FYS4310

Bipolar Process Integration

Pavement university of Aveiro, Portugal

FYS4310

Bipolar Process Integration

Outline

Simple

More advanced

Overview and some details

"Curriculum-reading list"

Understand how bipolar works, Understand design philosophy

17.6 not 17.7 (Review of Bipolar Devices [not Performance of BJT])

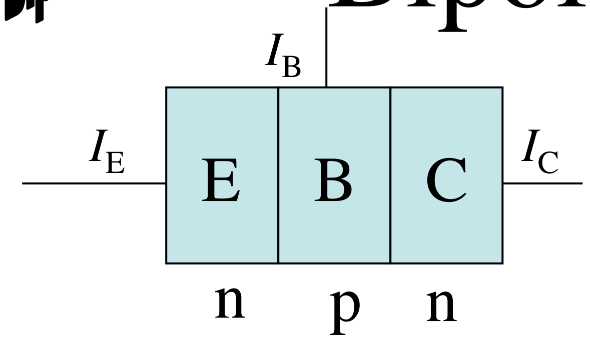
17.8, 17.9 not 17.10(Early Bipolar Process, Advanced, not BiCMOS)

(17.11 FET), 17.12 (Summary_

All lecture

Know about/understand interaction between processes

Bipolar parameters



$I_C = \alpha I_E$

$I_C = \beta I_B$

$I_E = I_C + I_B$

$\beta = \alpha/(1-\alpha)$

$\alpha = \beta/(\beta+1)$

$I_C = \alpha_T \gamma \, \delta \, I_E$

α_T :Base transport factor

γ :Emitter injection efficiency

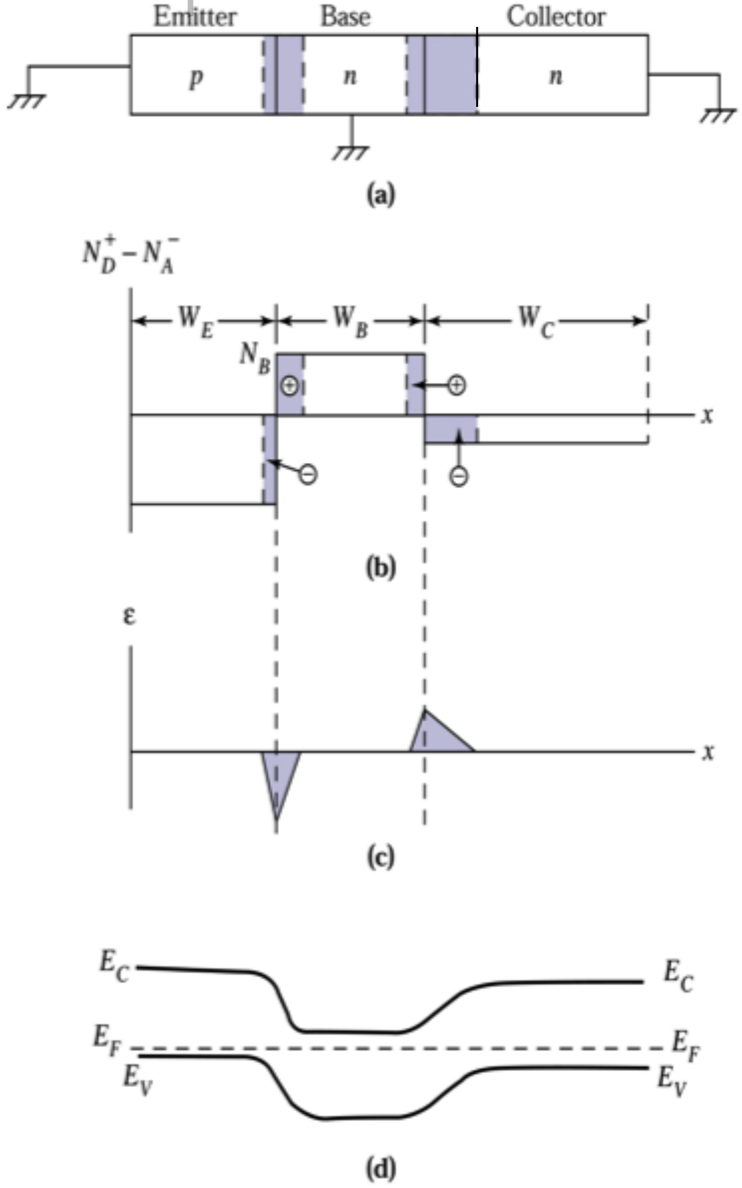
δ :Recombination factor

α: common base current gain

β: common emitter current gain

Bipolar Quick repetition

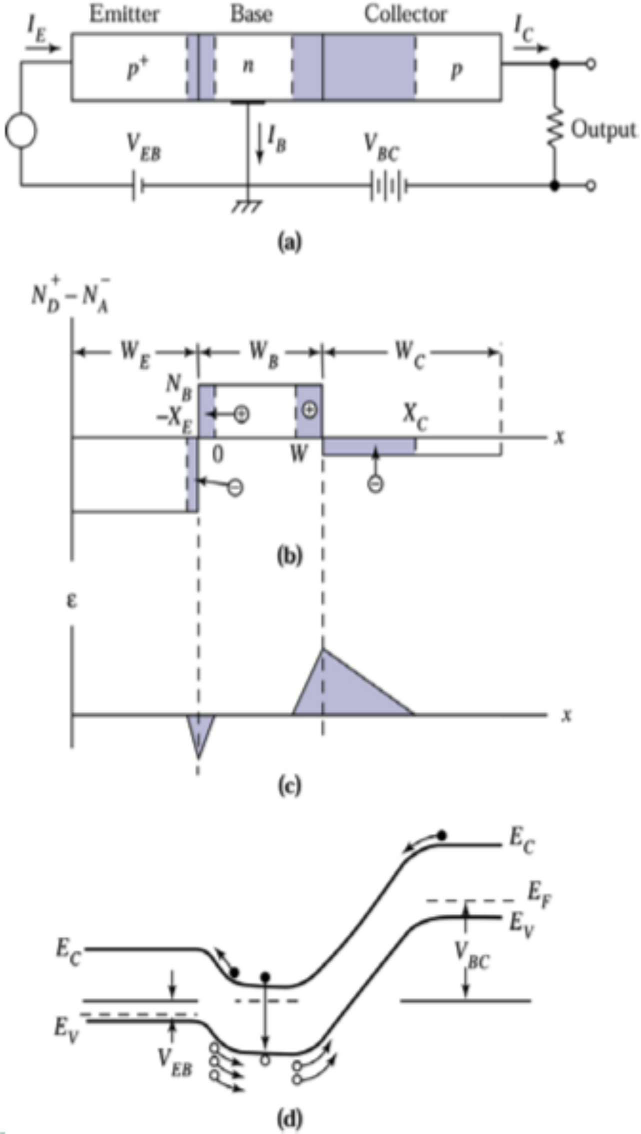
FYS4310 Bipolar Process Integration



Bipolar Transistor (no bias)

(*a*) A *p-n-p* transistor with all leads grounded (at thermal equilibrium). (*b*) Doping profile of a transistor with abrupt impurity distributions. (*c*) Electric-field profile. (*d*) Energy band diagram at thermal equilibrium.

Bipolar Quick repetition



Bipolar Transistor

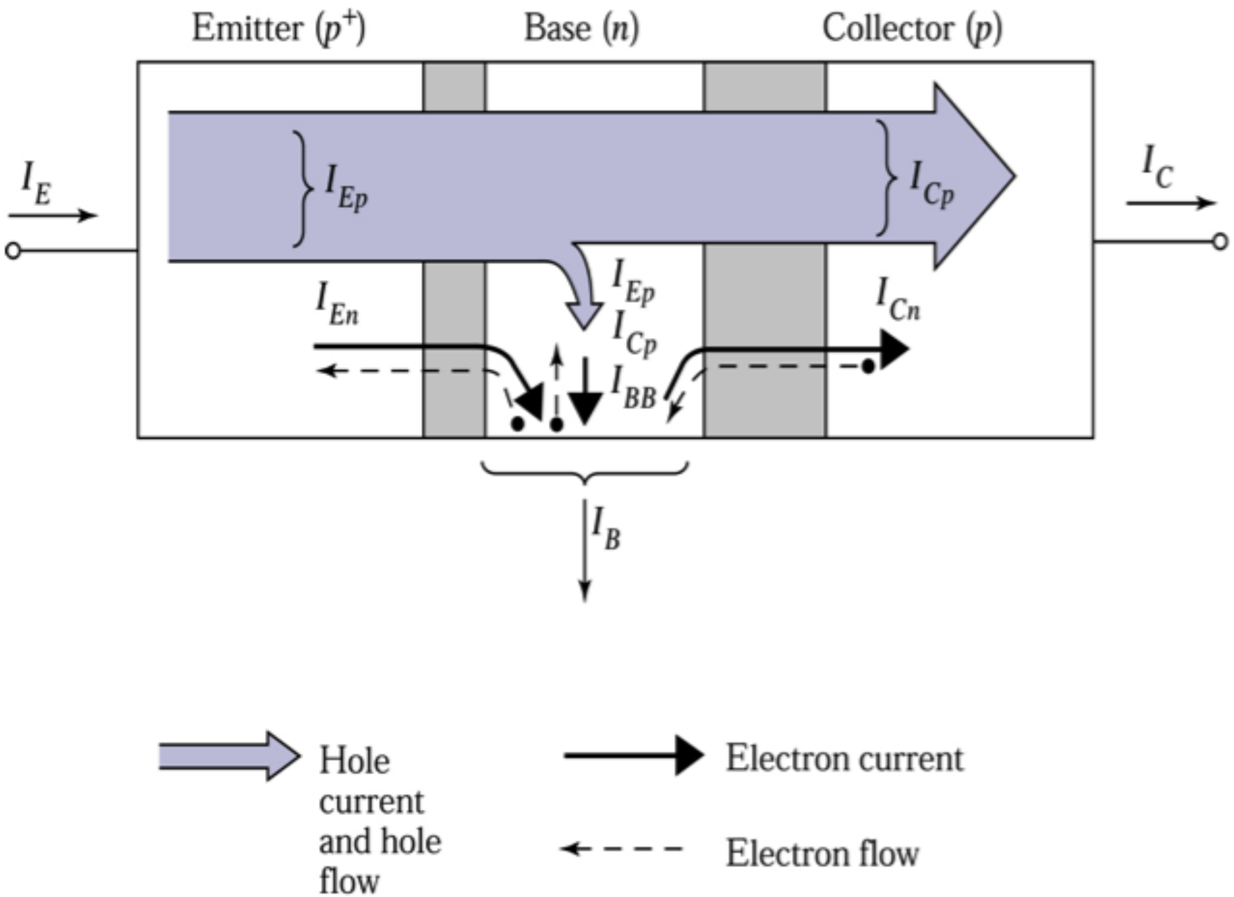
Active mode operation under bias

(a) The transistor is shown in this Figure under the active mode of operation. (*b*) Doping profiles and the depletion regions under biasing conditions. (*c*) Electric-field profile. (*d*) Energy band diagram.

Bipolar Quick repetition

Bipolar Transistor

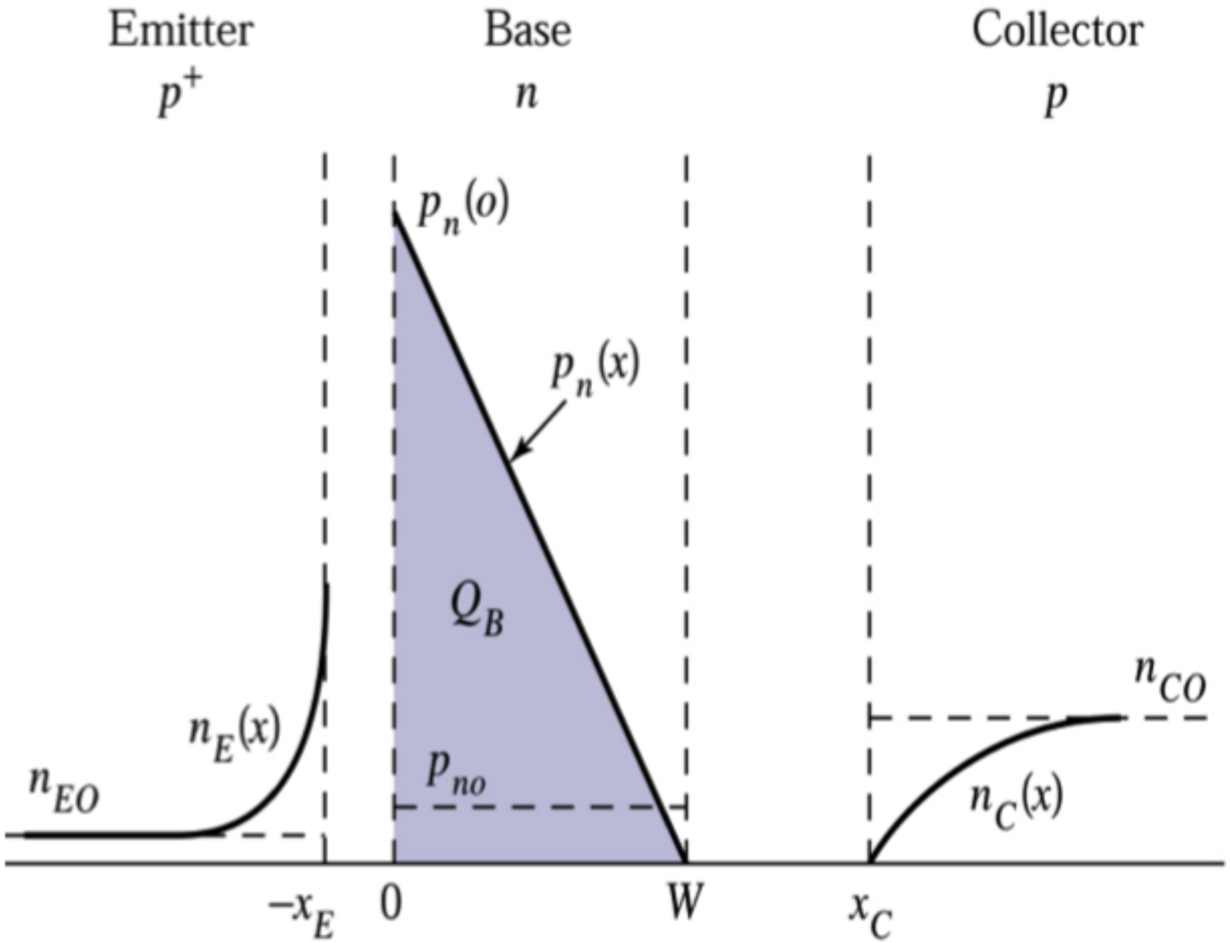
Current gain



Various current components in a *p-n-p* transistor under active mode of operation. The electron flow is in the opposite direction to the electron current.

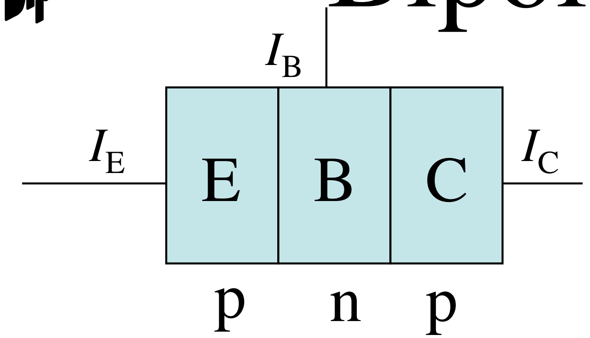
Bipolar Quick repetition

Carrier Distribution in Each Region



Minority carrier distribution in various regions of a *p-n-p* transistor under the active mode of operation.

Bipolar parameters



$I_C = \alpha I_E$ $I_E = I_C + I_B$

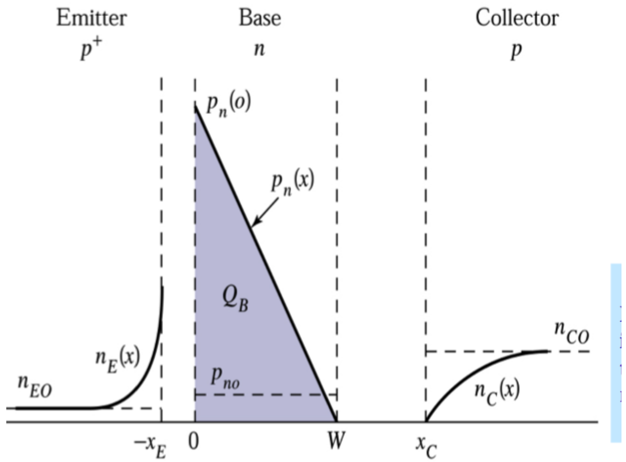
$I_C = \beta I_B$ $\beta = \alpha/(1-\alpha)$

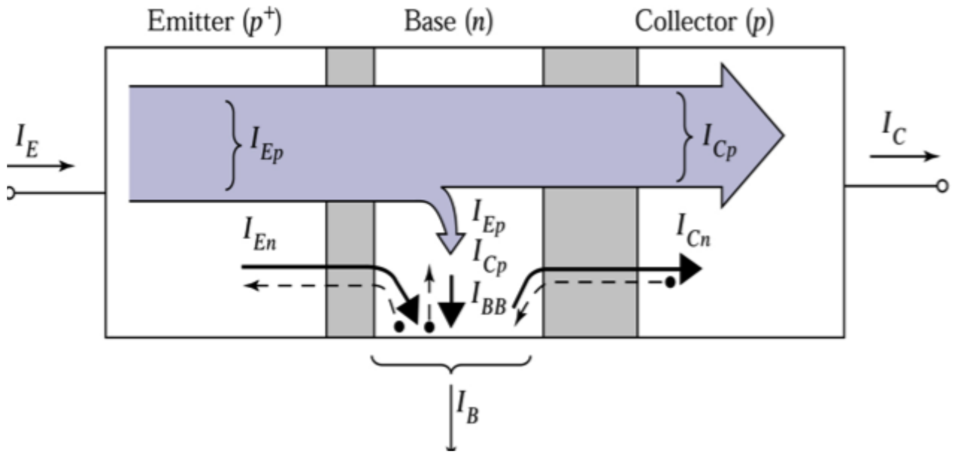
$I_C = \alpha_T \gamma \delta I_E$

α_T :Base transport factor

γ :Emitter injection efficiency

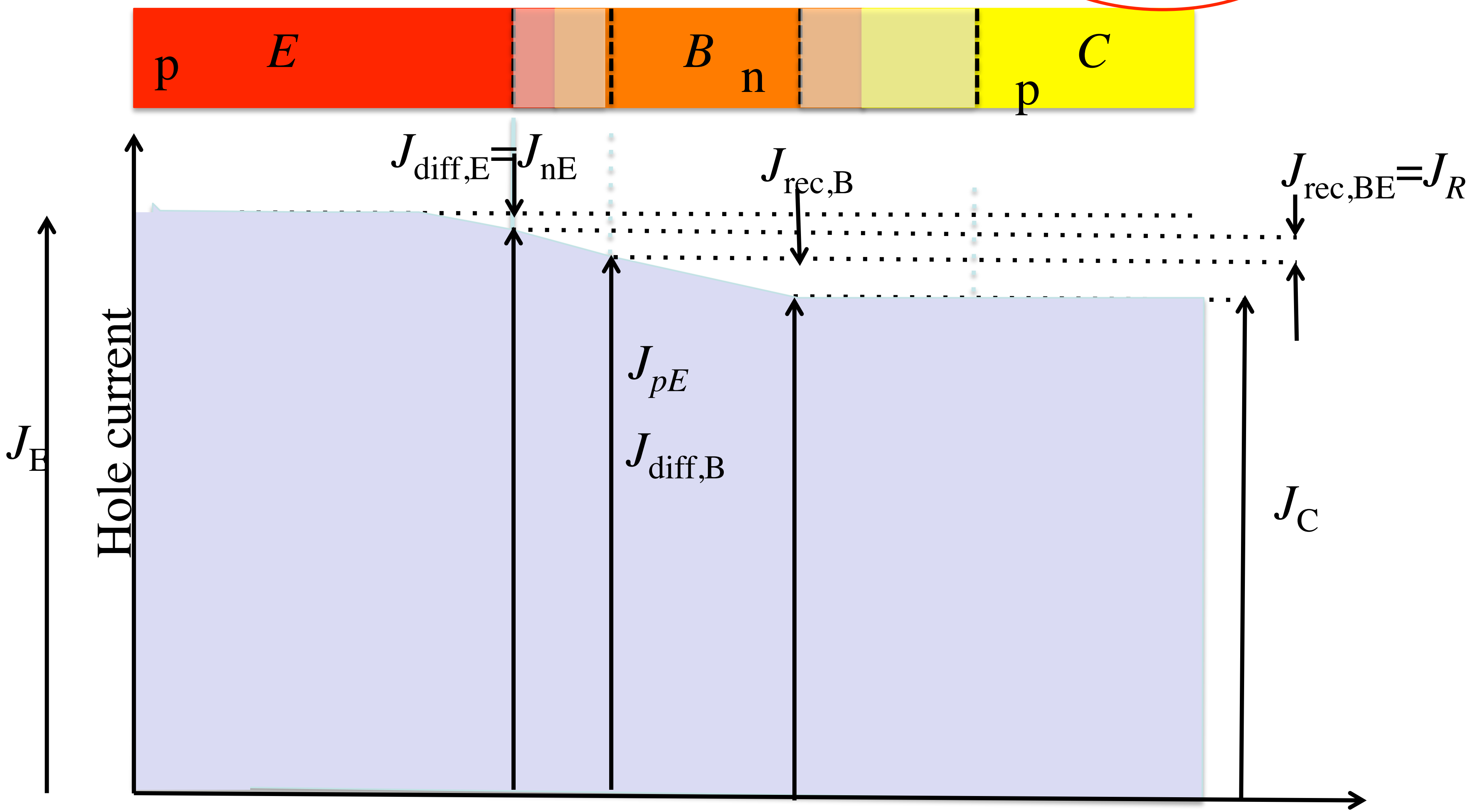
δ :Recombination factor





$$\text{DC} \quad \alpha_0 = \frac{J_C}{J_E} = \frac{J_{pC}+J_G+J_{nC0}}{J_{pE}+J_E+J_{nE}}$$

$$\text{AC} \quad \alpha = \frac{\partial J_C}{\partial J_E} = \frac{J_{pC}}{J_{pE}+J_R+J_{nE}} = \underbrace{\left(\frac{J_{pE}}{J_{pE}+J_{nE}}\right)}_{\gamma}\underbrace{\left(\frac{J_{pC}}{J_{pE}}\right)}_{\alpha_T}\underbrace{\left(\frac{J_{pE}+J_{nE}}{J_{pE}+J_{nE}+J_R}\right)}_{\delta}$$



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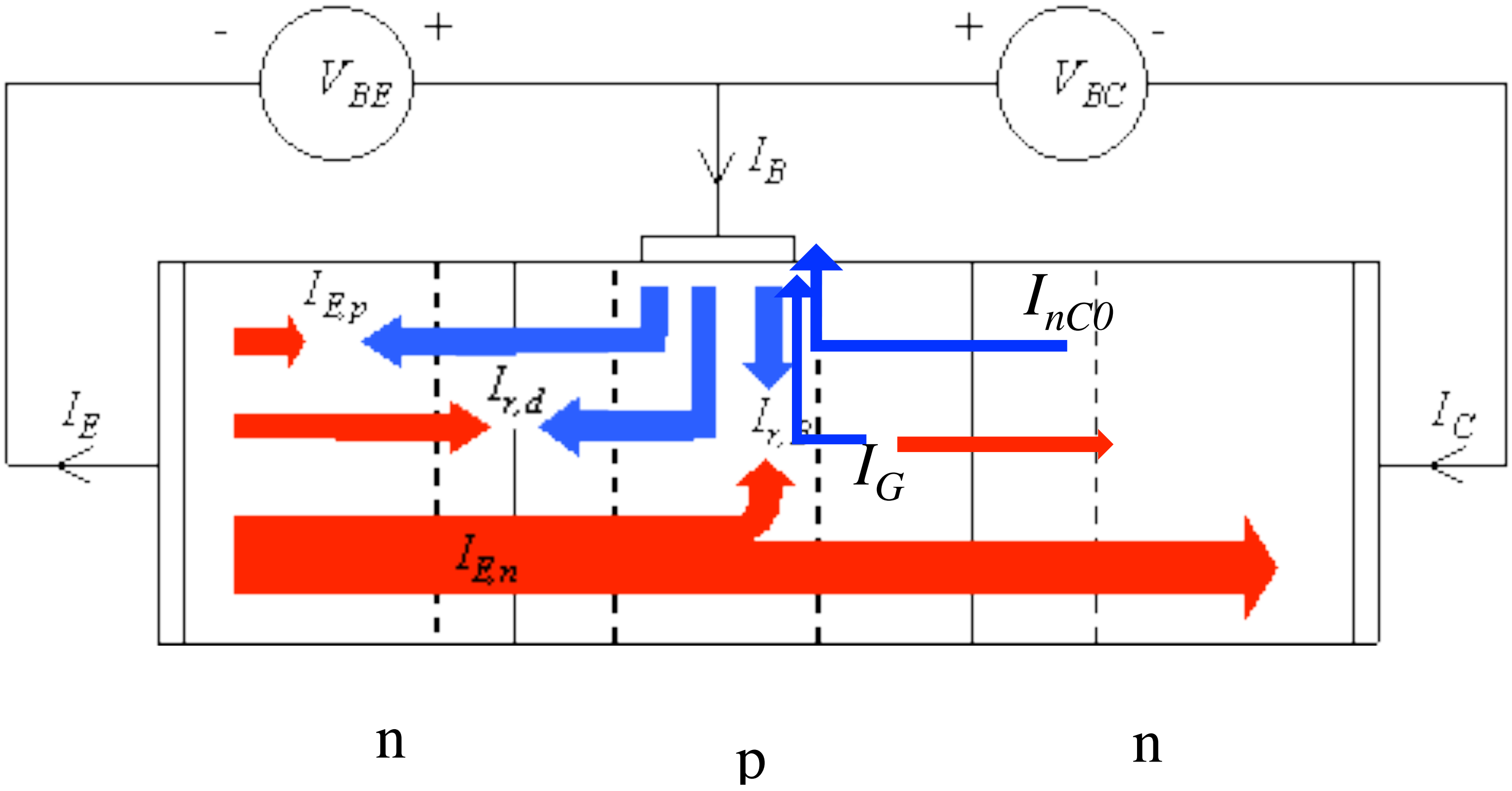
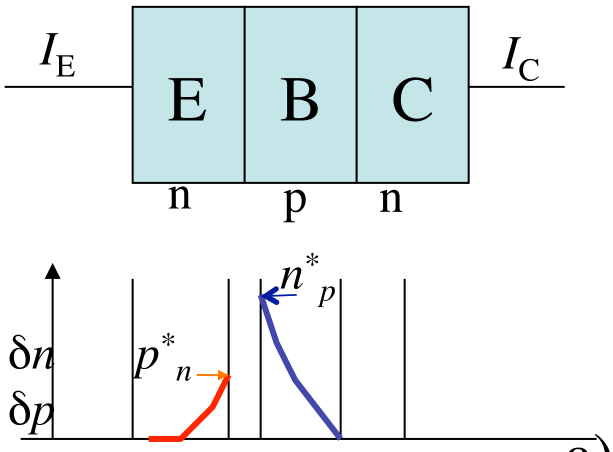


Emitter injection efficiency : γ



a)

b)

$$I_C = \alpha_T \gamma \delta I_E$$

$$\gamma = \frac{J_{nE}}{J_{pE} + J_{nE}}$$

$$J_{nE} = -D_{nB} \frac{\partial}{\partial x} n_p \bigg|_{x=0} = -D_{nB} \frac{n_{p0}\, e^{\frac{qV_{BE}}{kT}}}{W_B}$$

$$J_{pE} = \frac{D_{pE}\, p_{n0}\, e^{\frac{qV_{BE}}{kT}}}{L_{pE}}$$

$$\gamma = \frac{D_{nB}\, n_{p0}\, e^{\frac{qV_{BE}}{kT}}}{W_B \left(\frac{D_{nB}\, n_{p0}\, e^{\frac{qV_{BE}}{kT}}}{W_B} + \frac{D_{pE}\, p_{n0}\, e^{\frac{qV_{BE}}{kT}}}{L_{pE}} \right)} = \frac{1}{\frac{D_{pE} N_{AB} W_B}{D_{nB} L_{pE} N_{DE}} + 1}$$

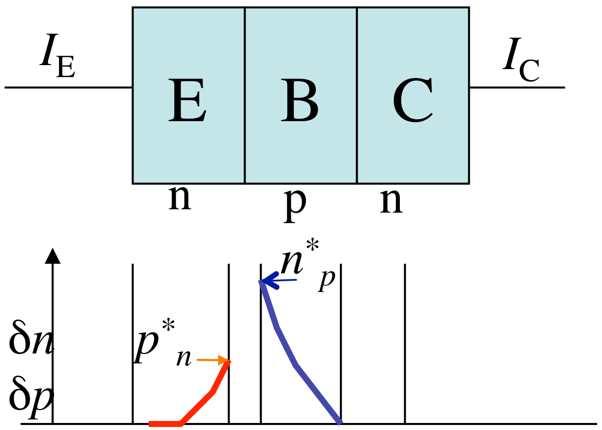
$\gamma = 1$

$n^*_p >> p^*_n$

$N_E >> N_B$

$W_E >> W_B$

Emitter injection efficiency : γ



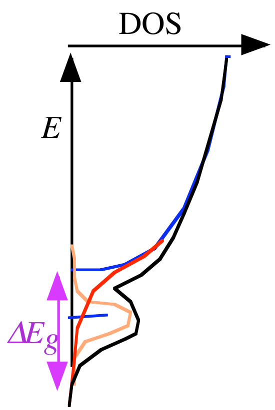
$I_C = \alpha_T \gamma\, \delta\, I_E$

$\gamma = 1$

$n^*_p >> p^*_n$

$N_E >> N_B$ a)

$W_E >> W_B$ b)

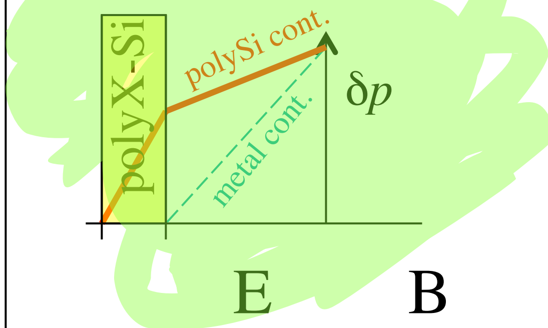


a) For very high emitter doping

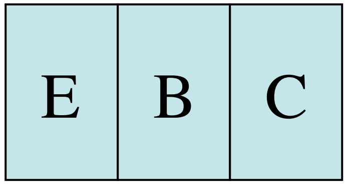
Band gap smaller, γ decreases

Heterojunction bipolar, E(Si), B(SiGe)

b) or poly emitter



Base transport factor : α_T



$\alpha_T = 1$

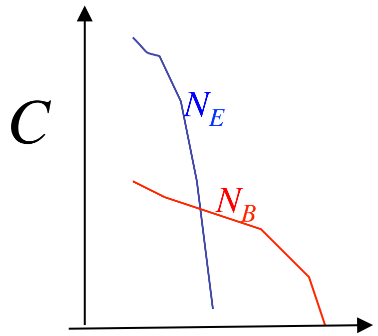
$I_C = \alpha_T \gamma \delta I_E$

W_B minimize

Limit: punch through, precision

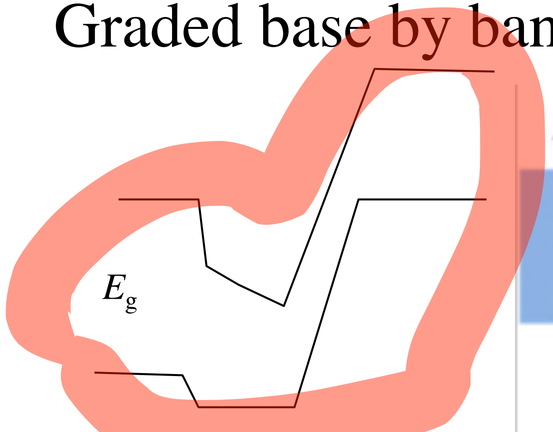
Also maximize speed

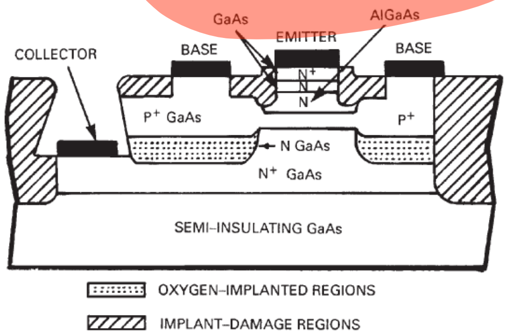
Graded base by doping

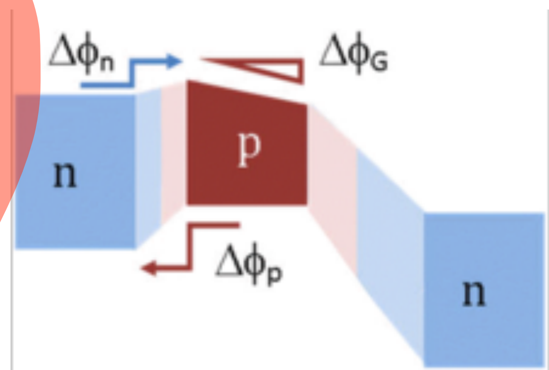


Gives electrical field in base

Graded base by band gap engineering







Bands in graded heterojunction npn bipolar transistor. Barriers indicated for electrons to move from emitter to base, and for holes to be injected backward from base to emitter; Also, grading of bandgap in base assists electron transport in base region; Light colors indicate depleted regions

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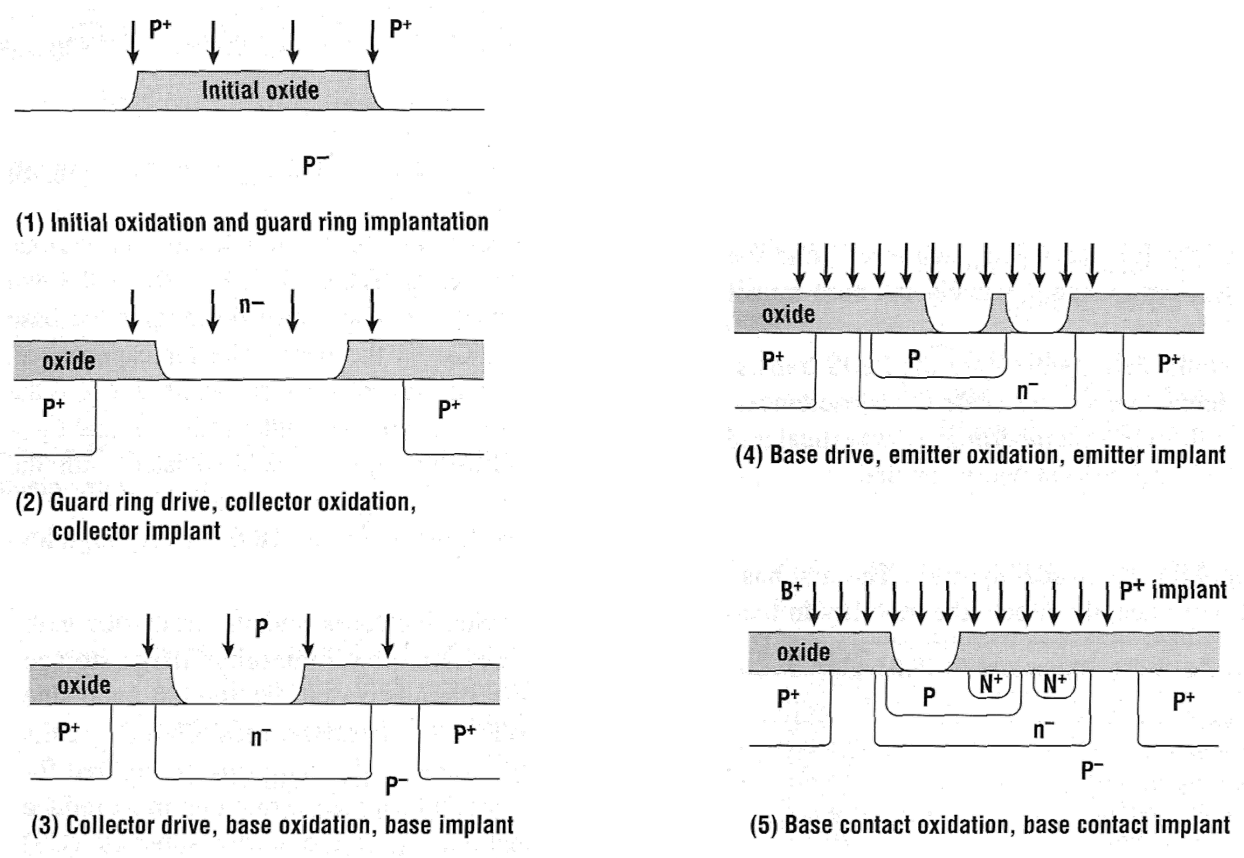
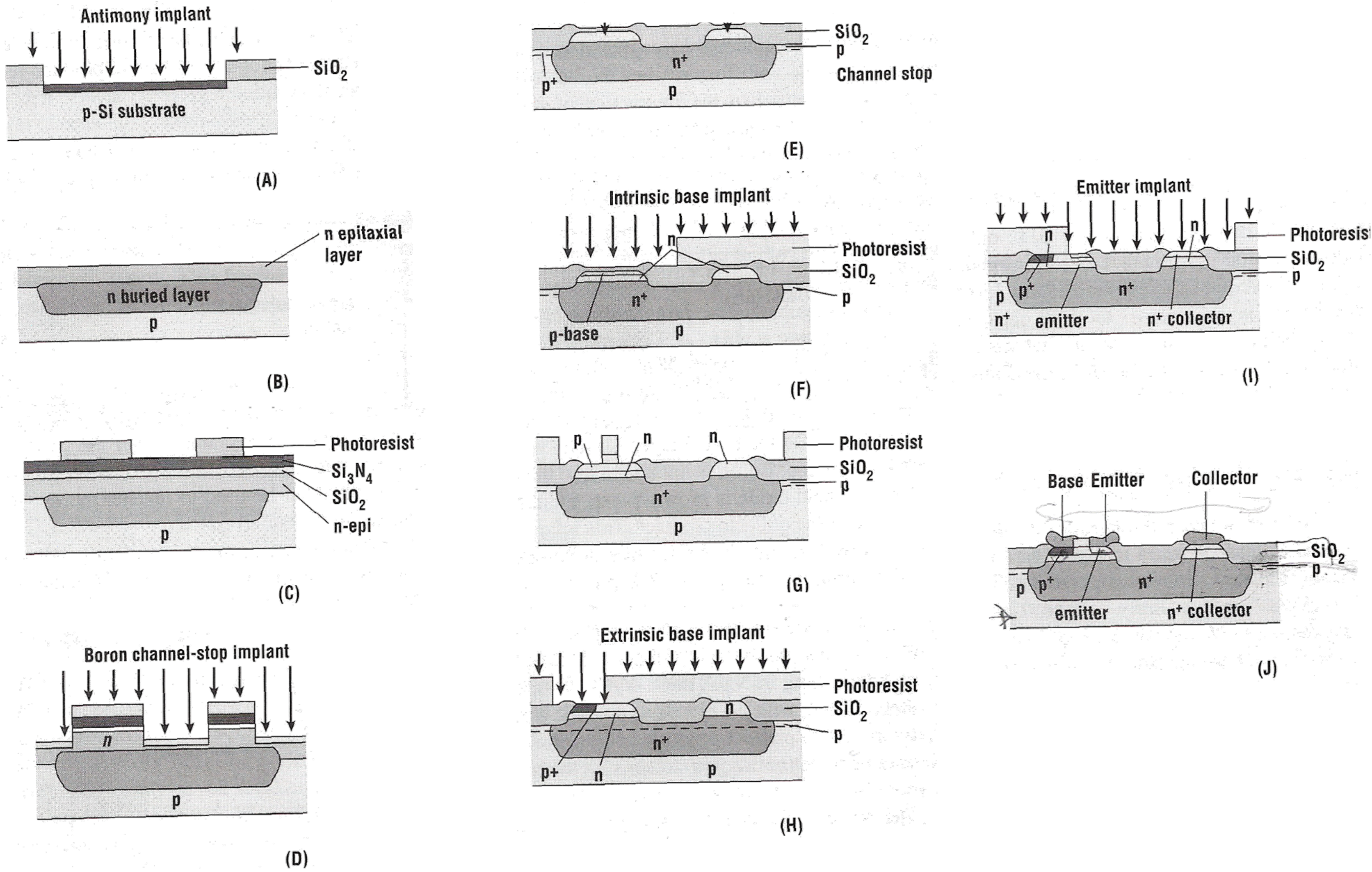
Figure 17.17 Process flow for a simple junction isolated triple diffused bipolar technology.



Oxide isolated triple diffused bipolar

Figure 17.19 Process flow for an oxide isolated triple-diffused bipolar technology without sinkers. Steps i A) buried layer formation, (B) epitaxial growth, (C) LOCOS patterning, (D) silicon recessing and channel stop implants, (E)local oxidation, (F) intrinsic base implant, (G) contact mask, (H) extrinsic base implant, (I) emitter and collector contact implant, and (J) metallization *(after Sze, reprinted by permission of John Wiley & Sons).*



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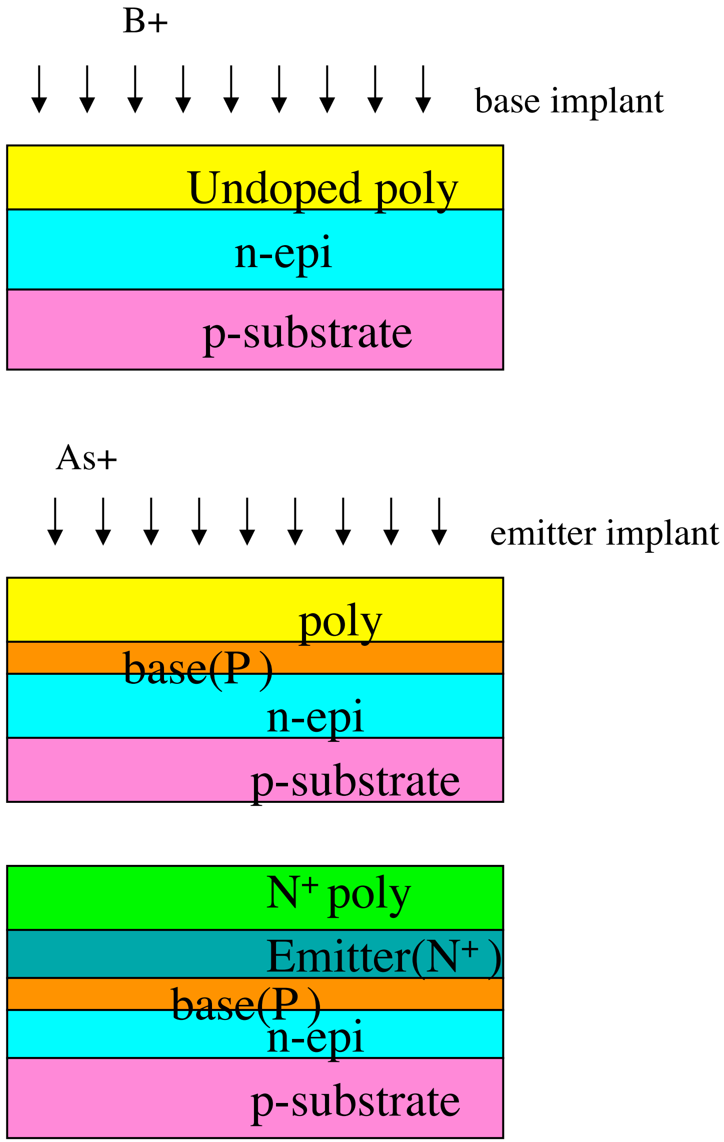
PolySi as diffusion source
For shallow junctions

Implant in Poly



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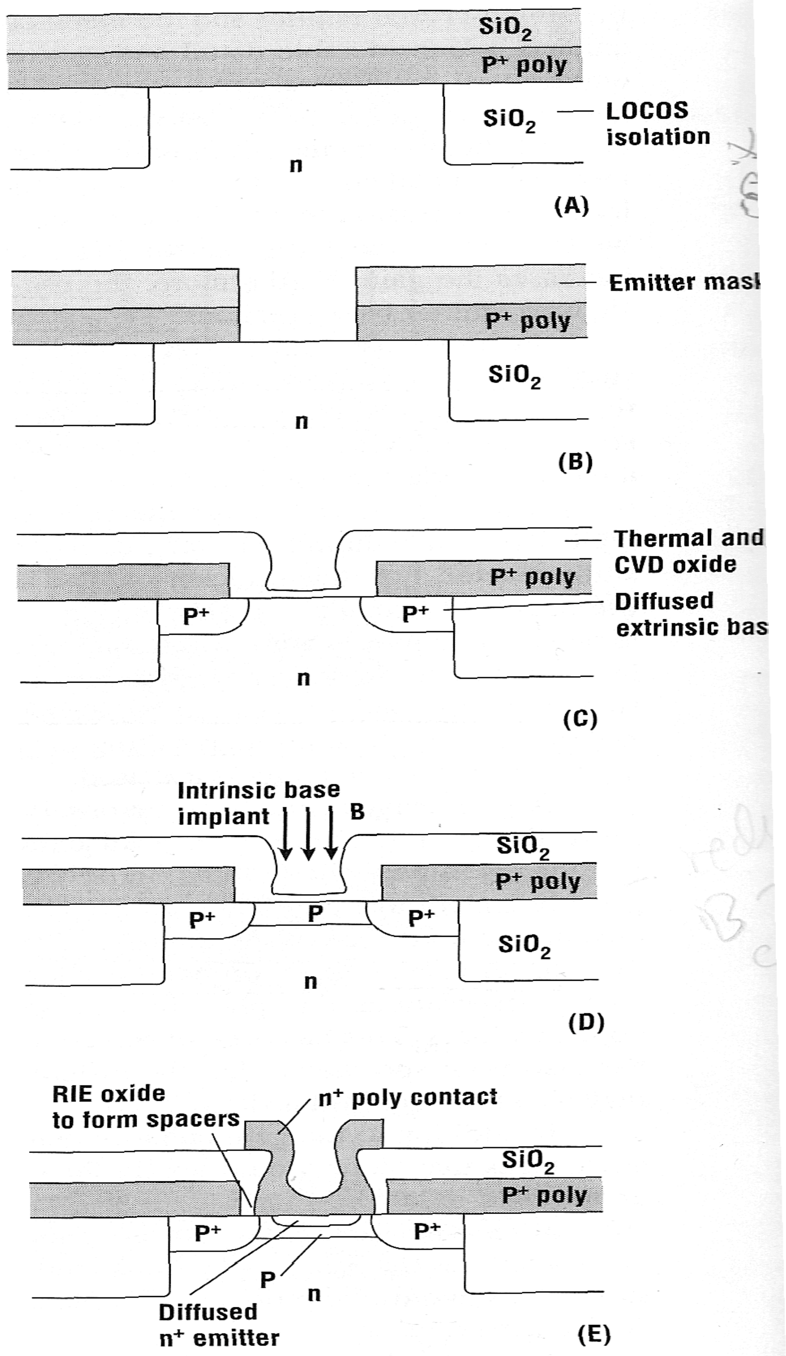
Bipolar Process Integration

Self –aligned doubly-poly bipolar

Reduces base-collector capacitance
Also much reduced footprint

The emitter stripe width is less than the minimum lithographic feature width,
typical it is 0.3 μm for 0.5 μm lithography

LOCOS oxide isolated



igure 18.11 Simple process flow for a self-aligned ouble-poly bipolar technology.

Self –aligned doubly-poly lateral bipolar

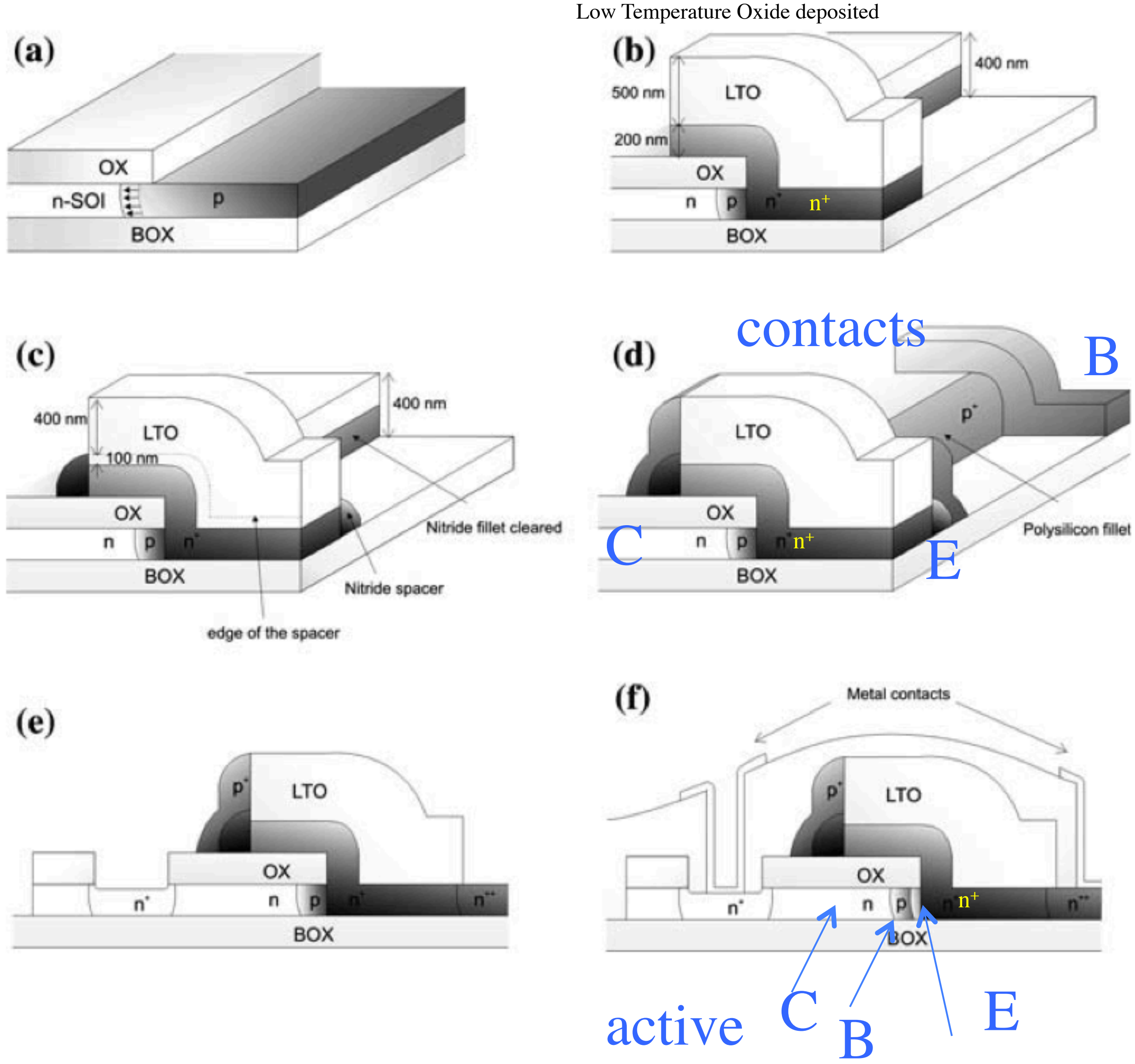
P. Pengpad · D. M. Bagnall

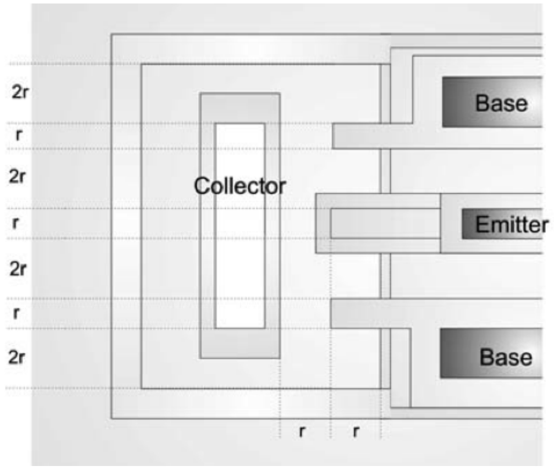
J Mater Sci: Mater Electron (2008) 19:183–187
DOI 10.1007/s10854-007-9300-y

SOI
LBJT Lateral BJT

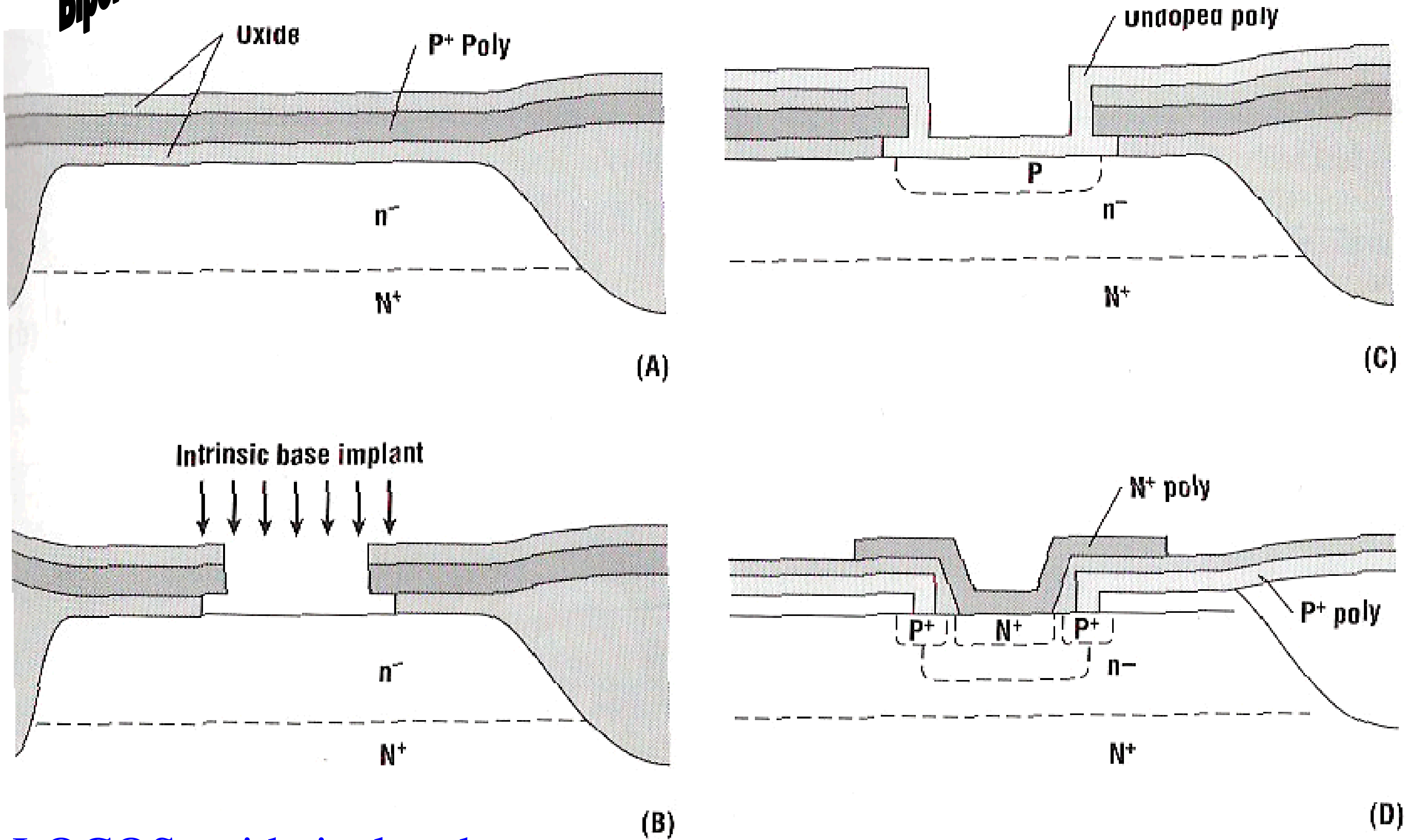
Reduces substrate capacitance
Oscillation freq 128 GHz

Transistor dimensions down to
(0.2–0.5) · (0.13–0.25) μm^2





“Antipov” emitter bipolar



LOCOS oxide isolated

Figure 18.14 The super self-aligned or Antipov emitter bipolar transistor.

Bipolar Process Integration

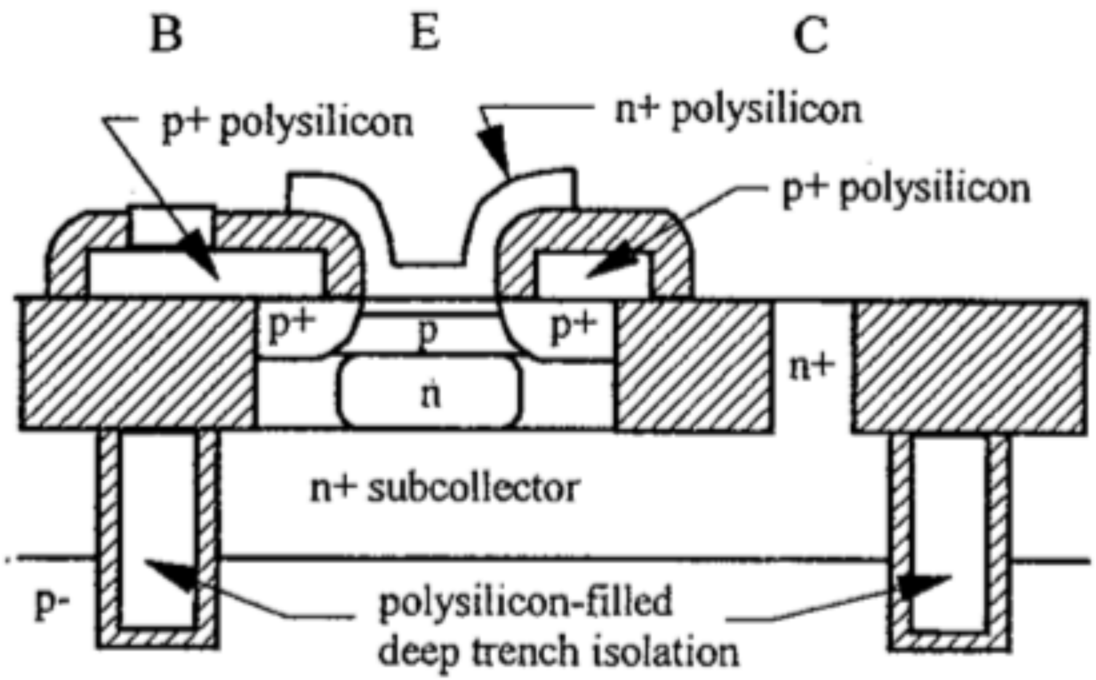
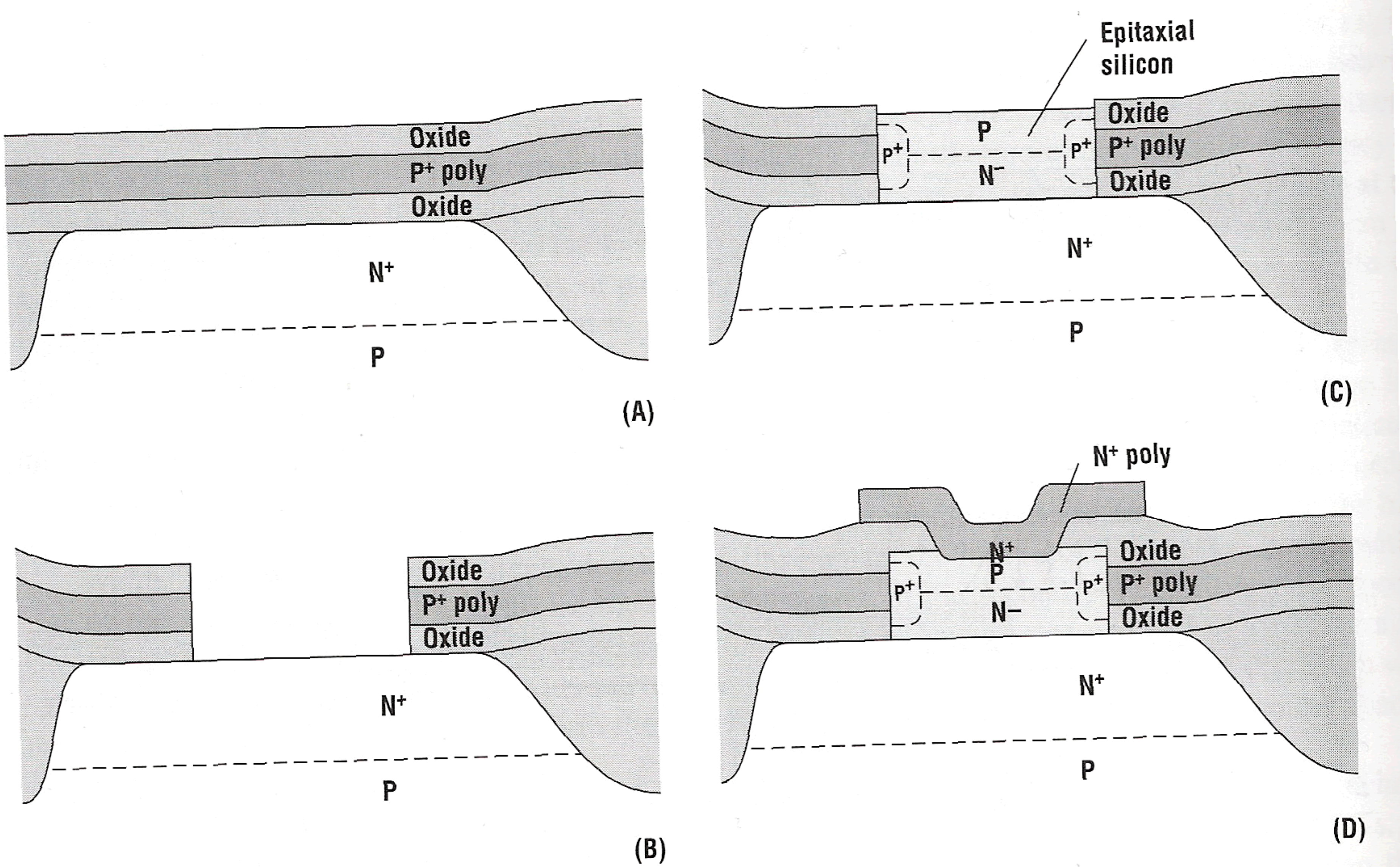


Fig. 1. Schematic cross-sectional view of a trench-isolated double-polysilicon self-aligned bipolar transistor with a pedestal collector (advanced bipolar transistor).

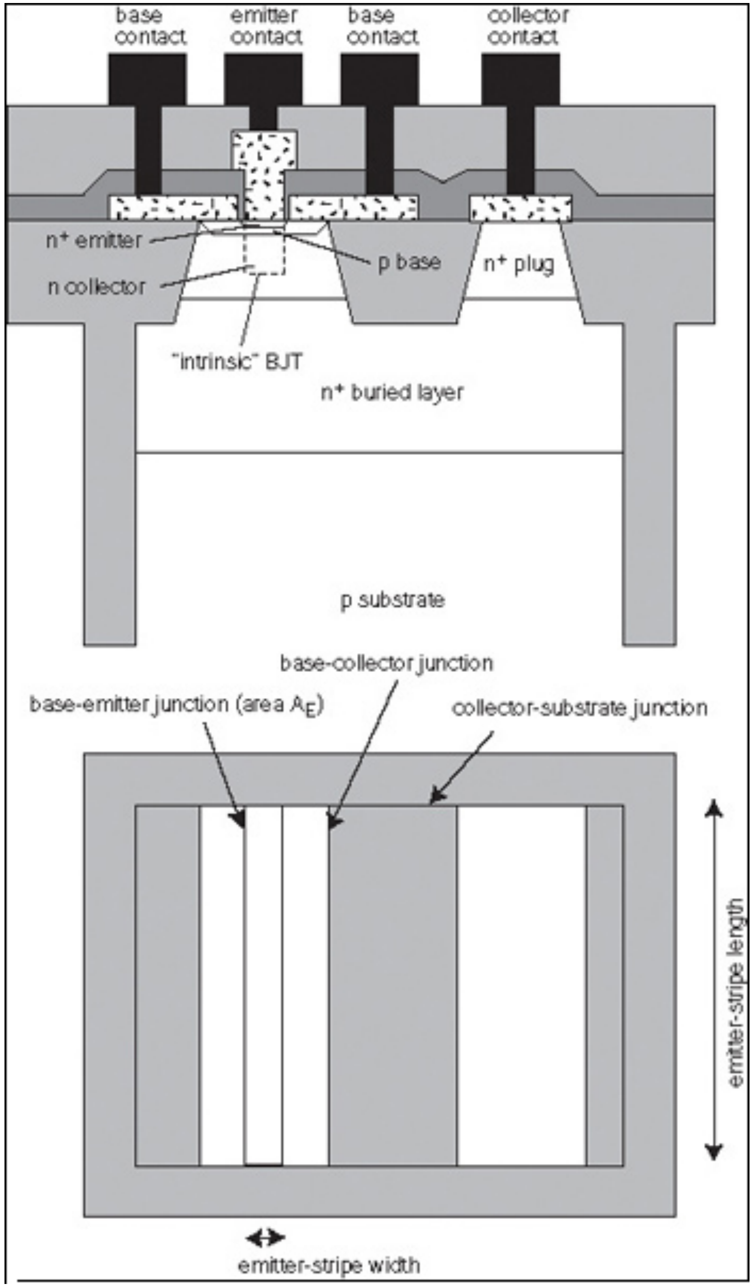
Trench isolated

Bipolar Process Integration

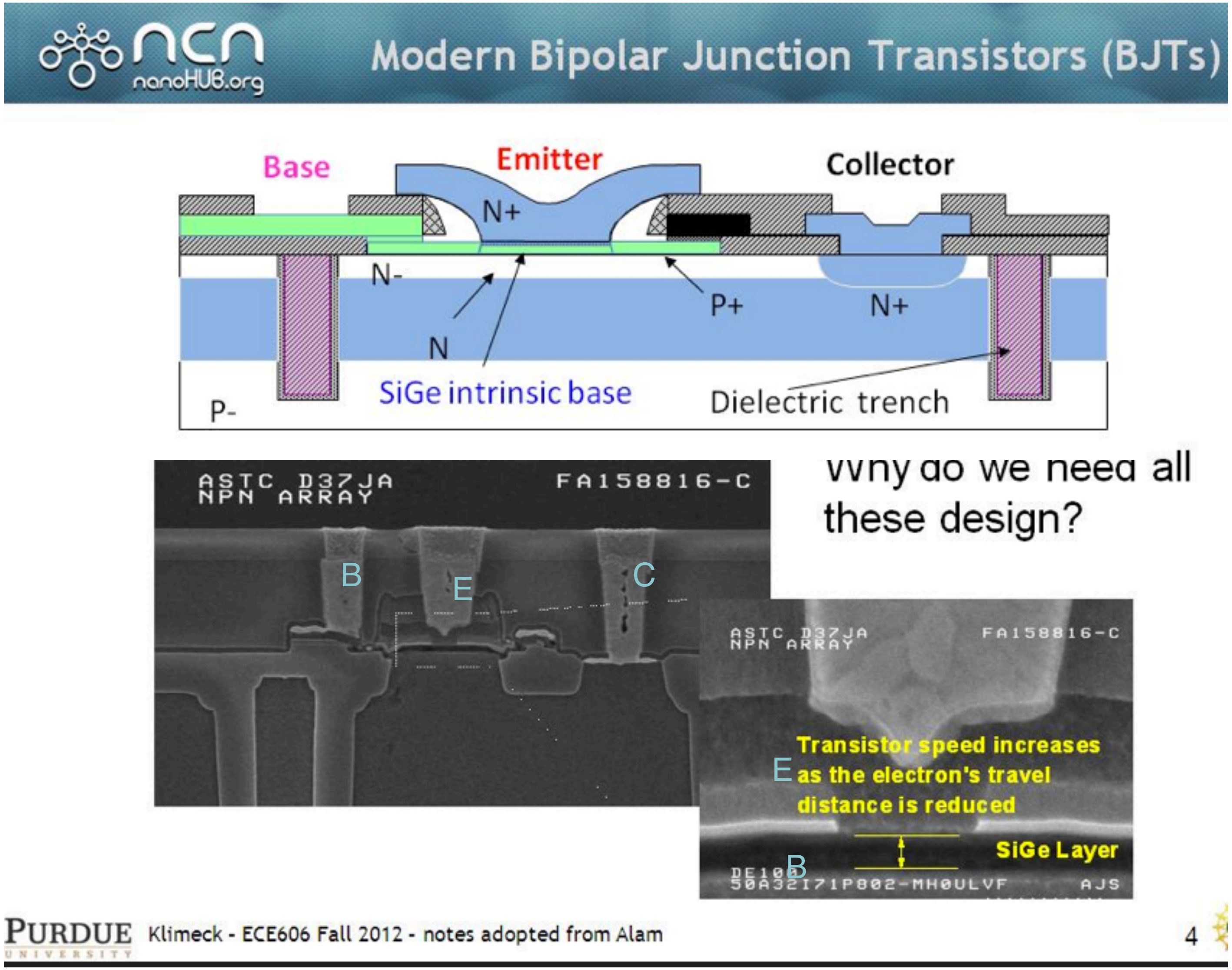


LOCOS oxide isolated

Trench isolated



Trench isolated SiGe



PRETTY? PICTURE

Amazing!

SiGe