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.
### Integrated Circuit Resistors

#### Resistor Layout

![Resistor Layout Diagram](image)

Resistance of a conductive sheet is expressed in terms of

\[ R = \frac{\rho L}{A} = \frac{\rho L}{WT} \quad (\Omega) \]

where

\[ \rho = \text{resistivity in } \Omega \cdot \text{m} \]

Ohms/square:

\[ R = \left( \frac{\rho S}{T} \right) \frac{L}{W} = \rho S \frac{L}{W} \quad (\Omega) \]

where

\[ \rho S \] is a sheet resistivity and has the units of ohms/square

### Base and Emitter Diffused Resistors

#### Cross-section of a Base Resistor:

![Base and Emitter Diffused Resistors](image)

Comments:

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

TCR = +1500 ppm/°C

Note:

\[ 1\% \frac{1}{^\circ C} = 10^4 \frac{1}{^\circ C} \]

Emitter Resistor:

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

TCR = +600 ppm/°C
Epitaxial Resistors

Typical resistance is 2-5kΩ/sq.

Epitaxial Pinched Resistor

Good for large values of sheet resistance.

Cross-section:

IV Curves and Model:

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:

Sheet resistance ≈ 4-10kΩ/sq.

Top View:

Collector-Base Capacitance ($C_\mu$)

Illustration:

Model:

Sidewall contribution:

Values (Includes the bottom plus sidewall capacitance):

Can also have base-emitter capacitance and collector-substrate capacitance
**PN Junction Capacitors**

Generally made by diffusion into the well.

![Diagram of PN Junction Capacitors](image1)

**Layout:**

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):

![Graph of Capacitance and Quality Factor](image2)

**Summary:**

<table>
<thead>
<tr>
<th>Terminal Under Test</th>
<th>Large Islands</th>
<th>Small Islands</th>
</tr>
</thead>
<tbody>
<tr>
<td>$C_{max}/C_{min}$</td>
<td>0.598</td>
<td>1.2</td>
</tr>
<tr>
<td>$Q_{min}$</td>
<td>1.23</td>
<td>1.21</td>
</tr>
<tr>
<td>$Q_{max}$</td>
<td>94.5</td>
<td>9.2</td>
</tr>
</tbody>
</table>

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

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

### DIODES

**BJT Diode**

Different configurations

<table>
<thead>
<tr>
<th>Diode</th>
<th>Condition</th>
<th>Series Resistance</th>
<th>$V_F$ @10mA</th>
<th>Breakdown Voltage</th>
<th>Storage Time</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$I_C = 0$</td>
<td>$r_{bb'}$</td>
<td>960mV</td>
<td>$B V_{EBO}$</td>
<td>≈70ns</td>
</tr>
<tr>
<td></td>
<td>$I_E = 0$</td>
<td>$r_{bb'} + r_{cc'}$</td>
<td>950mV</td>
<td>$B V_{CBO}$</td>
<td>≈130ns</td>
</tr>
<tr>
<td></td>
<td>$I_E = 0$ no emitter</td>
<td>$r_{bb'}/\beta$</td>
<td>950mV</td>
<td>$B V_{CBO}$</td>
<td>≈80ns</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$r_{bb'}/\beta + r_{cc'}$</td>
<td>850mV</td>
<td>$B V_{EBO}$</td>
<td>≈6ns</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$r_{bb'}$</td>
<td>940mV</td>
<td>$B V_{CBO}$</td>
<td>≈90ns</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>920mV</td>
<td>$B V_{EBO}$</td>
<td>≈150ns</td>
</tr>
</tbody>
</table>

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

Moat Etch

![Diagram of Moat Etch and Dielectric Isolation](image)

Dielectric isolation involves the creation of an isolated n-well with a moat etch, deposition of polycrystalline silicon as a support layer, and fabricating the NPN BJT in the isolated n-well. Figure 170-10 illustrates these steps.

**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 $\beta$ 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