MOD-4 GD-13

# Other Important Effects

## Drift in the Base Region

The net doping concentration in the base for an implanted junction transistor is given by $N = N_d - N_a$. However the net doping concentration $N$ varies along a profile that decreases from emitter edge to collector edge.

The impurity gradient $N(x_n)$ varies exponentially within the base region.

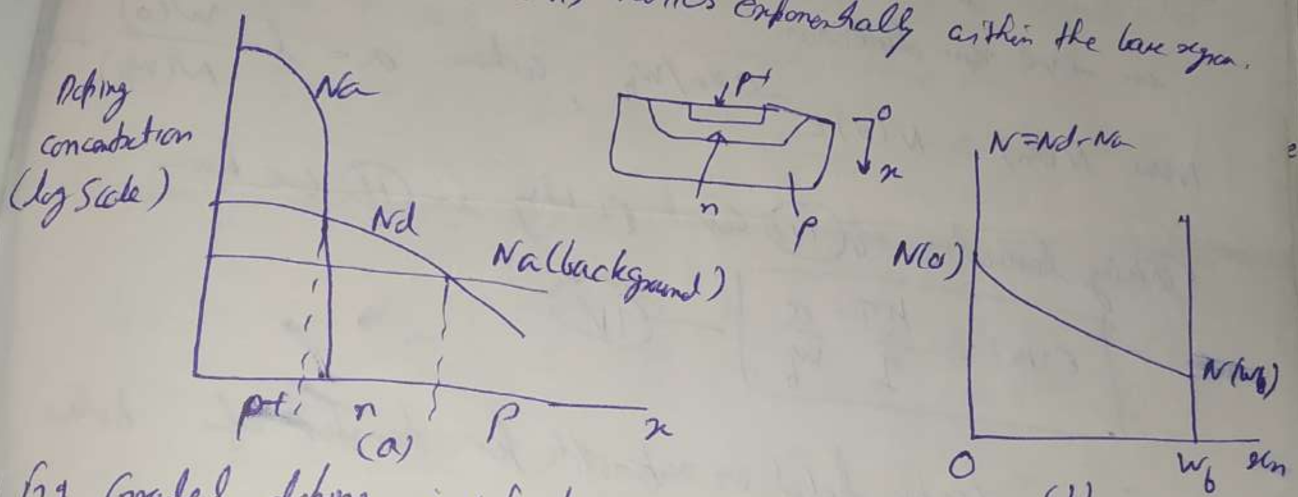



Fig Graded doping in the base region of a pnp transistor (a) Typical doping profile in a semilog plot (b) Approximate exponential distribution of the net donor concentration in the base region on a linear plot.

- Due to graded base region a built in electric field exists from E to C (pnp), hence adding a drift component to the transport of holes across the base.
- If the net donor doping of the base is large enough to allow the usual approximation $n(x_n) \simeq N(x_n)$, the balance of $e^-$ drift and diffusion currents at equilibrium requires

$$I_n(x_n) = qA\mu_n N(x_n)\mathcal{E}(x_n) + qAD_n \frac{dN(x_n)}{dx_n} = 0 \quad \text{— (I)}$$

Hence built in electric field

$$\mathcal{E} = \mathcal{E}(x_n) = -\frac{D_n}{\mu_n}\frac{1}{N(x_n)}\frac{dN(x_n)}{dx_n}$$

$$= -\frac{kT}{q}\frac{1}{N(x_n)}\frac{dN(x_n)}{dx_n} \quad \text{— (II)}$$

- For a doping profile $N(x_n)$ that decreases from E to C in +ve $x_n$- direction.

Now $N(x_n) = N(0)e^{-ax_n/W_b}$, where $a = \ln\frac{N(0)}{N(W_b)}$ — (III)

Taking derivative of (III) and putting in (II) we have

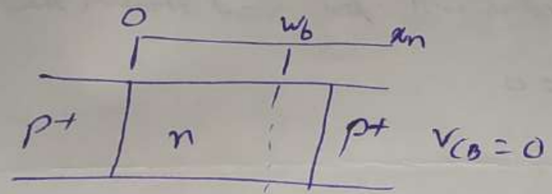
$$\boxed{\mathcal{E}(x_n) = \frac{kT}{q}\frac{a}{W_b}} \quad \text{— (IV)}$$

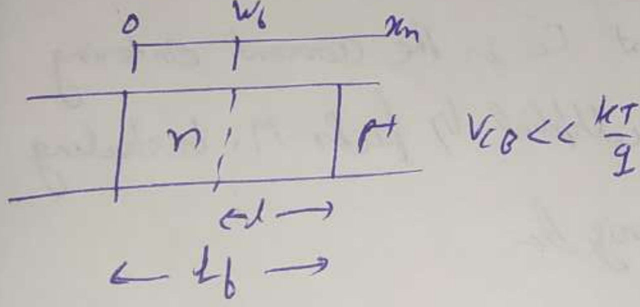
- Since electric field is responsible for transport of holes from E to C. hence $T_t$ is reduced in comparison to uniform base transistor. Due to this high-freq^n devices can be made.

Punch through effect
↓
base may be reduce to zero, breakdown of transistor conn.

## Base Narrowing / Base width modulation / Early effect

- Effect was firstly observed by J.M. Early.
- For a $p^+$-n-$p^+$ transistor, on reverse bias collector junc$^n$ penetrate more toward the base region.
- Due to decrease in $W_b$, $\beta$ increases hence $I_C$ increases, with collector volt, rather than staying const. as predicted from simple treatment.




$W_b = L_b - l$ , $l \propto \sqrt{V_{BC}}$

$$\rightarrow l = \left(\frac{2\epsilon V_{BC}}{qN_d}\right)^{1/2}$$

- A condition of punch through can arises when entire base is occupied by collector region due to high $V_{CB}$. Hence hole from E go to collector quickly and hence transistor effect lost.

- However in most of cases of transistor avalanche breakdown occurs before the punch through condition.

## Avalanche Breakdown

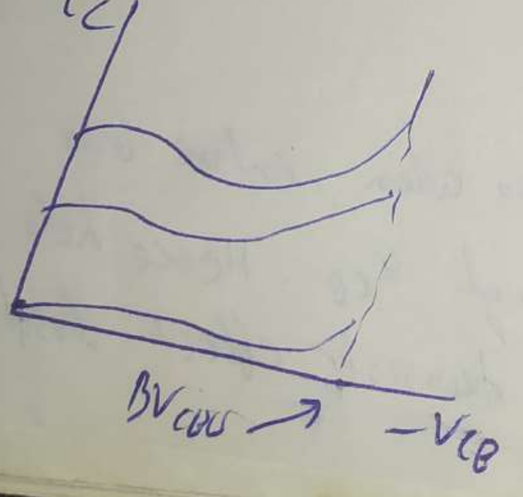
For CE case $BV_{CEO}$ is breakdown volt. and smaller than $BV_{CBO}$. and $I_B = 0$

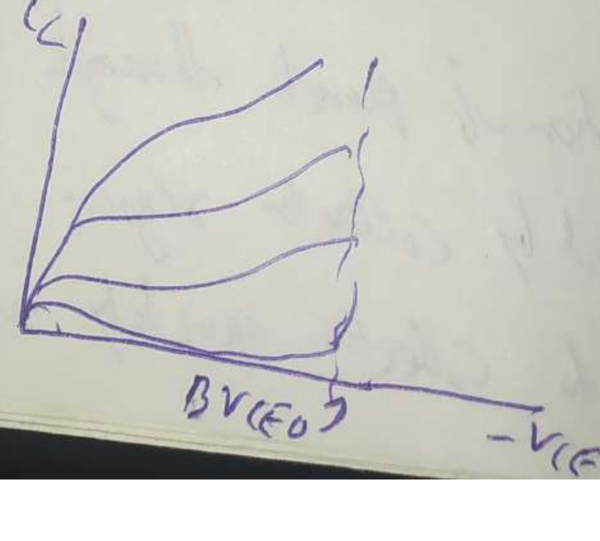
CB case $I_E = 0$

In each case terminal current $I_C$ is the current entering the collector depletion region multiplied by factor M. Including multiplication due to impact ionization

$$I_C = (\alpha_N I_E + I_{CO})M = (\alpha_N I_E + I_{CO})\frac{1}{1-(V_{BC}/BV_{CBO})^n}$$

M — Emperical expression



For limiting CB case $I_E = 0$, $I_C = MI_{CO}$

$BV_{CBO}$ — collector junction breakdown volt. in common base with emitter open.

In CE case $I_B = 0$ and $I_C = I_E$

$$I_C = \frac{MI_{CO}}{1 - M\alpha_N}$$

$I_C$ increases as $M\alpha_N$ approaches to unity

- In most of transistor $\alpha_N$ is close to unity, M need to only slightly larger than unity for approaching breakdown.