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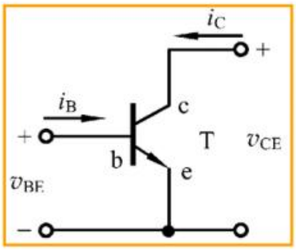
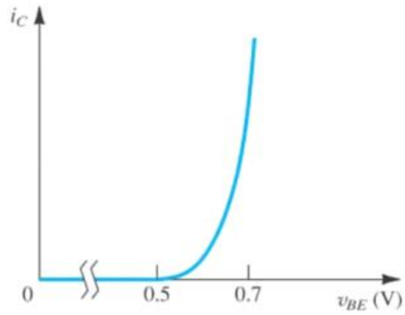
$i_C \sim v_{BE}$ curve:



At active mode

$$i_C = I_S\left(e^{(v_{BE}/V_T)} - 1\right) \approx I_S e^{(v_{BE}/V_T)}$$



$$I_S = \frac{A_E q D_n n_i^2}{N_B W_B} \qquad V_T = \frac{kT}{q} \approx 26mV$$

A_E: cross-sectional area of emitter area
q : electron charge = 1.6 * 10 $^{-19}$ C
D_n: diffusivity of electrons
n_i : number of thermally generated electrons
N_B: doping density in base
W_B: the width of base
T : absolute temperature

Could be controlled by manufacturing.

Temperature dependent

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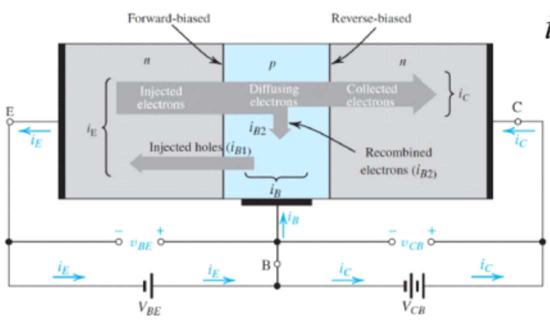
The analytical relationship between v_{BE} and i_B



$$i_B = \left(\boxed{\frac{A_E q D_p n_i^2}{N_D L_p}} + \boxed{\frac{A_E q W n_i^2}{2\tau_b N_A}}\right)\left(e^{\left(v_{BE}/V_T\right)} - 1\right)$$ (forget details)

Holes from B to E

Electrons from E to B

$$i_C = I_S\left(e^{(v_{BE}/V_T)} - 1\right)$$

$$\beta = \frac{i_C}{i_B} = \frac{1}{\dfrac{D_p N_A W}{D_n N_D L_P} + \dfrac{W^2}{2D_n \tau_B}}$$ (forget details)

- Electrons E ⟶ B => Base current (i_B)
- Holes B ⟶ E => Base current (i_B)

Big β, if:

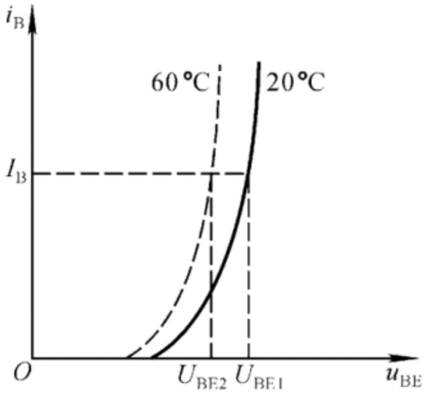
- W is small
- $N_A << N_D$

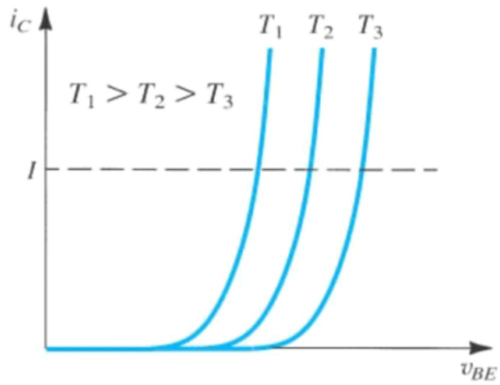
- Typically: 10 < β < 1000

Temperature effects on I-V curves

$$i_B = \left(\frac{A_E q D_p n_i^2}{N_D L_p} + \frac{A_E q W n_i^2}{2\tau_b N_A} \right) \left(e^{\left(\upsilon_{BE} / V_T \right)} - 1 \right)$$

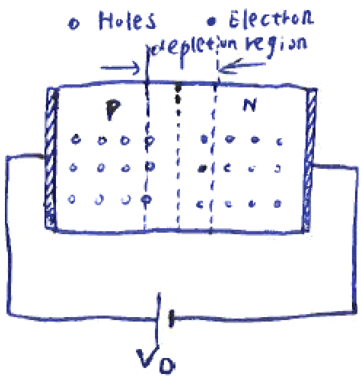
$$i_C = \frac{A_E q D_n n_i^2}{N_B W_B} \left(e^{(\upsilon_{BE}/V_T)} - 1 \right)$$





Blackboard Notes for lecture _ 1

slide 9:



diffusion movement will result in internal electric field to prevent holes diffusion from P region to N region

with applied external voltage. drift movement happens, it drives Holes movement from P region towards N region.

Therefore, when $V_D > 0$, ~~delep~~ the depletion region is narrow, the PN junction is ON,

when $V_D < 0$. the depletion region is thick, the PN junction is off.

slide 12:

No, since the depletion region is quite wide in PN diode, while it is quite thin in NPN transistor (Base region is only $1 \sim 2\ \mu m$)

slide 18:

when V_{CE} increases, the curve will shift towards right direction.

Reason: when V_{CE} increases, the collector lead will collect more electrons, that means more electrons will flow through Emitter region to Collector region, to keep Base current (i_B). more V_{BE} is needed to make electrons flow toward Base region.