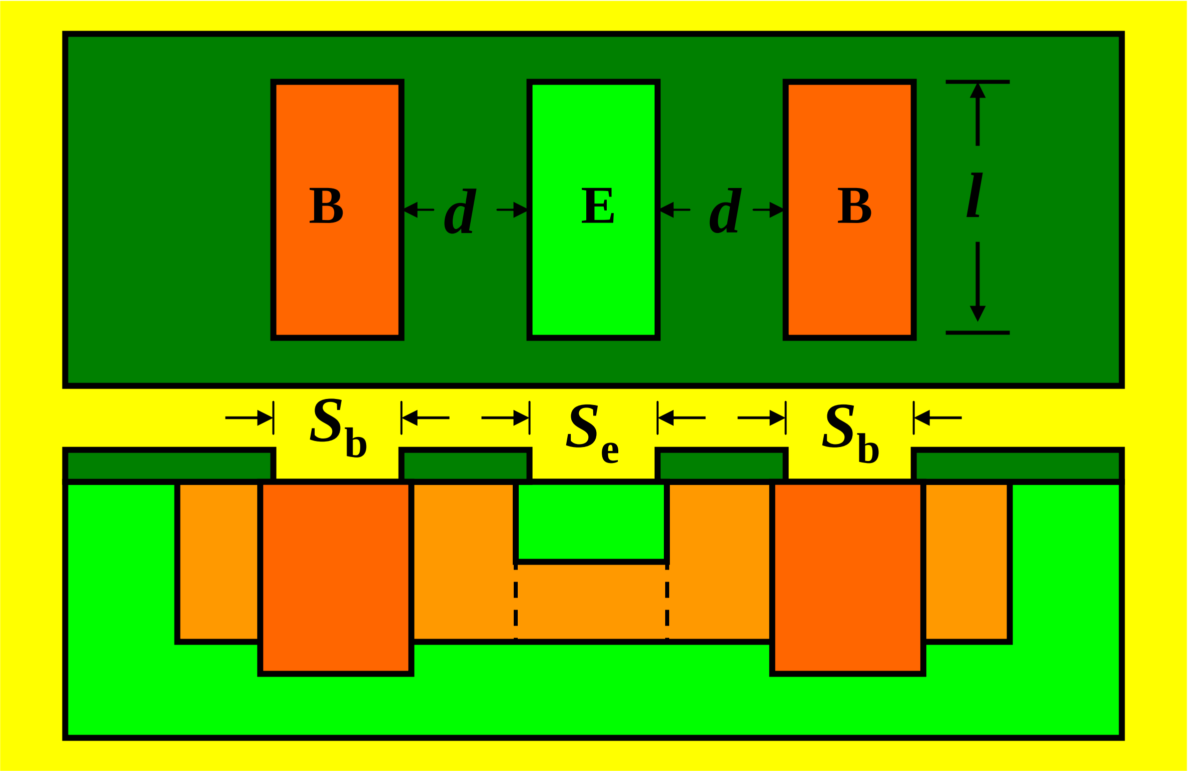
$$r_{\text{b}} = \frac{\text{长}}{\text{宽}} \times R_{\square \text{B2}}$$

3、Calculation

double finger r_{con} and r_b

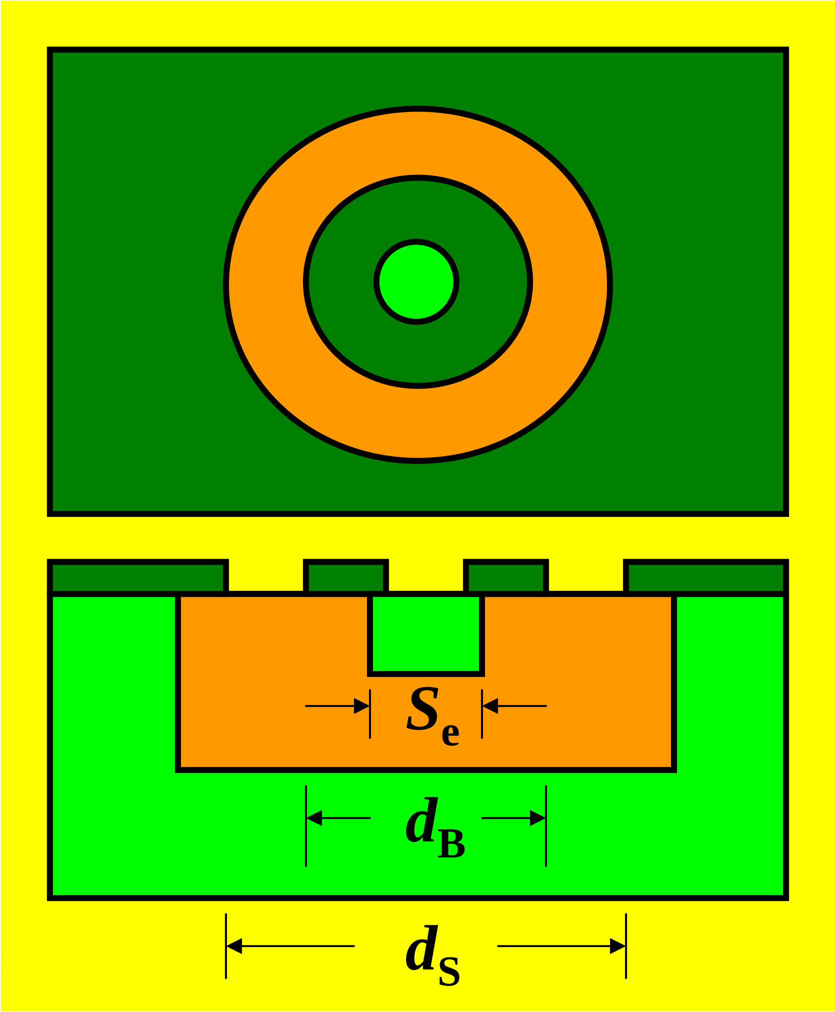
$$r_{con} = \frac{C_{\Omega}}{2lS_b}$$

$$r_b = \frac{d}{2l} R_{\square B2}$$



3、Calculation

for circle base



$$r_{con} = \frac{4C_{\Omega}}{\pi(d_S^2 - d_B^2)}$$

dr 段上的电阻为

$$\frac{dr}{2\pi r} R_{\square B2},$$

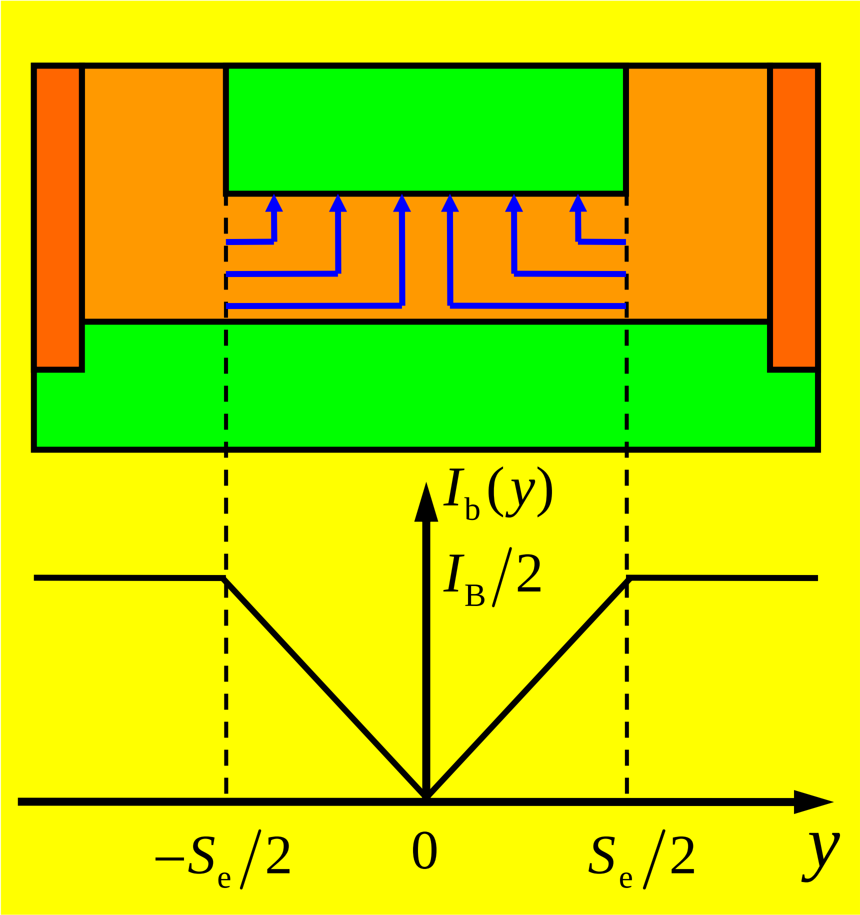
$$r_b = \int_{\frac{S_e}{2}}^{\frac{d_B}{2}} \frac{R_{\square B2}}{2\pi r} dr$$

$$= \frac{R_{\square B2}}{2\pi} \ln \frac{d_B}{S_e}$$

3、Calculation

3、$r_{b'}$与r_{cb}

for double finger



$$I_b(y)=\frac{I_B}{S_e}y\ ,$$

$$\frac{dy}{l}R_{\square B1}\ ,$$

$$I_b^2(y)\frac{dy}{l}R_{\square B1}=(\frac{I_B}{S_e})^2y^2\frac{R_{\square B1}}{l}dy$$

3、Calculation

$$P_{b'} = 2\int_0^{\frac{S_e}{2}} \left(\frac{I_B}{S_e}\right)^2 y^2 \frac{R_{\square B1}}{l} dy = I_B^2 \frac{S_e}{12l} R_{\square B1}$$

$$P_{b'} = I_B^2 \frac{S_e}{12l} R_{\square B1}$$

If

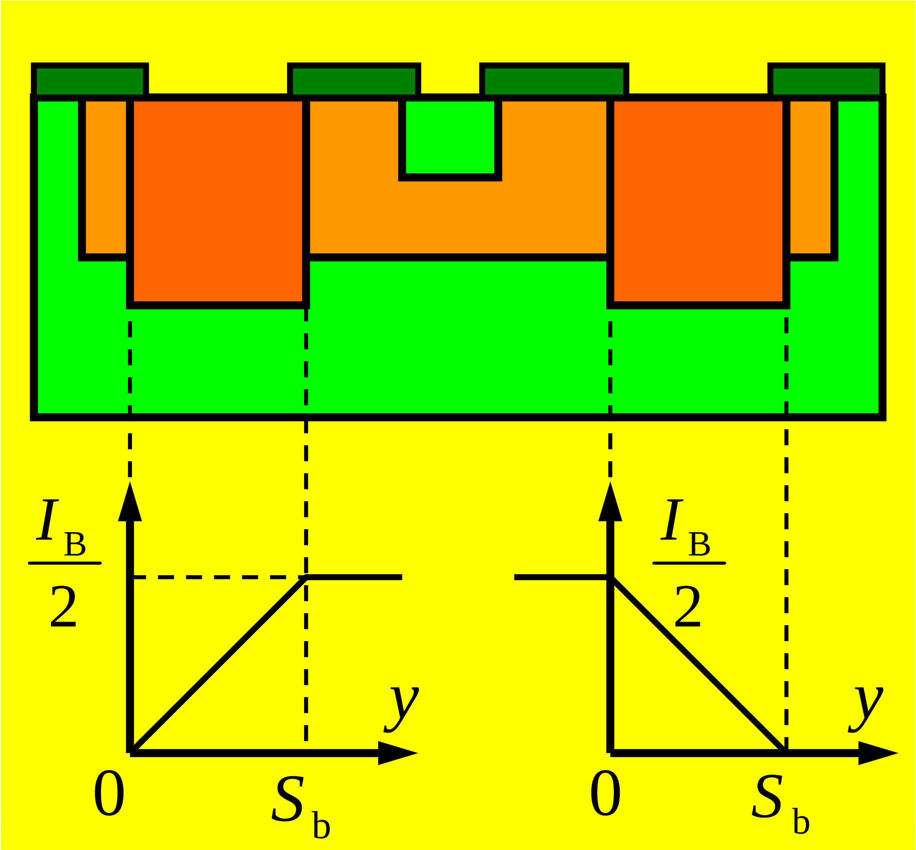
$$I_B^2 r_{b'} = I_B^2 \frac{S_e}{12l} R_{\square B1}$$

then

$$r_{b'} = \frac{S_e}{12l} R_{\square B1}$$

3、Calculation

double finger



$$I_b(y) = \frac{I_B}{2S_b} y,$$

$$P_{cb} = 2\int_0^{S_b} \left(\frac{I_B}{2S_b}\right)^2 y^2 \frac{R_{\square B3}}{l} dy$$

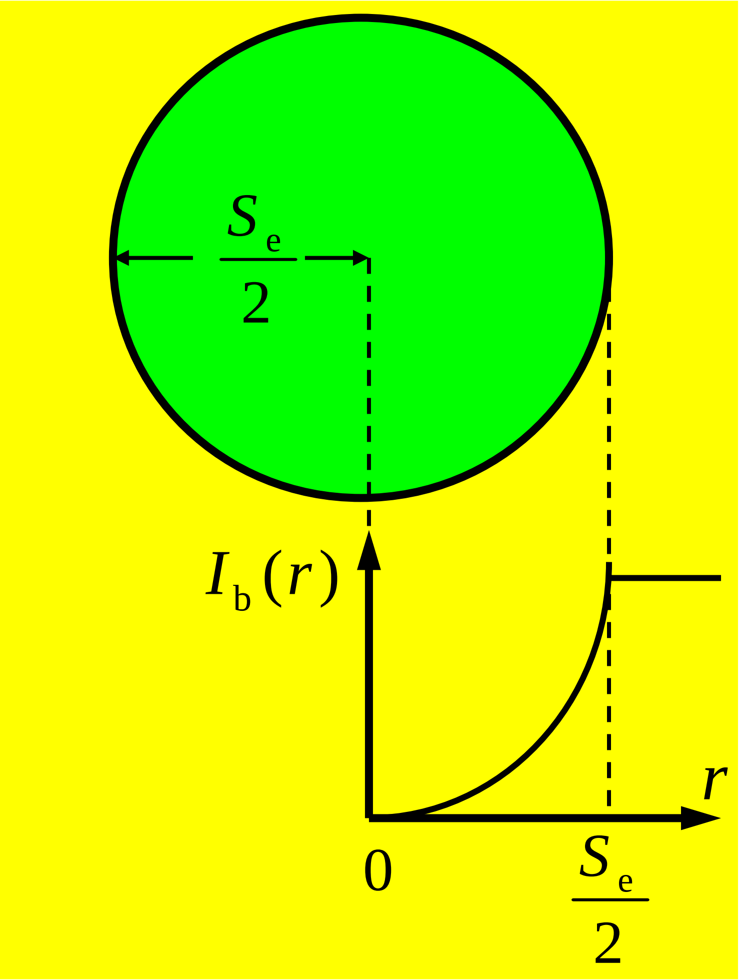
$$= I_B^2 \frac{S_b}{6l} R_{\square B3}$$

$$= I_B^2 r_{cb},$$

$$r_{cb} = \frac{S_b}{6l} R_{\square B3}$$

3、Calculation

for circle base



$$I_b(r) = \frac{4I_B}{S_e^2} r^2,$$

dr 段上的电阻为 $\frac{dr}{2\pi r} R_{\square B1}$,

$$P_{b'} = \int_0^{\frac{S_e}{2}} \left(\frac{4I_B}{S_e^2} r^2\right)^2 \frac{R_{\square B1}}{2\pi r} dr$$

$$= \frac{I_B^2}{8\pi} R_{\square B1}$$

$$= I_B^2 r_{b'},$$

$$r_{b'} = \frac{1}{8\pi} R_{\square B1}$$

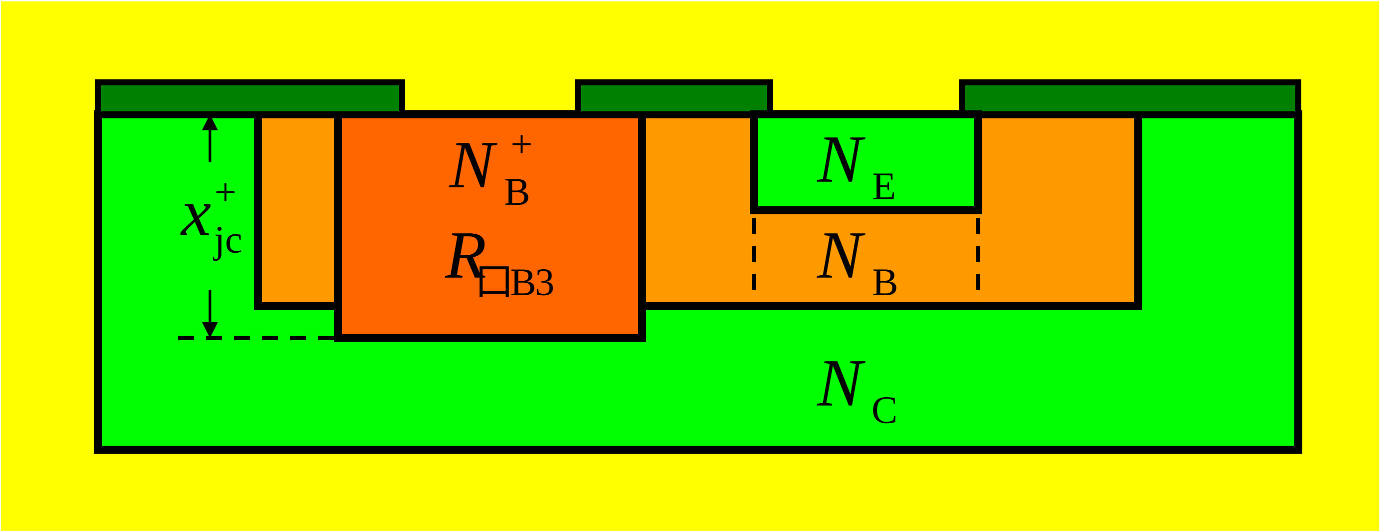
三、基极电阻的计算

$$r_{bb'} = r_{con} + r_{cb} + r_{b} + r_{b'}$$

bouble finger： $r_{bb'} = \frac{C_{\Omega}}{2lS_{b}} + \frac{S_{b}}{6l} R_{\square B3} + \frac{d}{2l} R_{\square B2} + \frac{S_{e}}{12l} R_{\square B1}$

Circle finger： $r_{bb'} = \frac{4C_{\Omega}}{\pi(d_{S}^{2} - d_{B}^{2})} + \frac{1}{2\pi} \ln \frac{d_{B}}{S_{e}} R_{\square B2} + \frac{1}{8\pi} R_{\square B1}$

4、Design



小结

•指出了BJT存在基极电阻并分析了基极电阻的组成特点。

•给出了基极电阻的求解方法和相关参数

•分析了减小基极电阻和克服电流集边效应的措施。

Thanks!