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NPTEL ONLINE CERTIFICATION COURSE

Microelectronics: Devices to Circuits

BJT: Second Order Effects

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Second Order Effects

Drift in the Base Region:

$$I_n(x_n) = qA\mu_n N(x_n)\mathscr{E}(x_n) + qAD_n\frac{dN(x_n)}{dx_n} = 0$$

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

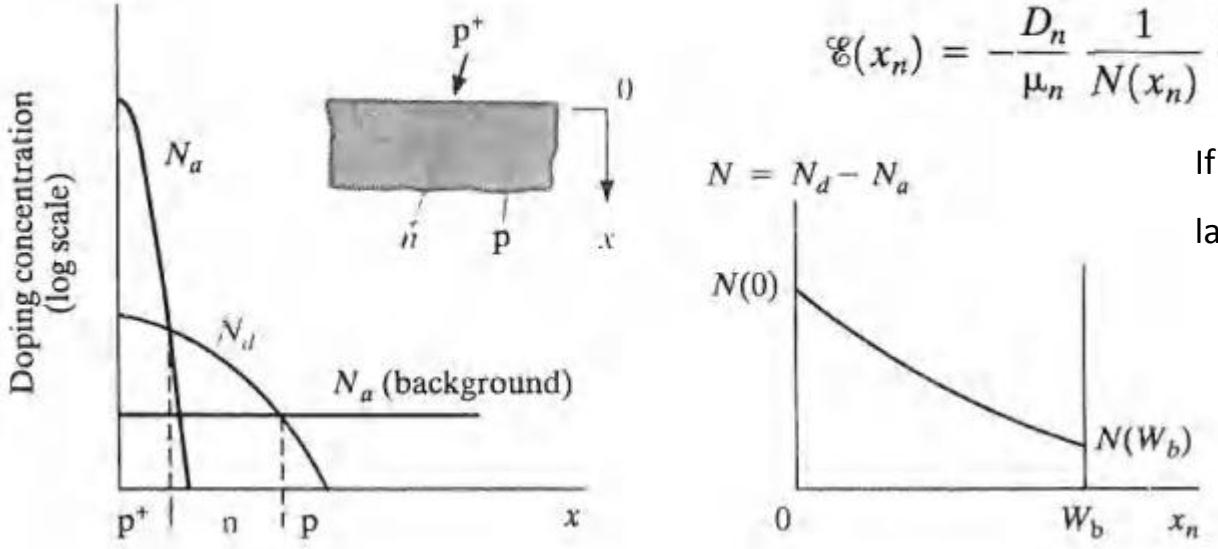


Fig.3. Graded doping in the base region of a p-n-p transistor

If the net donor doping in the base is large enough than

$$n(x_n) = N(x_n)$$

Source: Solid State Electronics Devices, BEN G. STREETMAN & SANJAY KUMAR BANERJEE, SIXTH EDITION

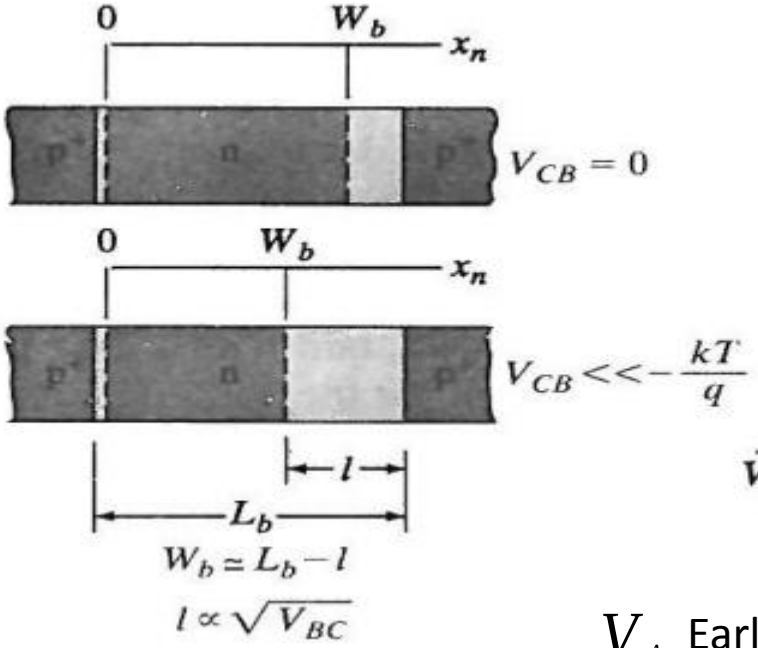
- There is a fairly sharp discontinuity in the doping profile.
- The donor concentration in the base region becomes smaller than the constant P- type background doping in the collector.
- Emitter is heavily doped (P+) shallow region.
- The net Doping concentration $N_d - N_a = N$ varies along a profile which decreases from the emitter edge to the collector edge.
- Doping distribution in the base is a portion of a Gaussian.
- Due to graded base region a built in electric field exists from emitter to collector (for P-n-p), there by adding a drift component to the transport of holes across the base.

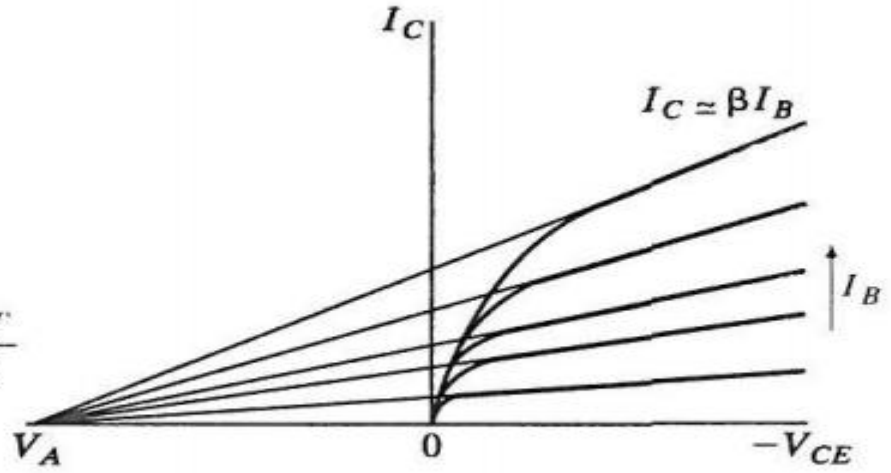
Source: Solid State Electronics Devices, BEN G. STREETMAN & SANJAY KUMAR BANERJEE, SIXTH EDITION

Base Narrowing (base-width modulation , Early Effect)

- Effective width of the base decreased.
- Base region is lightly doped.
- The depletion region at the reverse-biased collector junction can extended significantly into the n-type base region.
- The decrease in base width causes β increases, hence the collector current increases with collector voltage.

Source: Solid State Electronics Devices, BEN G. STREETMAN & SANJAY KUMAR BANERJEE, SIXTH EDITION





V_A Early Voltage

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

Fig.4. Base-width modulation

Source: Solid State Electronics Devices, BEN G. STREETMAN & SANJAY KUMAR BANERJEE, SIXTH EDITION

Avalanche Breakdown:

- Avalanche breakdown, which occurs when the minority carriers that cross the depletion region under the influence of the electric field gain sufficient kinetic energy to be able to break covalent bonds in atoms with which they collide.

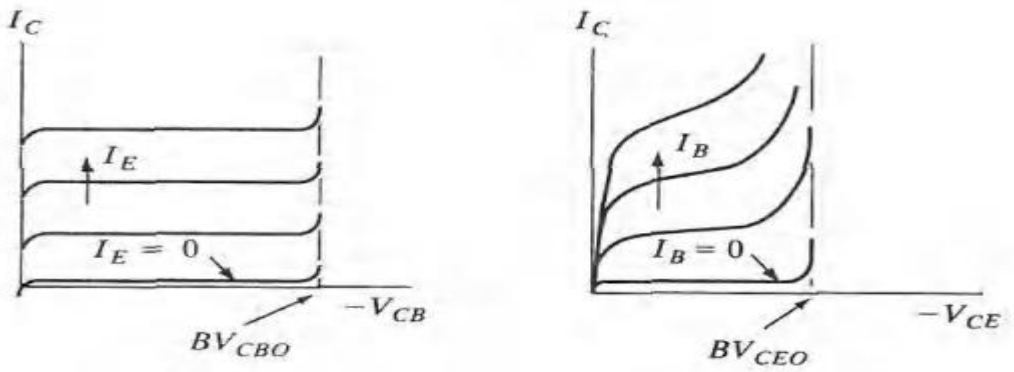


Fig.5.Avalanche breakdown for CB , CE configuration

BV_{CBO} Break down voltage for common –base configuration

BV_{CEO} Break down voltage for common –emitter configuration

Source: Solid State Electronics Devices, BEN G. STREETMAN & SANJAY KUMAR BANERJEE, SIXTH EDITION

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

Where M is a multiplication factor

Injection level, Thermal Effects:

- Parameters α and β of a practical transistor may vary considerably with injection level, which is determined by magnitude of I_E and I_C.
- For very low injection, the assumption of negligible recombination in the junction depletion region is invalid.

Source: Solid State Electronics Devices, BEN G. STREETMAN & SANJAY KUMAR BANERJEE, SIXTH EDITION

- The base conductivity modulation effects results in a decrease in ϒ(emitter injection efficiency).
- Large value of I_C is responsible for significant power dissipation in the transistor and therefore heating effect of the device.
- Power dissipation due to collision of carriers into the lattice.
- Power dissipation does not exceed the maximum power rating of the device.
- In the devices designed for high power capability, the transistor is mounted on an efficient heat sink, so that thermal energy can be transferred away from the junction.

Source: Solid State Electronics Devices, BEN G. STREETMAN & SANJAY KUMAR BANERJEE, SIXTH EDITION

- If the temperature of the device is allowed to increase due to power dissipation or thermal environment, the transistor parameters changes.
- The most important parameter depend on the temperature are the carrier lifetimes and diffusion coefficients.
- The mobility decreases with increasing temperature in the lattice –scattering range, varying approximately as $T^{\frac{3}{2}}$.
- D_p decreases as the temperature increases, thereby causing a drop in β due to an increasing transit time τ_t.
- β becomes larger as device is heated.

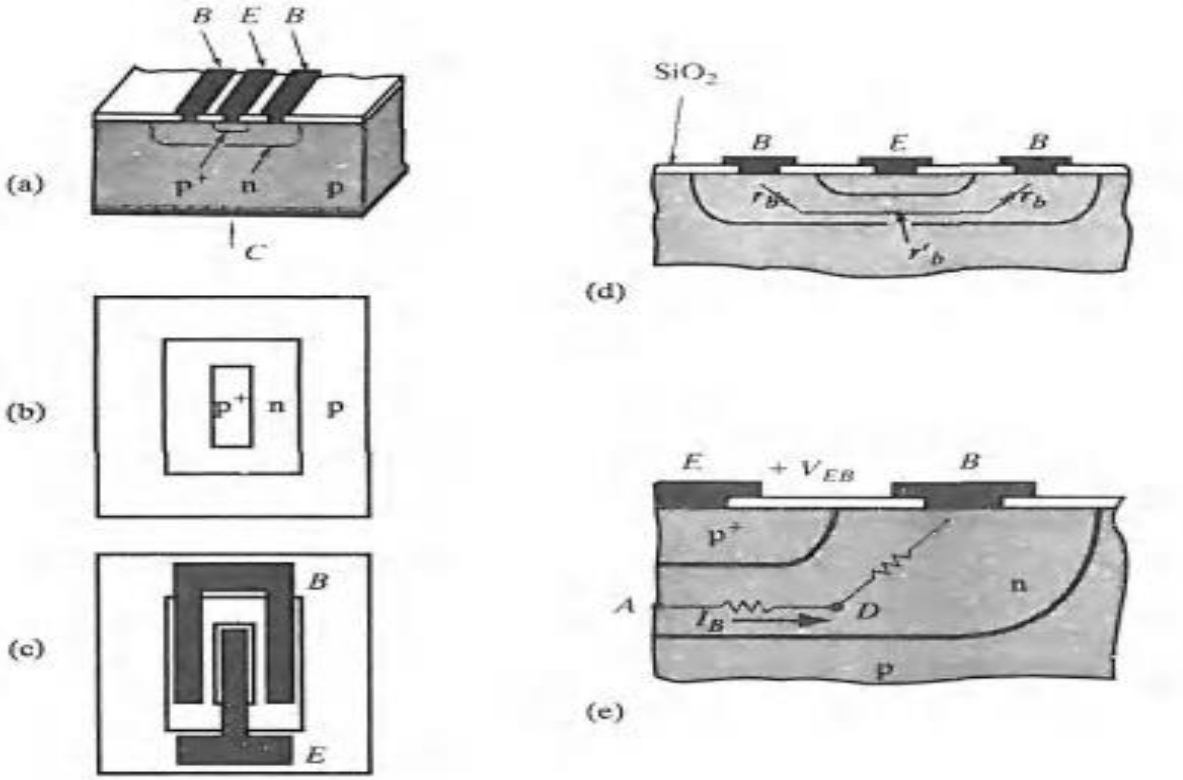
Source: Solid State Electronics Devices, BEN G. STREETMAN & SANJAY KUMAR BANERJEE, SIXTH EDITION

- The thermal runaway can occur if the circuit is not designed to prevent it.
- Runway of the collector current can result in overheating and destruction of the device.

Base resistance and emitter crowding:

- Large area bipolar transistor can have non-uniform current distribution due to the resistance of the base layer.

Source: Solid State Electronics Devices, BEN G. STREETMAN & SANJAY KUMAR BANERJEE, SIXTH EDITION



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Recapitulation

- BJT can be used as a inverter on in saturation region and off in cutoff.
- Second order effects affect the performance of the BJT devices.
- Base region is lightly doped in BJT devices.
- Carrier mobility decreases with increases in temperature.
- To avoid the thermal runaway designer used the heat sink.
- Structural effects are important in determining the operation of the transistor.

Thank You