

半导体器件物理


The Physics of Semiconductor Devices

(18)

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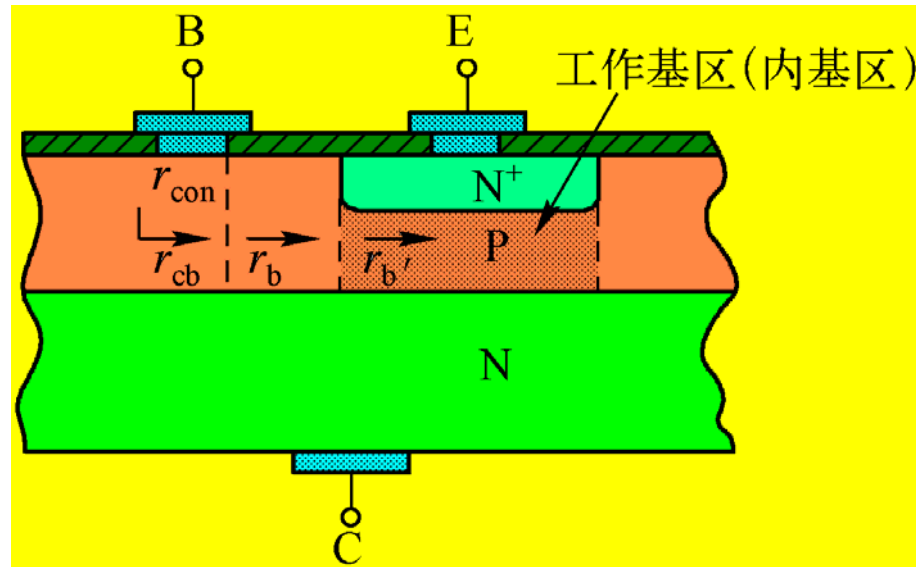
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Ch4 power characteristics of BJT

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

contruction
influence
calculation
design

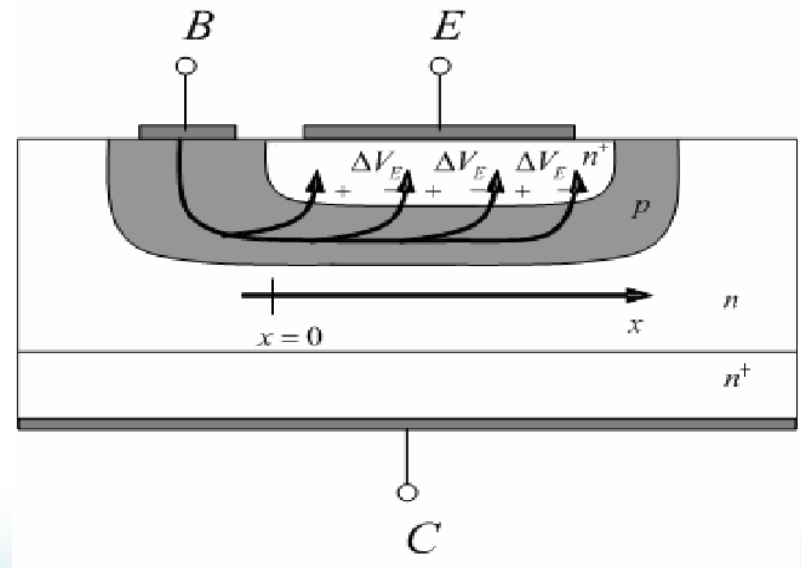
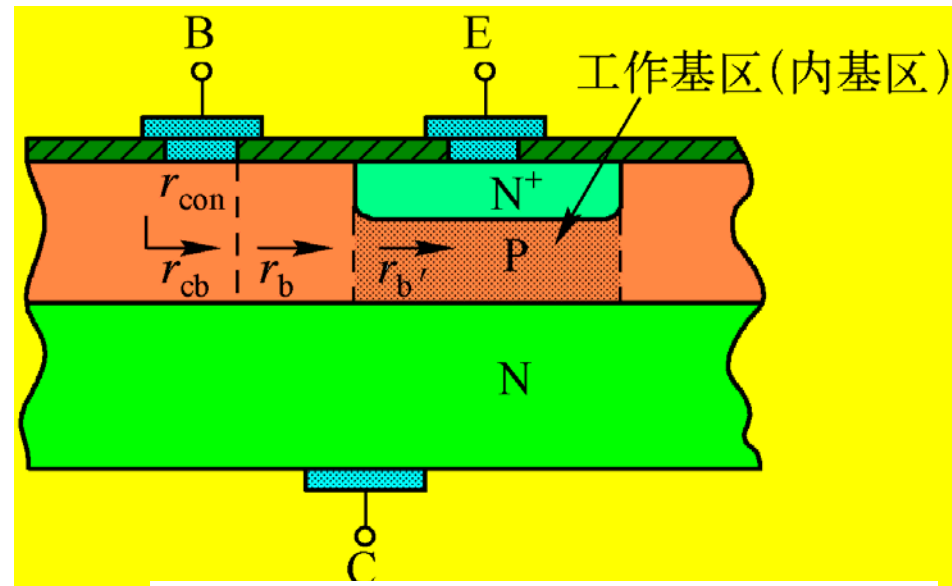
1、contruction



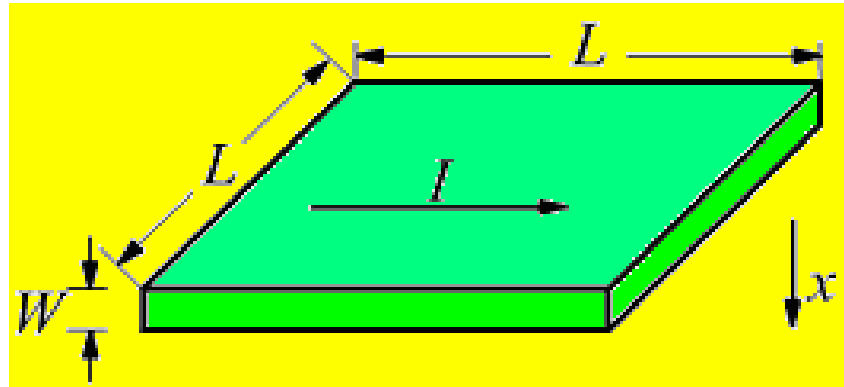
Large area bipolar transistors can have a very non-uniform current distribution due to the resistance of the base layer. Since the base current is applied through the thin base layer, there can be a significant series resistance in large devices.

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,

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

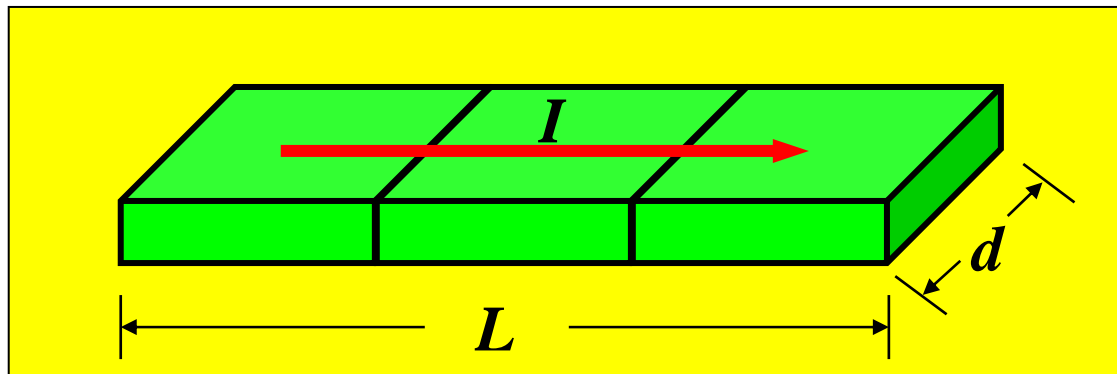
For semiconductor with uneven doping ,

$$R_{\square} = \frac{1}{\int_0^W \sigma dx} = \frac{1}{q\mu \int_0^W N dx}$$

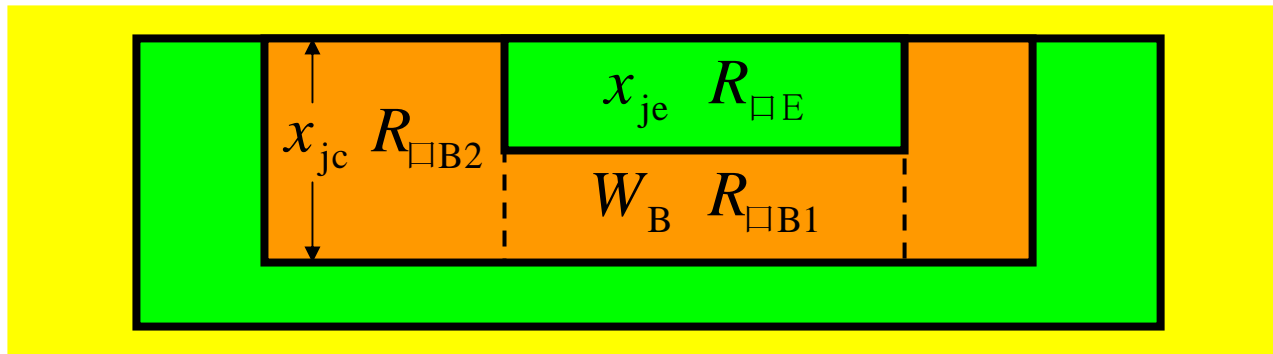
3、Calculation

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

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。

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

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。

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

3、 Calculation

(2) 、 r_{con} and r_b

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

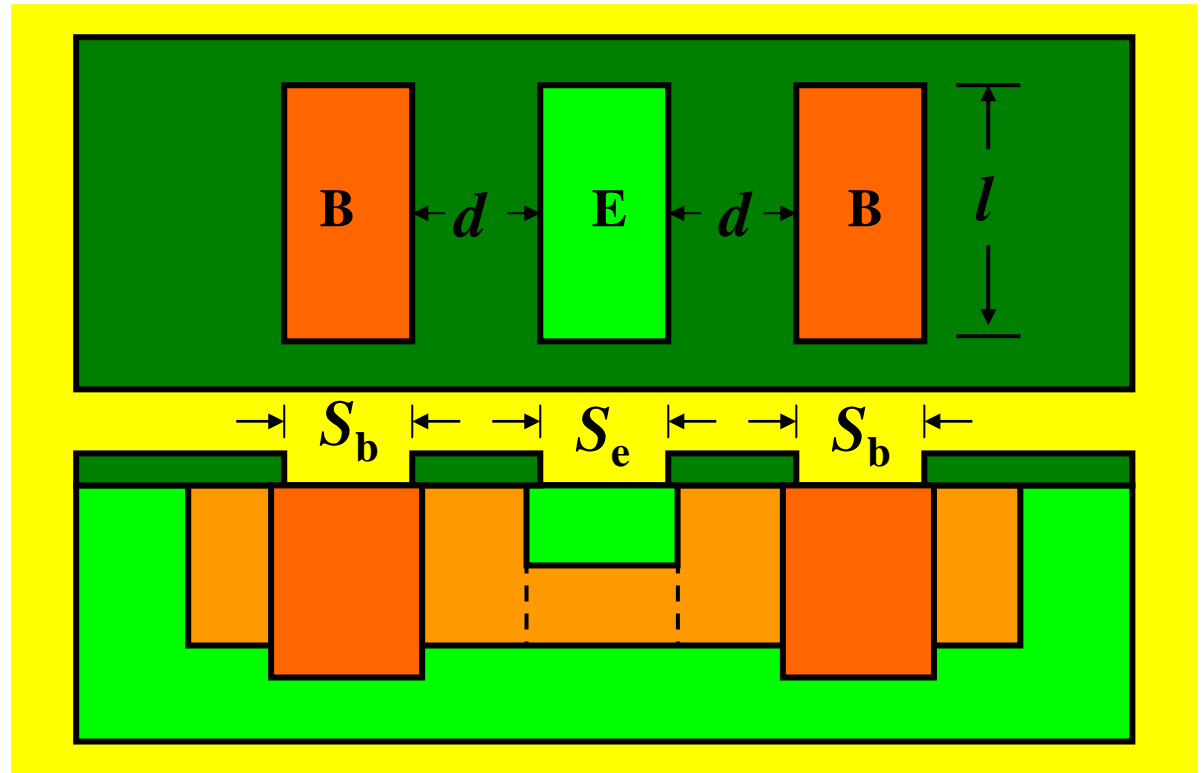
$$r_b = \frac{\text{长}}{\text{宽}} \times R_{\square B2}$$

3、 Calculation

double finger r_{con} and r_b

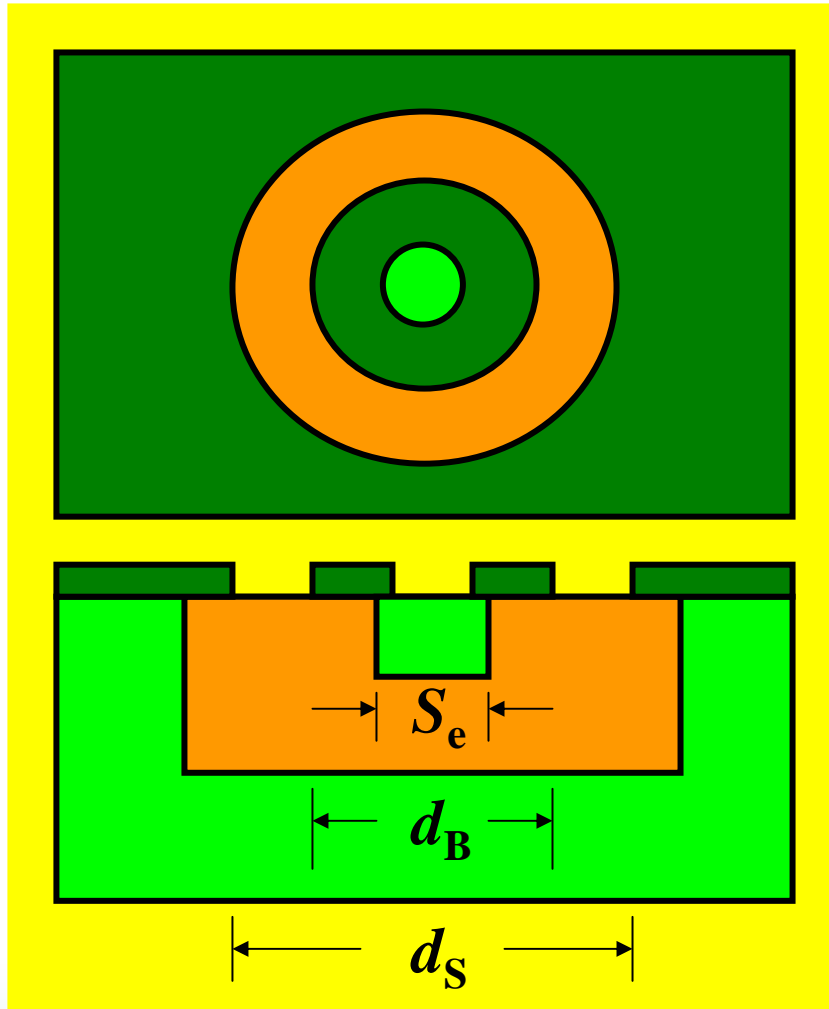
$$r_{\text{con}} = \frac{C_{\Omega}}{2lS_b}$$

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



3、 Calculation

for circle base



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

dr 段上的电阻为

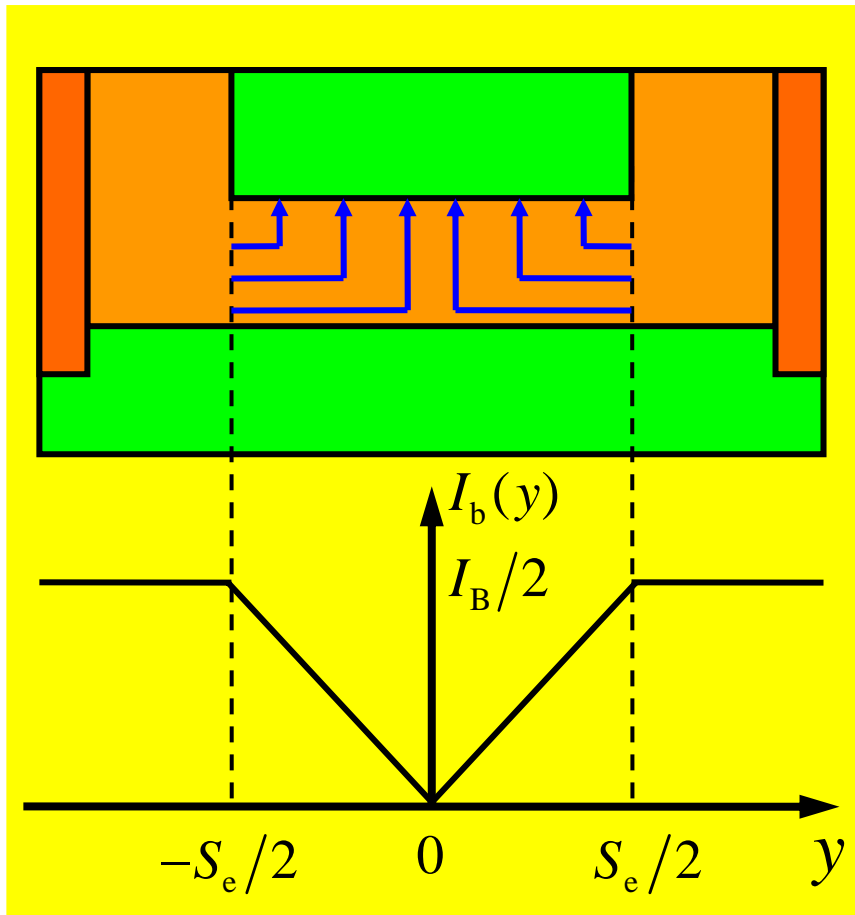
$$\frac{dr}{2\pi r} R_{\square B2},$$

$$\begin{aligned} r_b &= \int_{\frac{S_e}{2}}^{\frac{d_B}{2}} \frac{R_{\square B2}}{2\pi r} dr \\ &= \frac{R_{\square B2}}{2\pi} \ln \frac{d_B}{S_e} \end{aligned}$$

3、 Calculation

3、 r_b 与 r_{cb}

for double finger



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

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

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

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

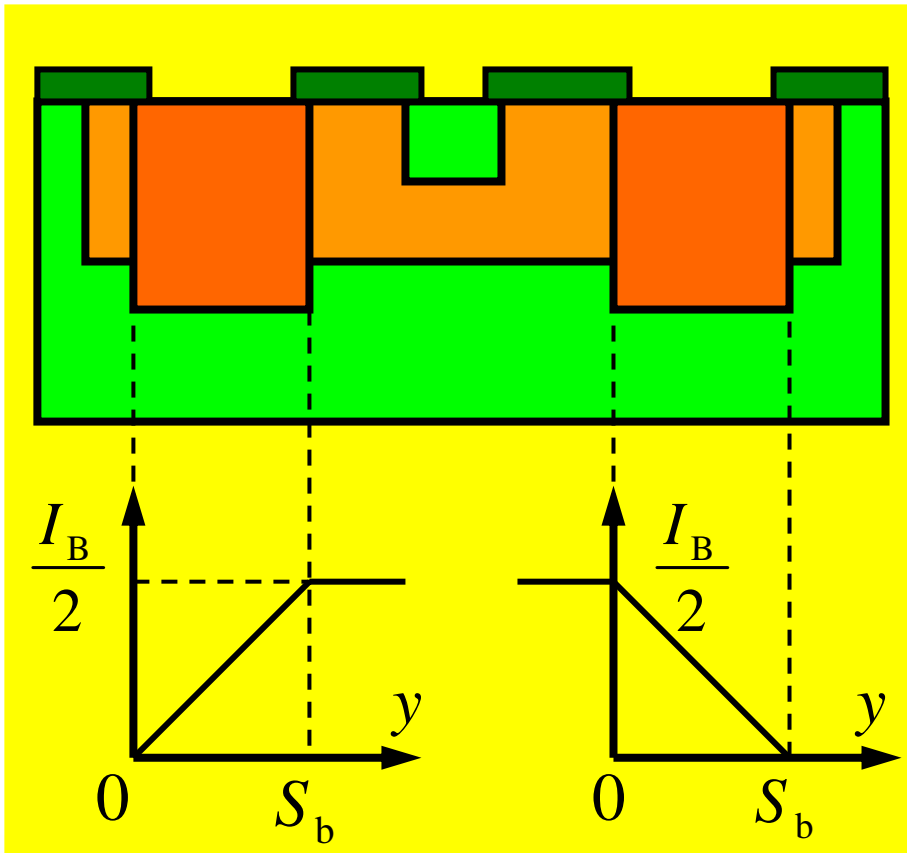
$$I_B^2 r_{b'} = I_B^2 \frac{S_e}{12l} R_{\square B1}$$

then

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

3、 Calculation

double finger



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

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

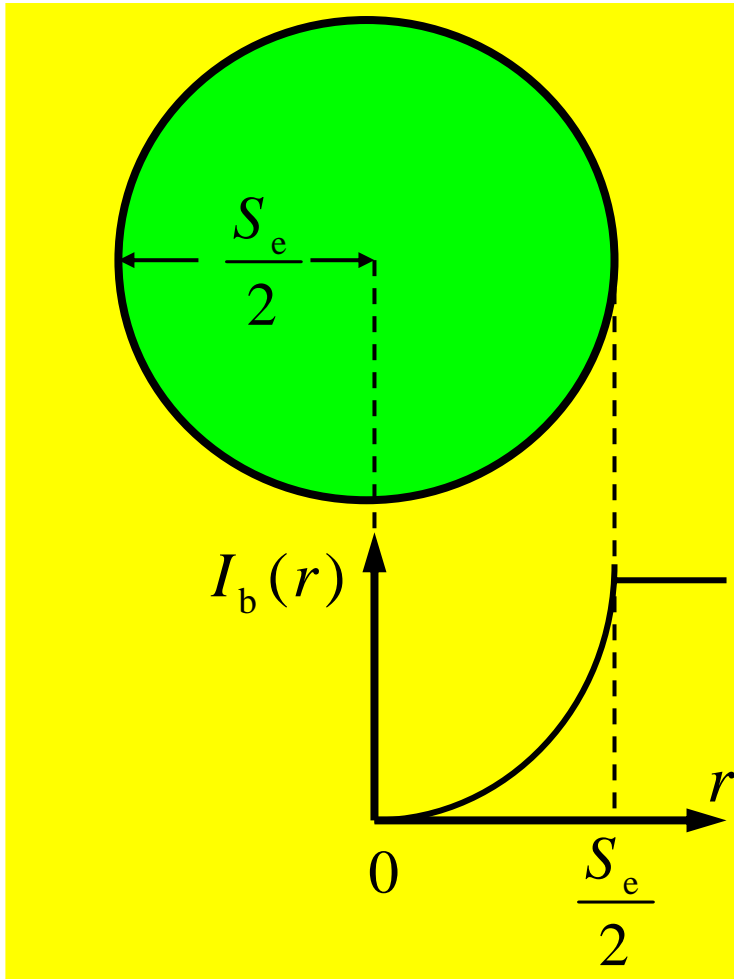
$$= I_B^2 \frac{S_b}{6l} R_{\square B3}$$

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

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

3、 Calculation

for circle base



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

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

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

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

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

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

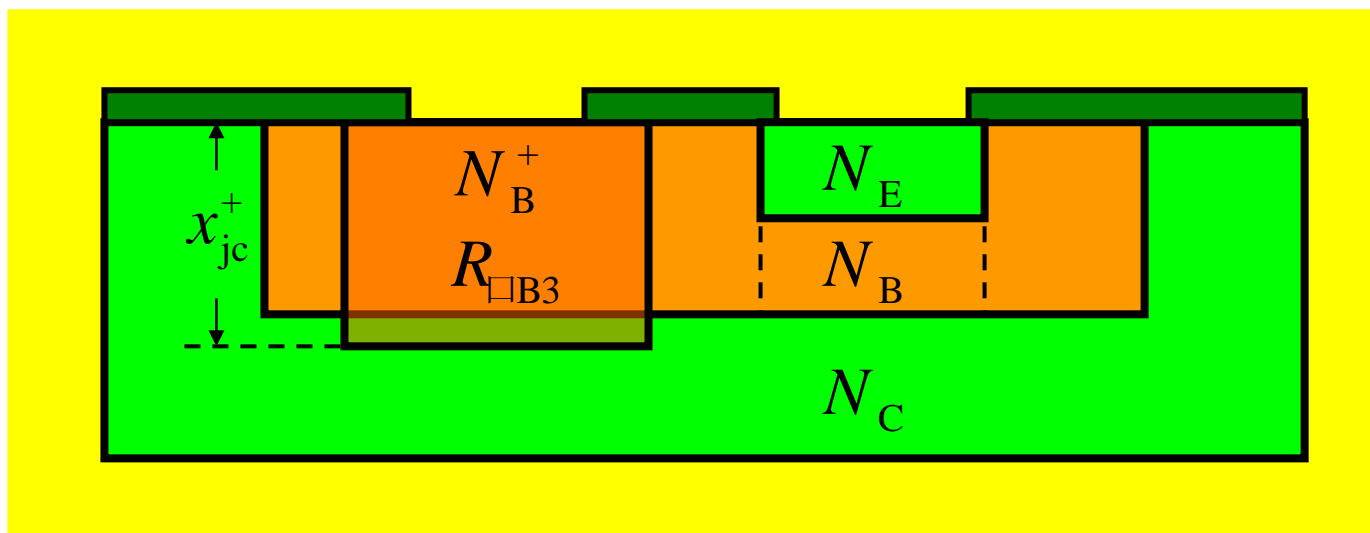
三、基极电阻的计算

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

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!