LECTURE 170 – PASSIVE COMPONENTS IN BIPOLAR ICs
(READING: Text-Sec. 2.6 and 2.7)

INTRODUCTION

Objective

- Demonstrate the passive components compatible with BJT technology

Outline

- Resistors
- Capacitors
- High-performance active devices compatible with BJT technology

Cross-Section of an NPN BJT

All passive components must be compatible with this structure.

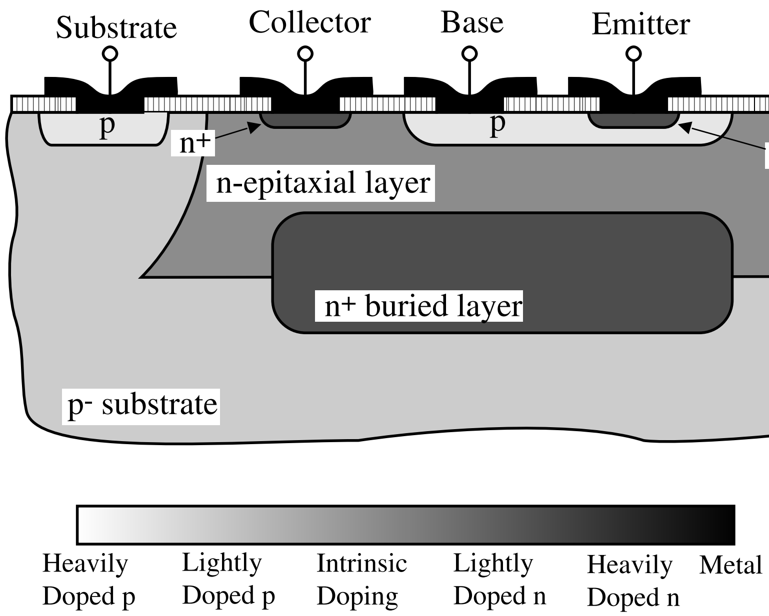


Fig170-01

INTEGRATED CIRCUIT RESISTORS

Resistor Layout

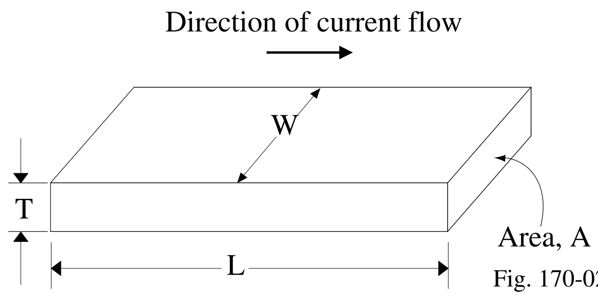


Fig. 170-02

Resistance of a conductive sheet is expressed in terms of

$$R = \frac{\rho L}{A} = \frac{\rho L}{WT} \ (\Omega)$$

where

ρ = resistivity in Ω-m

Ohms/square:

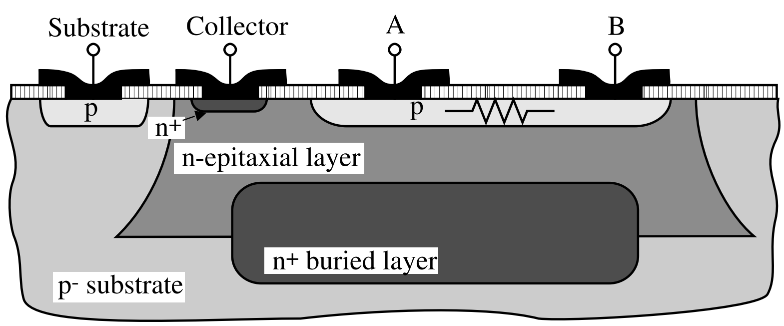
$$R = \left(\frac{\rho}{T}\right)\frac{L}{W} = \rho_S \frac{L}{W} \ (\Omega)$$

where

ρ_S is a sheet resistivity and has the units of ohms/square

Base and Emitter Diffused Resistors

Cross-section of a Base Resistor:



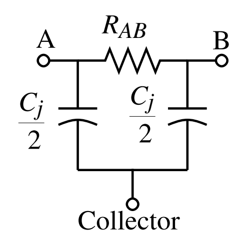


Fig. 170-03

Comments:

Sheet resistance ≈ 100 Ω/sq. to 200 Ω/sq.

TCR = +1500ppm/°C

Note:

$$\frac{1\%}{°C} = \frac{10^4}{°C}$$

Emitter Resistor:

Sheet resistance ≈ 2 Ω/sq. to 10 Ω/sq. (Generally too small to make sufficient resistance in reasonable area)

TCR = +600ppm/°C

Epitaxial Resistors

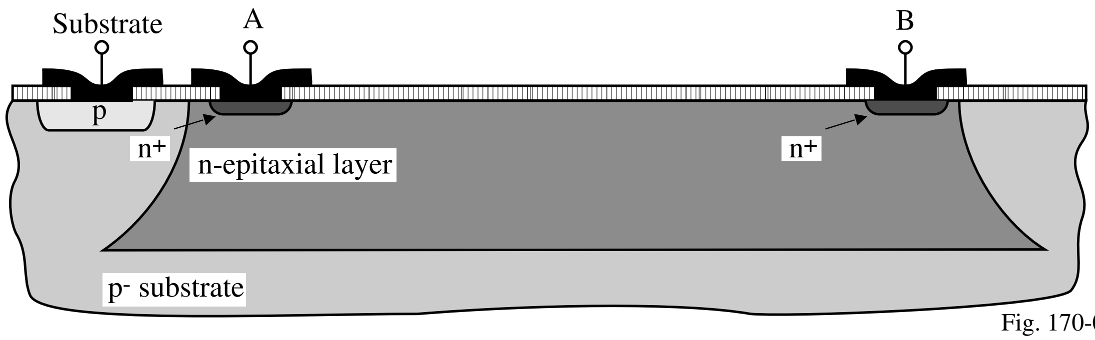


Fig. 170-04

Typical resistance is 2-5kΩ/sq.

Epitaxial Pinched Resistor

Good for large values of sheet resistance.

Cross-section:

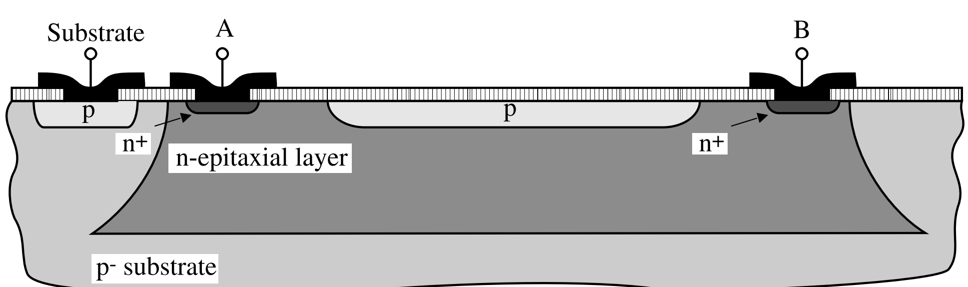


Fig 170-05

IV Curves and Model:

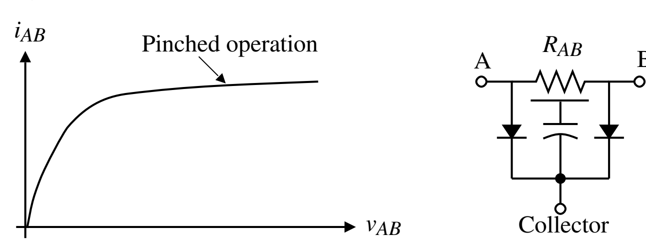


Fig. 170-06

Comments:

Sheet resistance is 4 to 10kΩ/sq.

Voltage across the resistor is limited to 6V or less because of breakdown

TCR ≈ 2500ppm/°C

Epitaxial Pinched Resistors

Cross section:

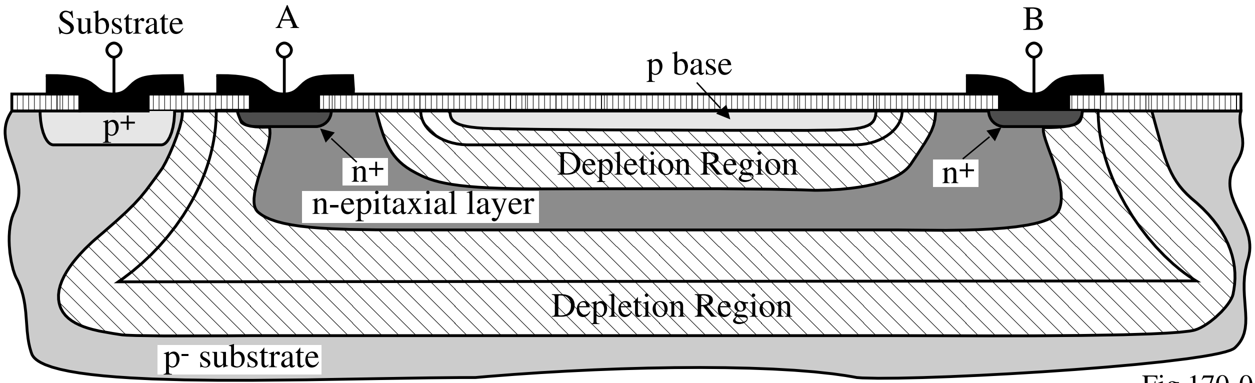


Fig 170-05

Sheet resistance ≈ 4-10kΩ/sq.

Top View:

Fig 170-07

Collector-Base Capacitance (C_μ)

Illustration:

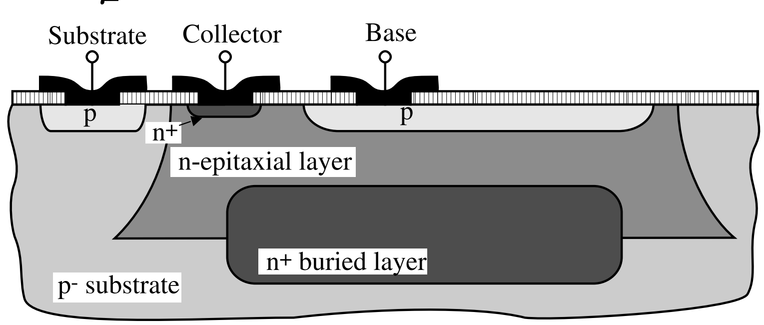


Fig. 170-08A

Model:

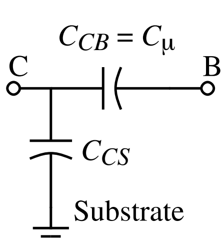


Fig 170-08B

Sidewall contribution:

$$A_{sidewall} = P \cdot d \frac{\pi}{2}$$

where

P = perimeter of the capacitor

d = depth of the diffusion

Values (Includes the bottom plus sidewall capacitance):

$C_\mu \approx 1\text{fF}/\mu\text{m}^2$ (dependent on the reverse bias voltage)

Can also have base-emitter capacitance and collector-substrate capacitance

PN Junction Capacitors

Generally made by diffusion into the well.

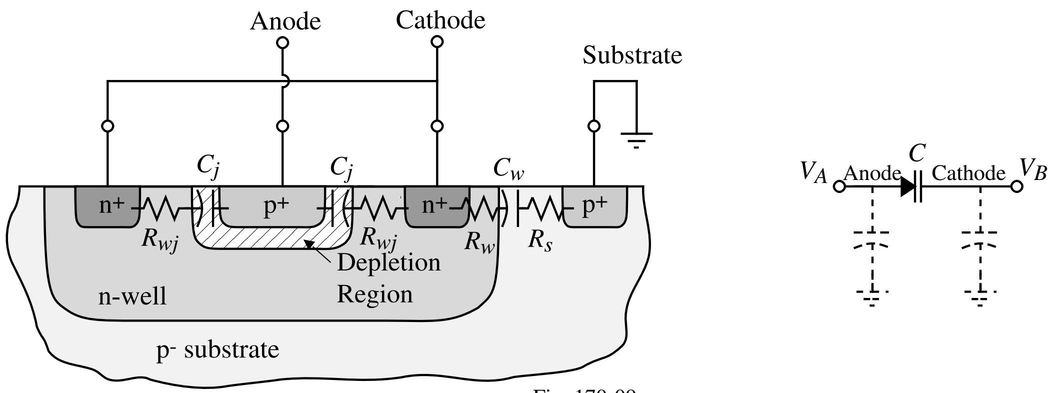


Fig. 170-09

Layout:

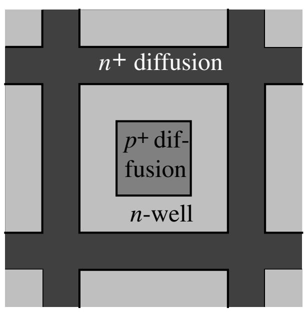


Fig. 170-10

Minimize the distance between the $p+$ and $n+$ diffusions.

Two different versions have been tested.

- Large islands – 9μm on a side
- Small islands – 1.2μm on a side

PN-Junction Capacitors – Continued

It can be shown that the anode should be the floating node and the cathode must be connected to ac ground.

Experimental data (Q at 2GHz, 0.5μm CMOS):

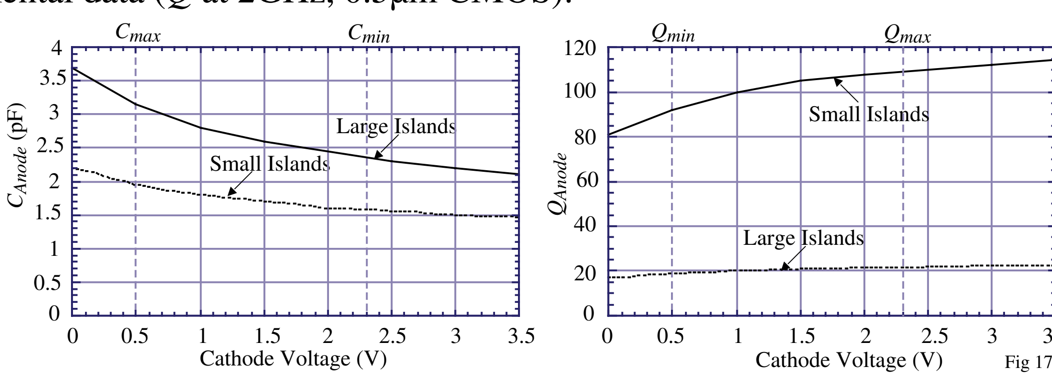


Fig 170-11

Summary:

Terminal Under Test	598 1.2μm x 1.2μm islands			42 9μm x 9μm islands		
	C_{max}/C_{min}	Q_{min}	Q_{max}	C_{max}/C_{min}	Q_{min}	Q_{max}
Anode	1.23	94.5	109	1.32	19	22.6
Cathode	1.21	8.4	9.2	1.29	8.6	9.5

Electrons as majority carriers lead to higher Q because of their higher mobility.
Also, the resistance, R_{wj}, is reduced in the small islands compared with the large islands giving higher Q.

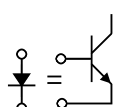
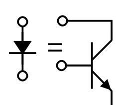
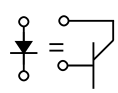
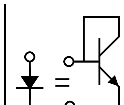
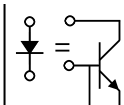
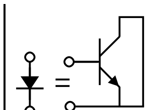
Integrated Circuit Passive Component Performance Summary

Component Type	Range of Values	Absolute Accuracy	Relative Accuracy	Temperature Coefficient	Voltage Coefficient
Base Diffused	100-200Ω/sq.	±20%	0.2%	+1750ppm/°C	-
Emitter Diffused	2-10Ω/sq.	±20%	±2%	+600ppm/°C	-
Epitaxial	2k-5kΩ/sq.	±50%	±10%	+2500ppm/°C	Poor
Epitaxial Pinched	4k-10kΩ/sq.	±50%	±7%	+3000ppm/°C	Poor
Thin Film	0.1k-2kΩ/sq.	±5-±20%	±0.2-±2%	±10 to ±200ppm/°C	-

DIODES

BJT Diode

Different configurations

Diode	 Fig 170-12A	 Fig 170-12B	 Fig 170-12C	 Fig 170-12D	 Fig 170-12E	 Fig 170-12F
Condition	$I_C = 0$	$I_E = 0$	$I_E = 0$ no emitter	$V_{CB} = 0$	$V_{EB} = 0$	$V_{CE} = 0$
Series Resistance	r_{bb}'	$r_{bb}' + r_{cc}'$	$r_{bb}' + r_{cc}'$	r_{bb}'/β	$r_{bb}'/\beta + r_{cc}'$	r_{bb}'
V_F @10mA	960mV	950mV	950mV	850mV	940mV	920mV
Breakdown Voltage	BV_{EBO}	BV_{CBO}	BV_{CBO}	BV_{EBO}	BV_{CBO}	BV_{EBO}
Storage Time	≈70ns	≈130ns	≈80ns	≈6ns	≈90ns	≈150ns

Base-collector shorted BJT is the most attractive diode for most applications.

Dielectric Isolation

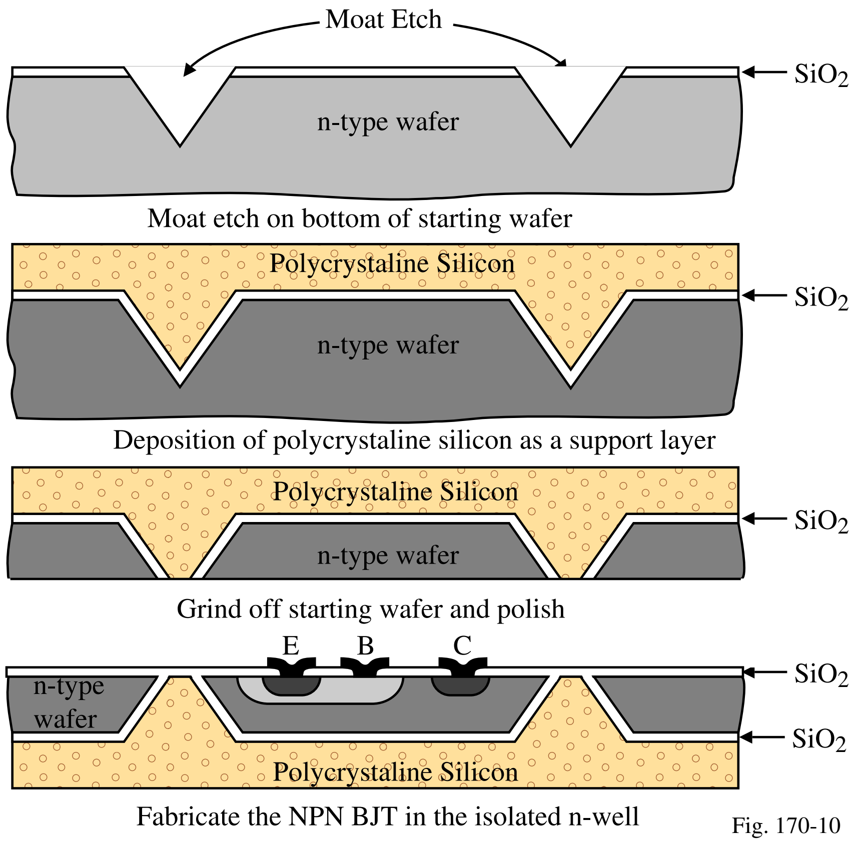


Fig. 170-10

Compatible High-Performance Transistors

- Superbeta transistors

  Allow the emitter diffusion to almost reach the collector side of the base creating a very small base width. Reduces the breakdown voltage but increases β to as much as 2000 to 5000.

- p-channel MOS transistor

  Use the base diffusions to create the source and drain in an n-epitaxial island and thin oxide and metal to form the gate.

- Double-diffused pnp transistors

  Diffuse a p collector into the n-epitaxial region along with a n-diffusion for the base and a heavily doped p diffusion for the emitter.

SUMMARY

- Showed passive components that were compatible with bipolar IC technology
- Capacitors use pn-junctions and are depletion capacitors
- Resistors include:
  - Base/emitter diffused
  - Epitaxial
  - Epitaxial pinched
- Diodes
  - Base-collector shorted diode is the best choice for most applications
- Modifications to the standard bipolar technology include:
  - Dielectric isolation
  - High-performance transistors

