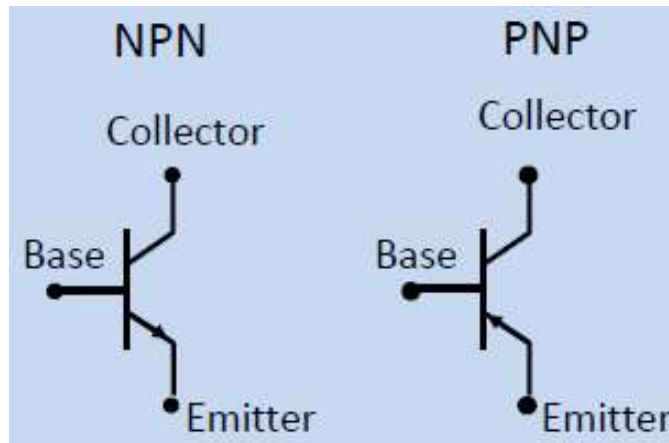
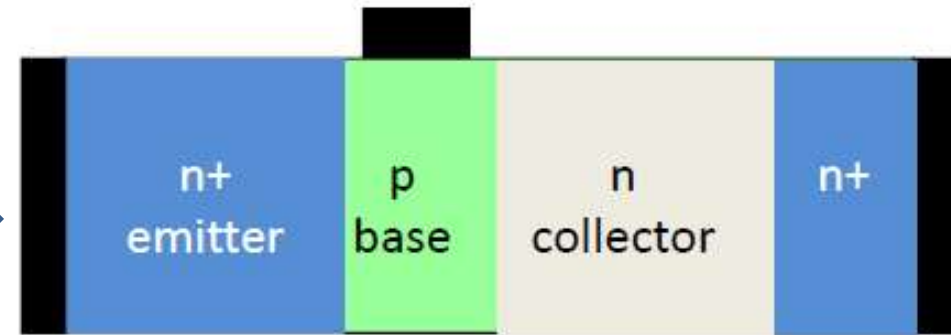
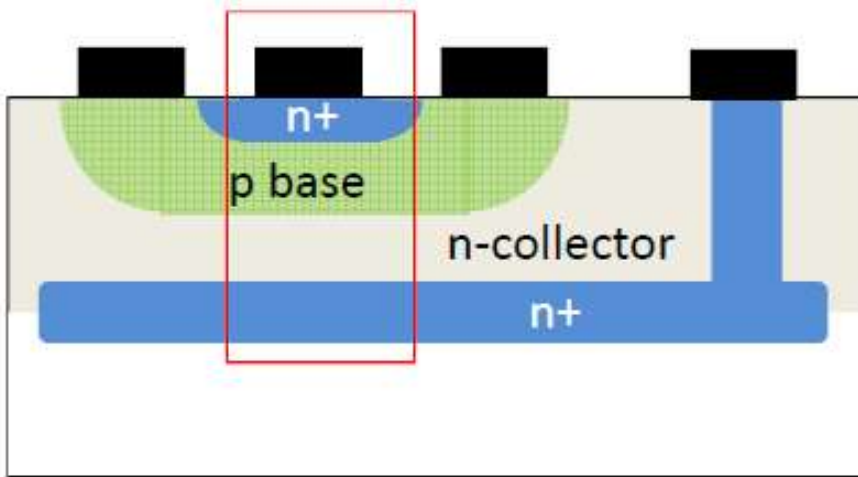
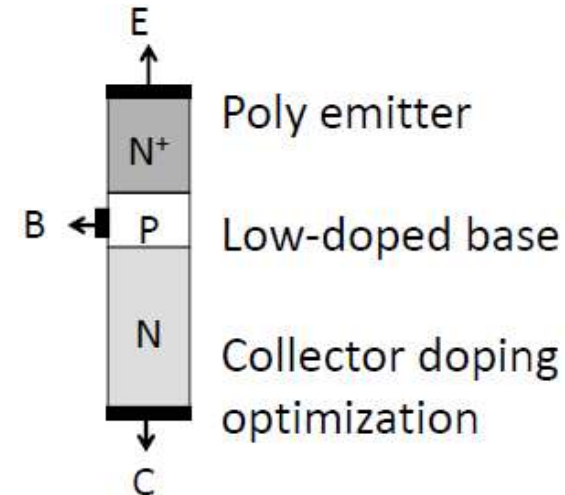


Bipolar Junction Transistor (BJT)

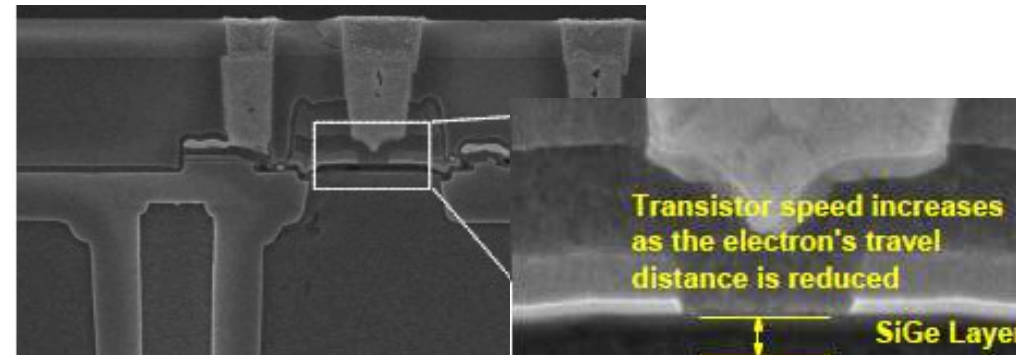
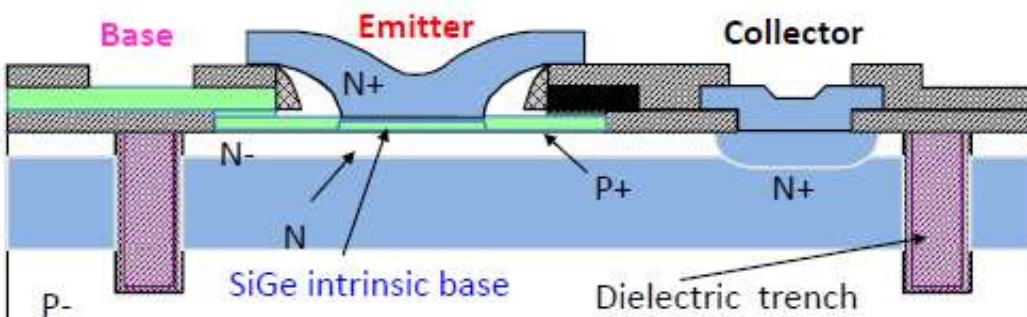


$$I_C + I_B + I_E = 0$$

$$V_{EB} + V_{BC} + V_{CE} = 0$$



HBT



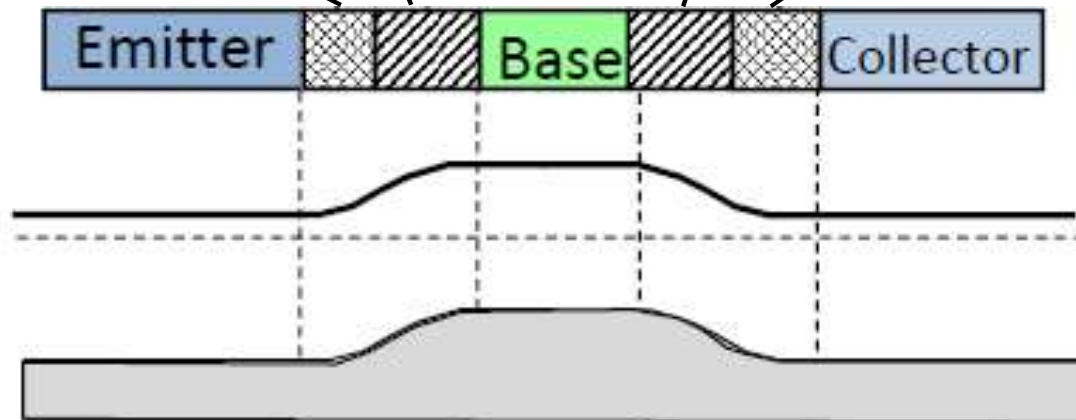
BJT in equilibrium

$$x_{p,BE} = \sqrt{\frac{2k_s\epsilon_0}{q} \frac{N_E}{N_B(N_E + N_B)} V_{bi}}$$

$$x_{p,BC} = \sqrt{\frac{2k_s\epsilon_0}{q} \frac{N_C}{N_B(N_C + N_B)} V_{bi}}$$

$$x_{n,E} = \sqrt{\frac{2k_s\epsilon_0}{q} \frac{N_B}{N_E(N_B + N_E)} V_{bi}}$$

$$x_{n,C} = \sqrt{\frac{2k_s\epsilon_0}{q} \frac{N_B}{N_C(N_C + N_B)} V_{bi}}$$



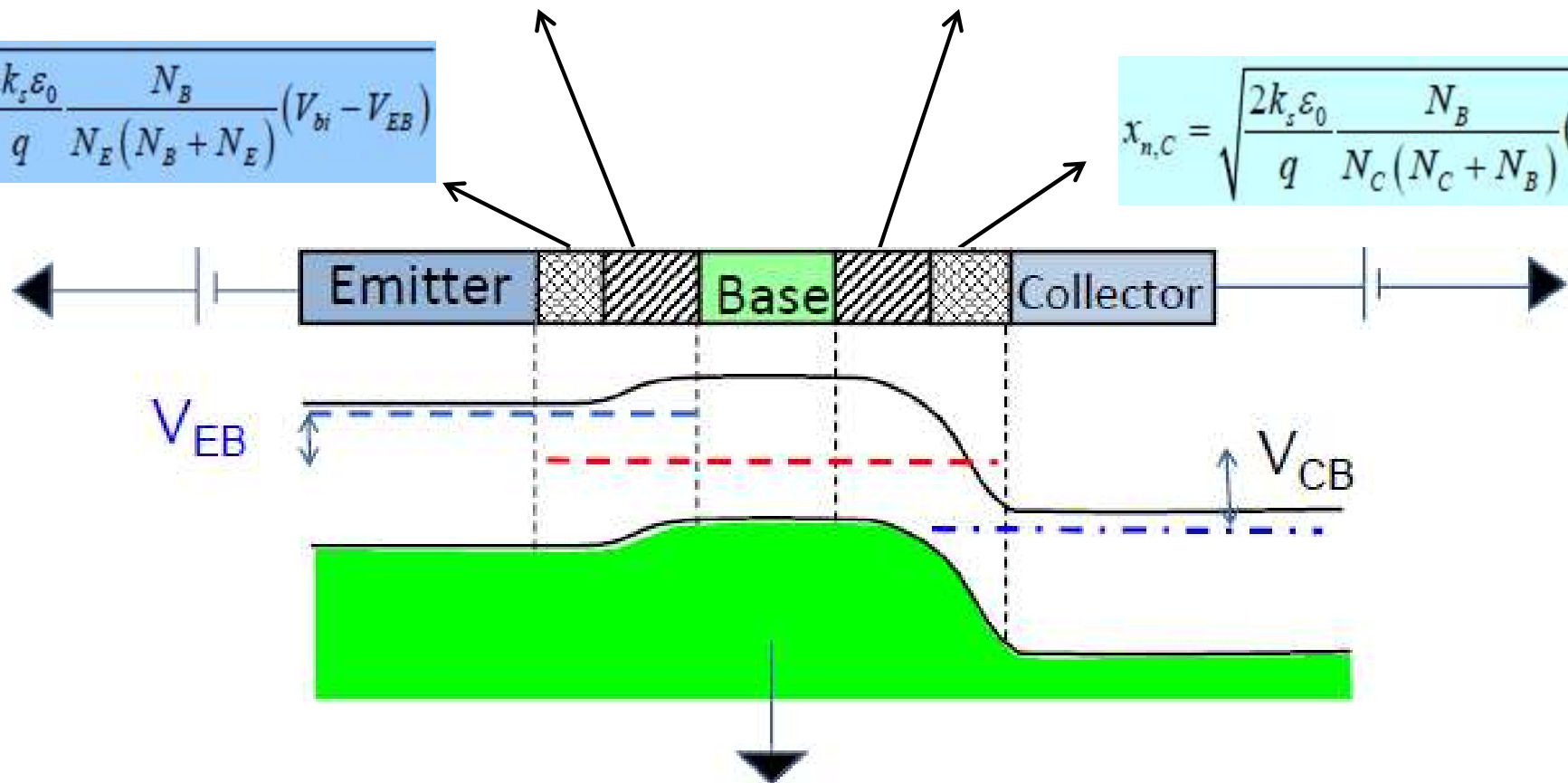
BJT under bias

$$x_{p, BE} = \sqrt{\frac{2k_s \epsilon_0}{q} \frac{N_E}{N_B (N_E + N_B)} (V_{bi} - V_{EB})}$$

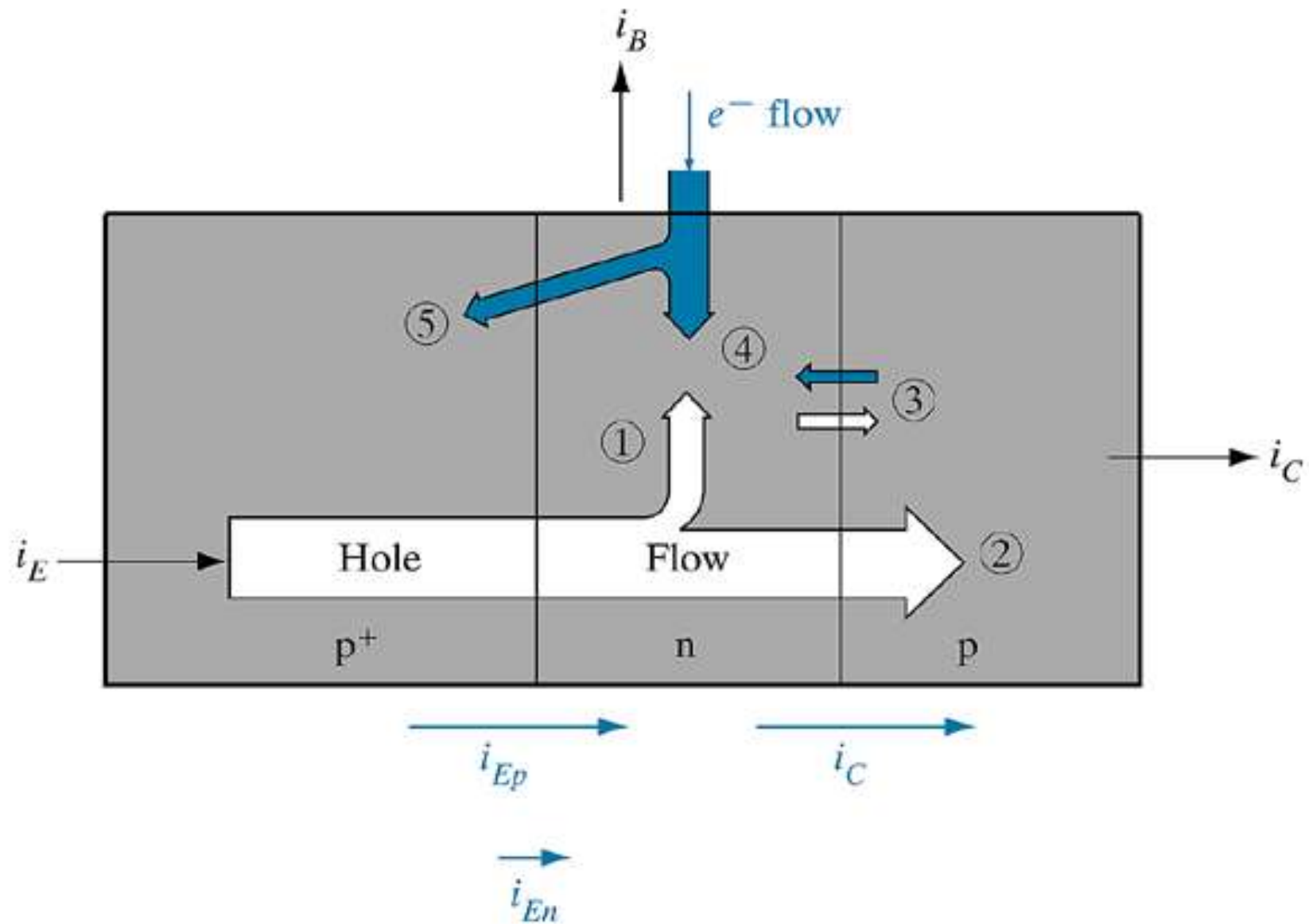
$$x_{p, BC} = \sqrt{\frac{2k_s \epsilon_0}{q} \frac{N_C}{N_B (N_C + N_B)} (V_{bi} - V_{CB})}$$

$$x_{n, E} = \sqrt{\frac{2k_s \epsilon_0}{q} \frac{N_B}{N_E (N_B + N_E)} (V_{bi} - V_{EB})}$$

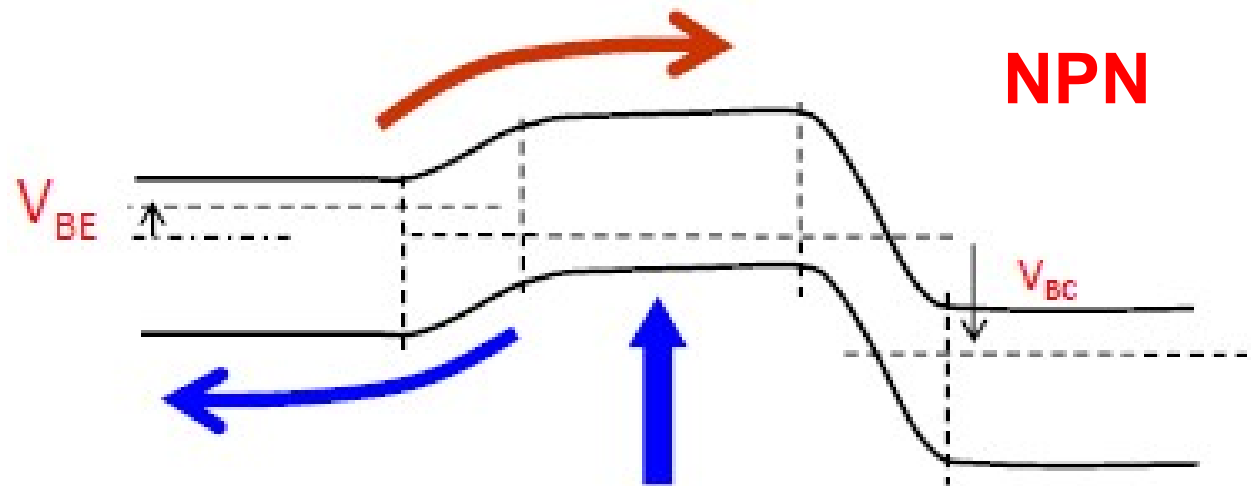
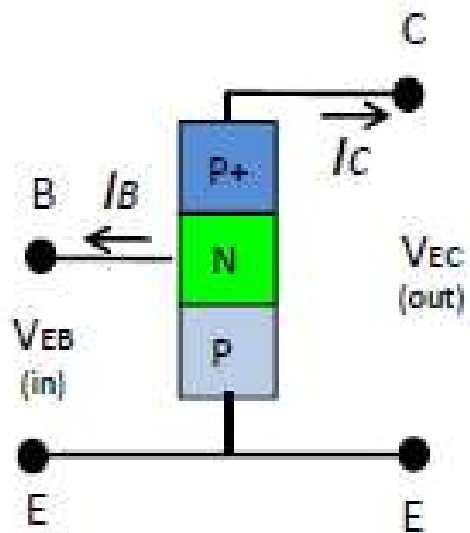
$$x_{n, C} = \sqrt{\frac{2k_s \epsilon_0}{q} \frac{N_B}{N_C (N_C + N_B)} (V_{bi} - V_{CB})}$$



Current components



Essence of current gain



Common Emitter

Input

$$I_B \approx \frac{qD_p}{W_E} \frac{n_{i,E}^2}{N_E} (e^{qV_{BE}\beta} - 1)$$

Response

Input

$$I_E \approx \frac{qD_n}{W_B} \frac{n_{i,B}^2}{N_B} (e^{qV_{BE}\beta} - 1)$$

Response

NPN

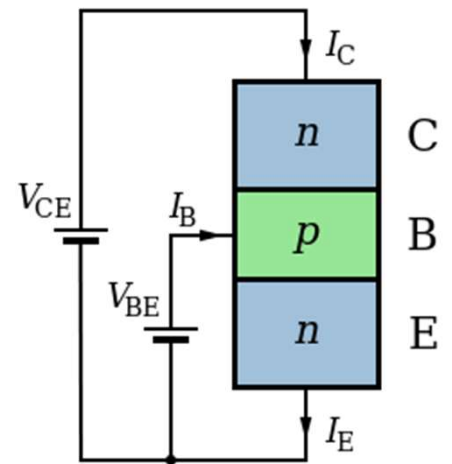
Current gain

$$\beta_{DC} = \frac{I_C}{I_B} \approx \frac{D_n W_E n_{i,B}^2 N_E}{W_B D_p n_{i,E}^2 N_B}$$

$$\beta_{DC} \approx \frac{D_n W_E}{W_B D_p} \frac{N_E}{N_B}$$

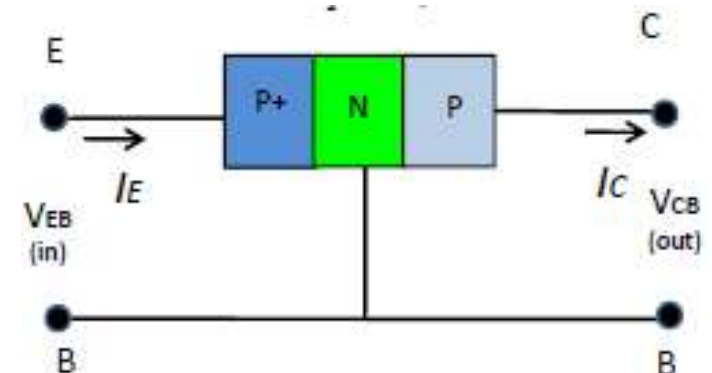
Homojunction

Common-emitter



Common-base

$$\alpha_{DC} = \frac{I_C}{I_E} \Rightarrow \beta_{DC} = \frac{I_C}{I_B} = \frac{I_C}{I_E - I_C} = \frac{\alpha_{DC}}{1 - \alpha_{DC}}$$



BJT design

For a given Emitter length

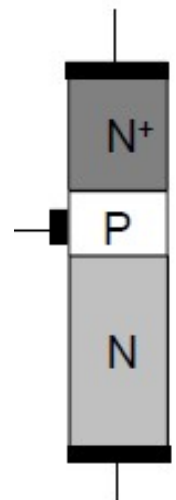
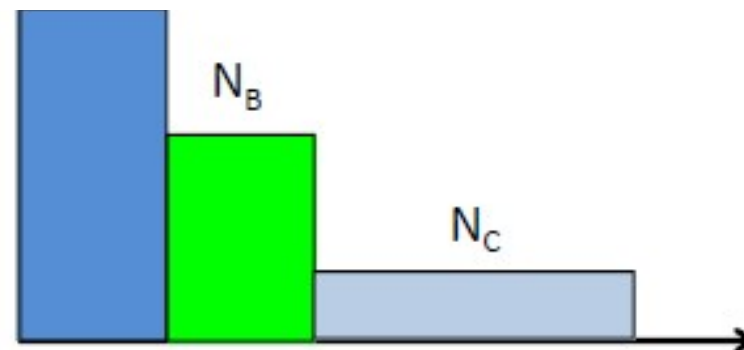
~ 1 , same material

$$\beta_{DC} \approx \frac{D_n W_E n_{i,B}^2 N_E}{W_B D_p n_{i,E}^2 N_B}$$

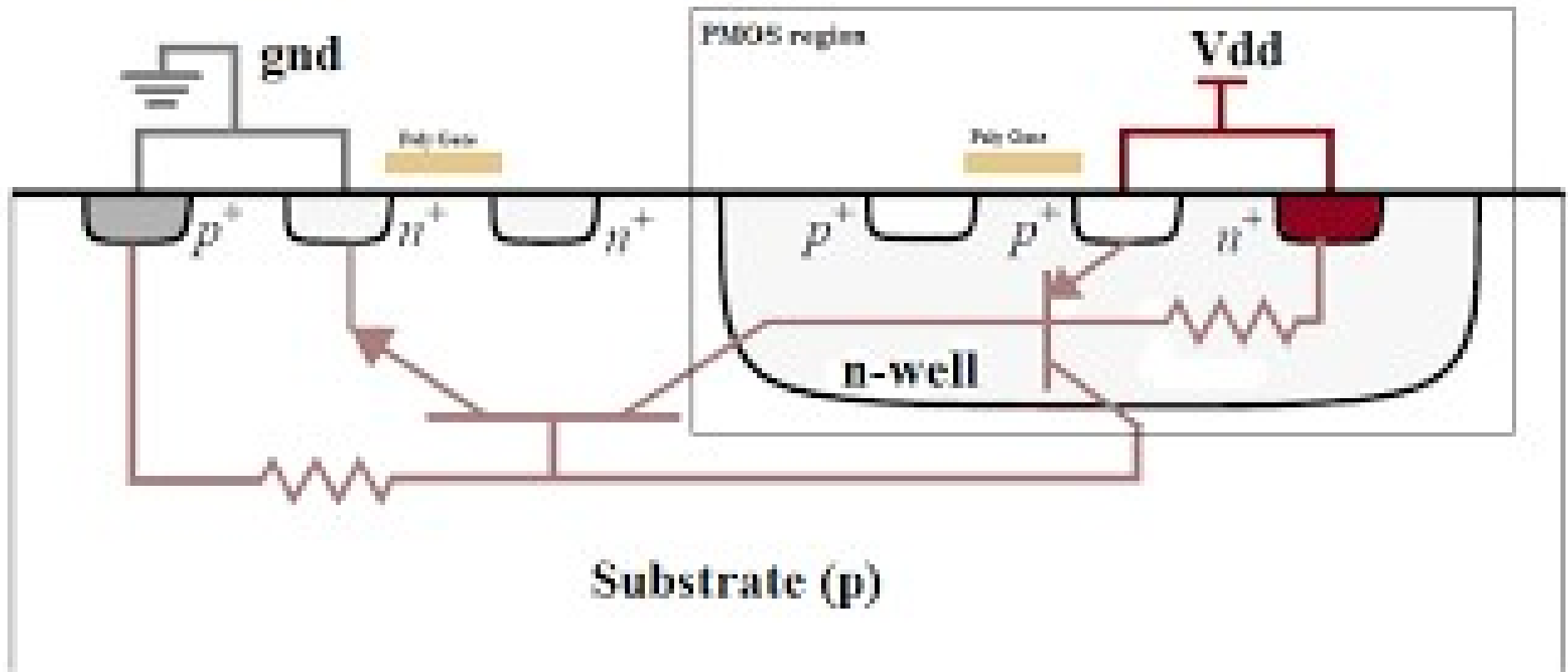
$$\beta_{DC} = \frac{D_B W_E N_E}{D_E W_B N_B}$$

Make-Base short ...
(few mm in 1950s, 200 Å now)

Emitter doping higher
than Base doping

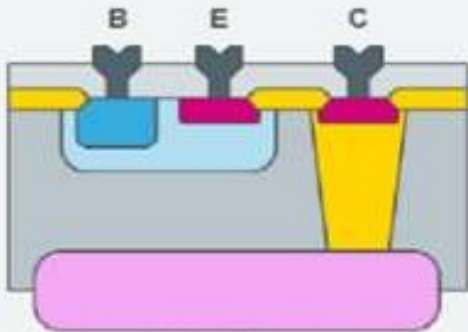


CMOS Latch-up



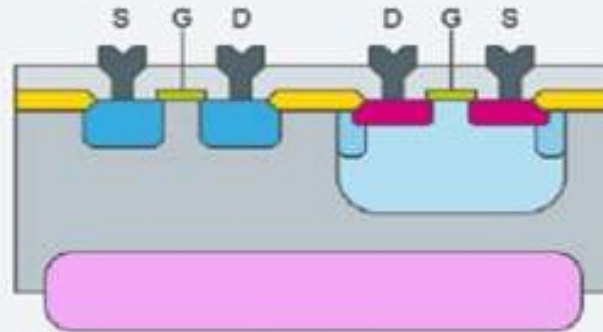
BCD Technology

BIPOLAR



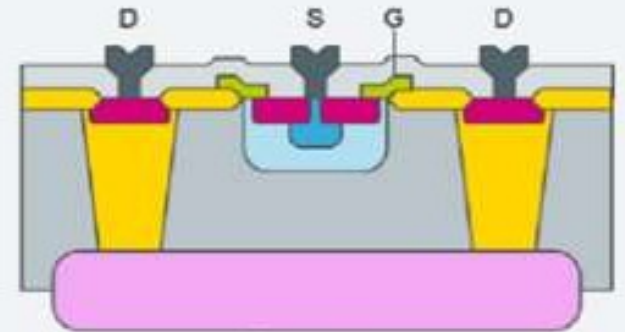
Analog

CMOS



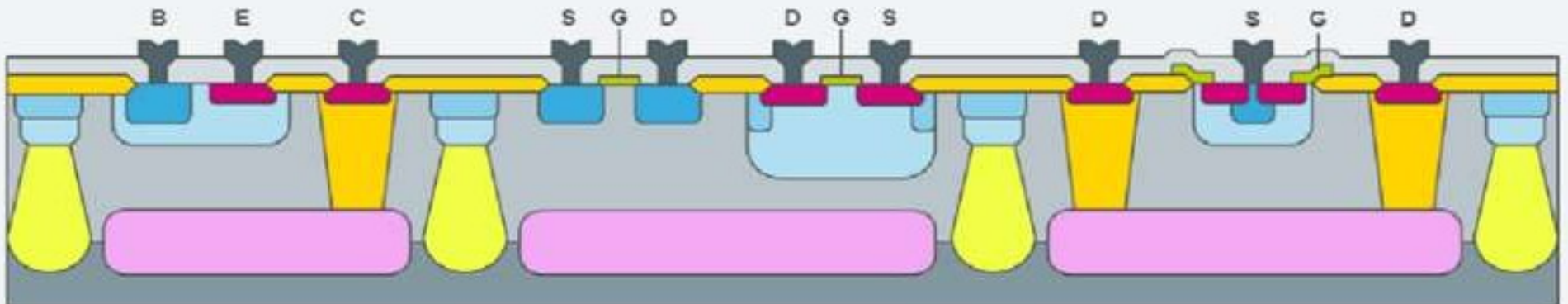
Digital

DMOS



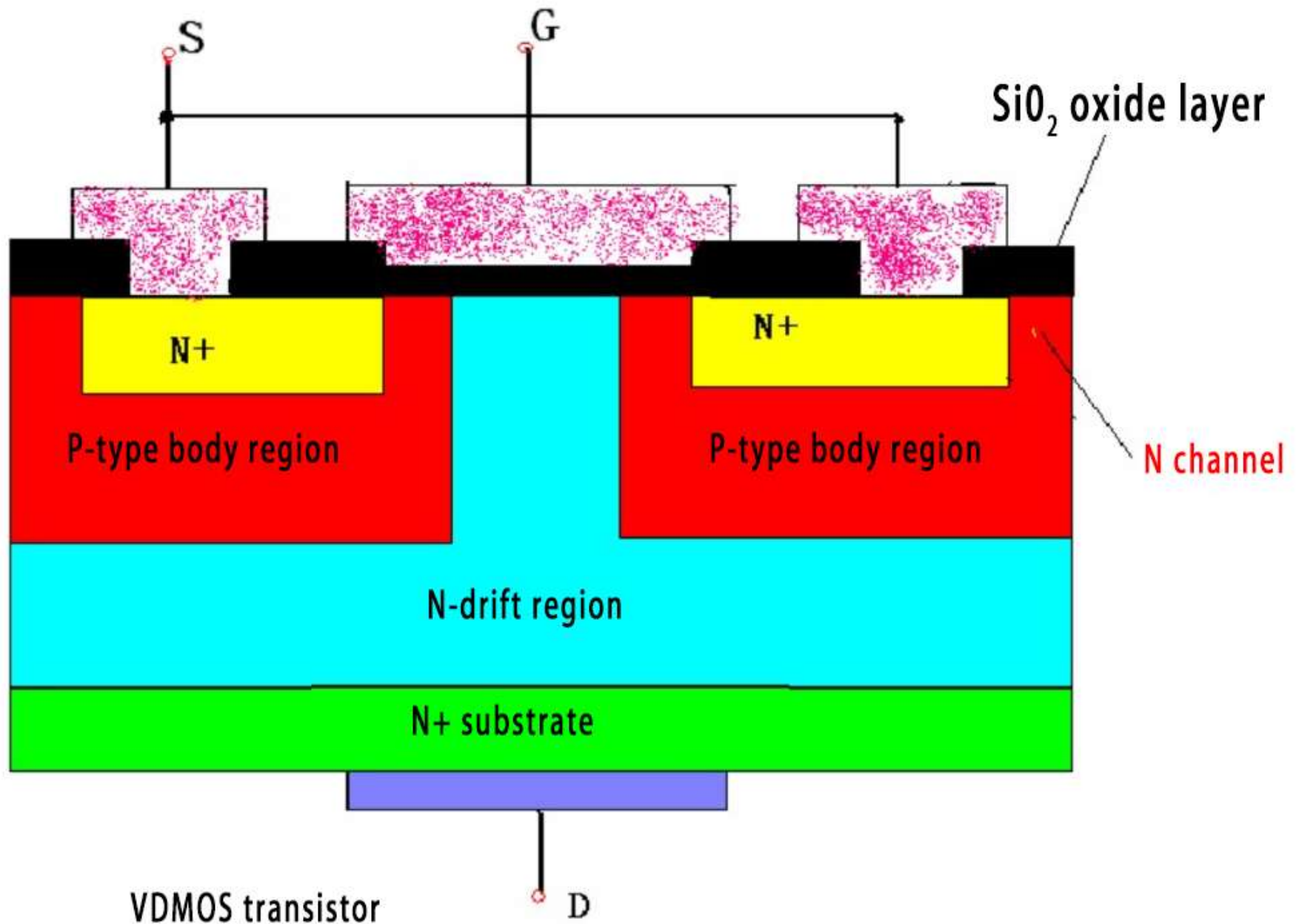
Power

BCD



Merged in one process platform

BCD Technology



IGBT

