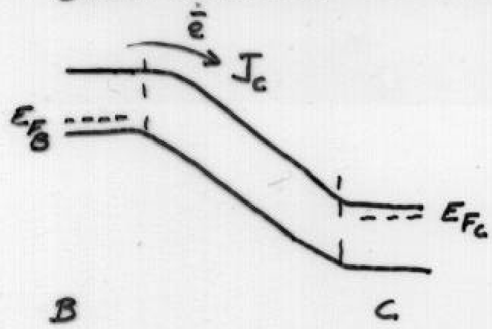
HIGH LEVEL INJECTION AT THE COLLECTOR: KIRK EFFECT

REMINDER: LOW N_D IN THE COLLECTOR FOR:
- INCREASING V_{BV}
- REDUCING EARLY EFFECT
- REDUCING BASE PUNCH-THR.

BASE-COLLECTOR JUNCTION:

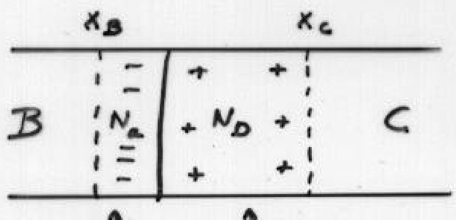


$J_c \equiv$ DRIFT CURRENT IS SPACE CHARGE REGION

$$J_c = e\, n(x)\, v(x)$$

BUT: $v(x) = v_L$: SATURATION VELOCITY (LARGE DEPLETION FIELD)

IN SPACE CHARGE REGION $\Rightarrow$ $\boxed{n(x) = \dfrac{J_c}{e v_L} \gg N_a^-, N_D^+}$ IF LARGE J_c (HIGH LEVEL INJECTION)



ADD $\bar{e}$ TO N_a^-

NEUTRALIZE N_D^+, REVERSE THE FIELD

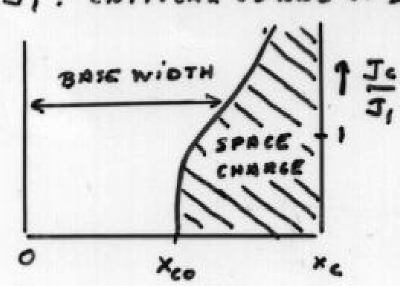
$\Rightarrow$ $\boxed{\text{BASE WIDENING}}$ (KIRK EFFECT)

$$\boxed{|x_c - x_B|_{\text{HIGH LEVEL}} = \frac{|x_c - x_B|_{\text{LOW LEVEL}}}{\sqrt{1 + \dfrac{J_c}{J_1}}}}$$

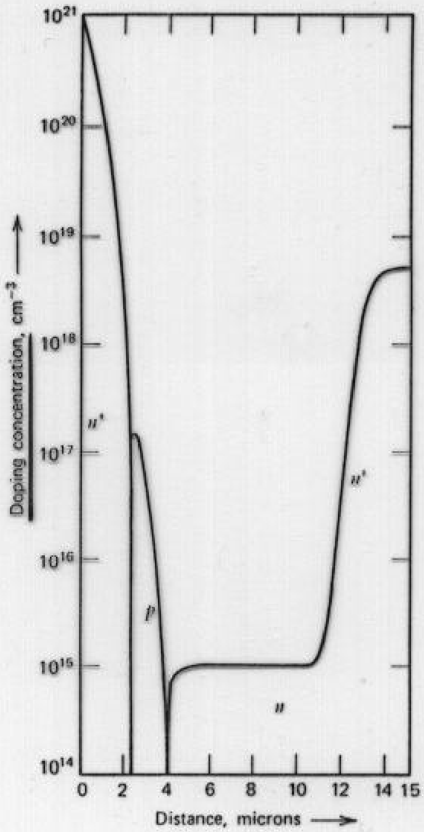
J_1 : CRITICAL CURRENT DENSITY

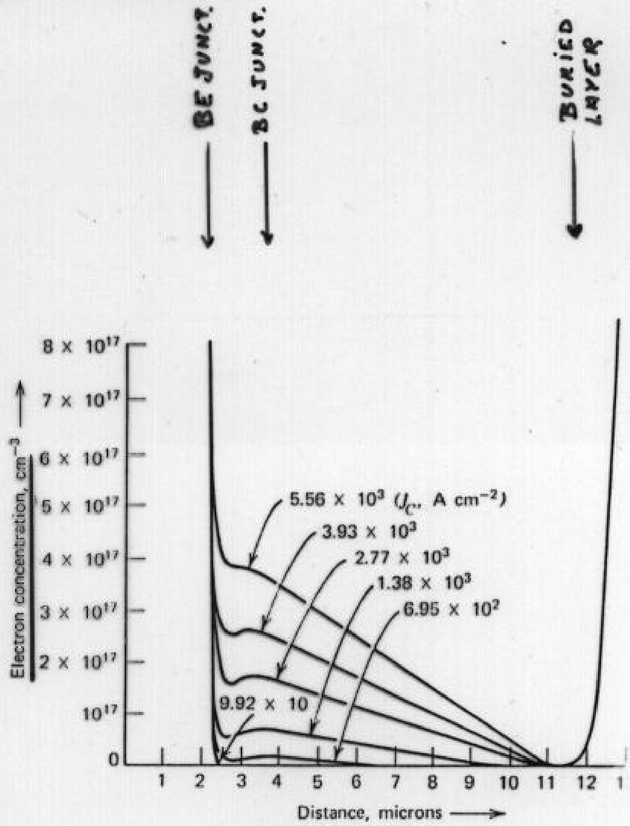
UNDER VERY HIGH INJECTION:

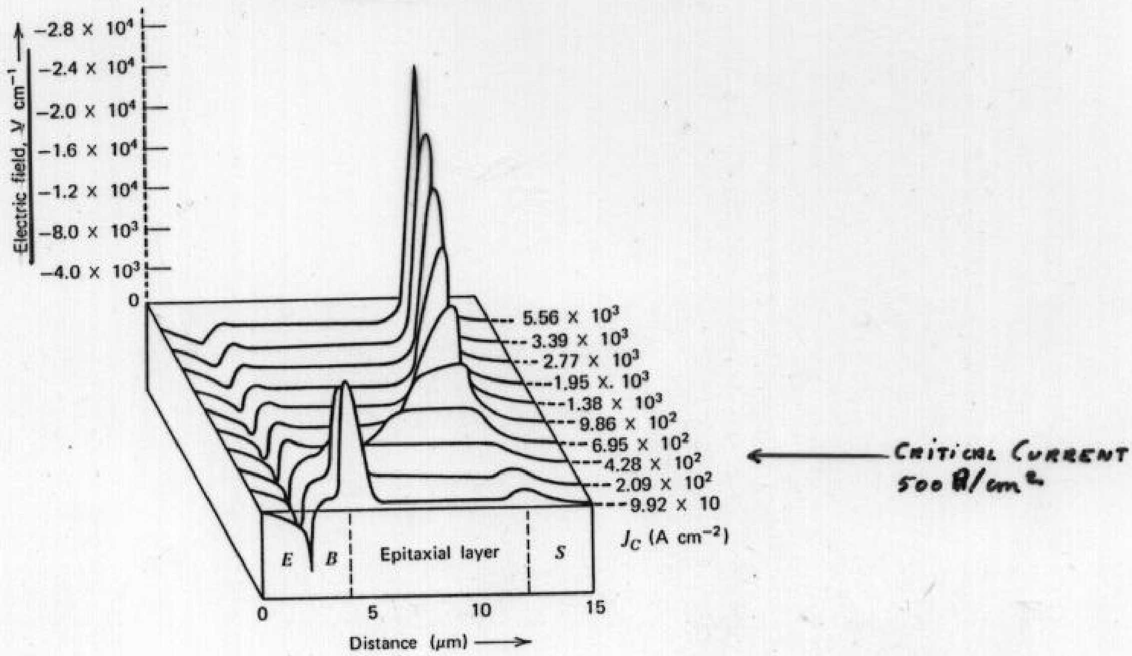
SPACE CHARGE FIELD IS PUSHED BACK TO BURIED LAYER



KIRK EFFECT: COMPUTER SIMULATION



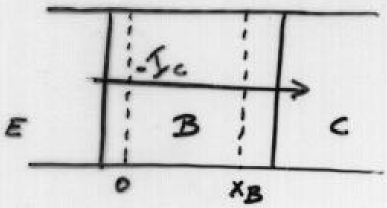




BASE TRANSIT TIME

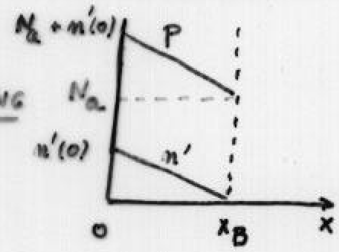
$$\boxed{\tau_B = \frac{Q_{nB}}{J_c}}$$

- $Q_{nB} = qA_E \int_0^{x_B} n'(x)\,dx$
- $J_c = \dfrac{q\tilde{D}_n n_i^2 A_E\, e^{\frac{qV_{BE}}{kT}}}{\int_0^{x_B} p(x)\,dx}$



$$\boxed{\tau_B = \frac{\left(\int_0^{x_B} p\,dx\right)\left(\int_0^{x_B} n'\,dx\right)}{\tilde{D}_n n_i^2 \exp\left(\frac{qV_{BE}}{kT}\right)}}$$

UNIFORM DOPING



BUT
- $n_i^2 e^{\frac{qV_{BE}}{kT}} = n'(0)\,p(0)$

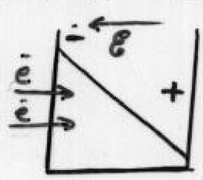
$= n'(0)\,[N_a + n'(0)]$

- $\int_0^{x_B} p\,dx = \frac{1}{2}(n'(0) + 2N_a)\,x_B$
- $\int_0^{x_B} n'\,dx = \frac{1}{2}n'(0)\,x_B$

$$\tau_B = \frac{\frac{x_B}{2}[n'(0) + 2N_a][\frac{1}{2}n'(0)x_B]}{\tilde{D}_n\, n'(0)\,[N_a + n'(0)]}$$

$$\boxed{\tau_B = \frac{x_B^2}{4\tilde{D}_n}\left[1 + \frac{N_a}{n'(0) + N_a}\right]}$$

- LOW LEVEL INJECTION $n'(0) \ll N_a$ $\qquad \tau_B = \dfrac{x_B^2}{2\tilde{D}_n}$
- HIGH LEVEL INJECTION $n'(0) \gg N_a$ $\qquad \tau_B = \dfrac{x_B^2}{4\tilde{D}_n}$ $\qquad$ WEBSTER EFFECT



ELECTRIC FIELD ASSOCIATED WITH THE CHARGE IN THE BASE
- PREVENTS MAJORITY CARRIERS TO DIFFUSE TO THE ~~BASE~~ COLLECTOR
- HELP MINORITY CARRIERS TO REACH THE COLLECTOR JUNCTION

NON UNIFORM DOPING

$$\tau_B = \frac{x_B^2}{\tilde{D}_n}\int_0^1 \frac{dy}{p(y)}\int_y^1 d\xi\, p(\xi) = \frac{x_B^2}{\nu \tilde{D}_n} \qquad \nu = \frac{1}{\int_0^1 \frac{1}{p(y)}\left\{\int_y^1 d\xi\, p(\xi)\right\}dy}$$