



# LECTURE 19

-BJT

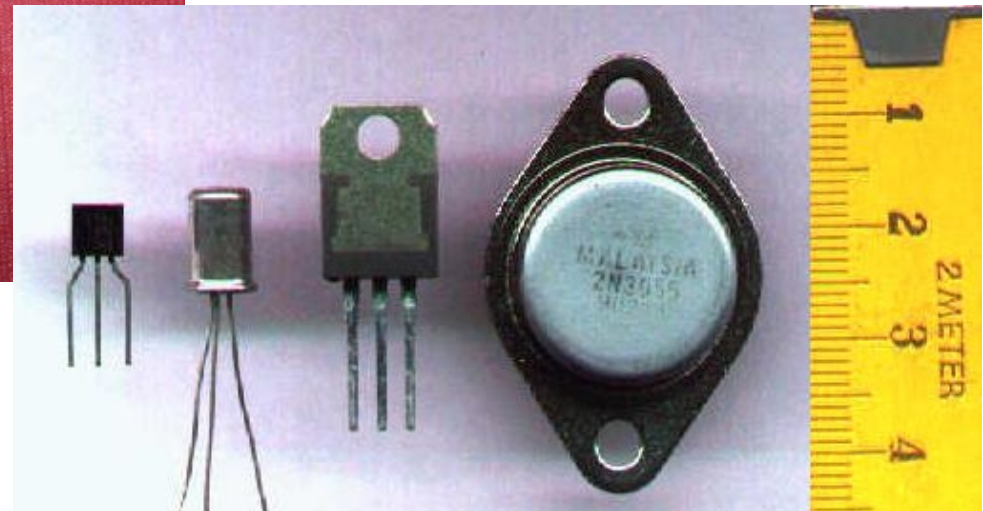
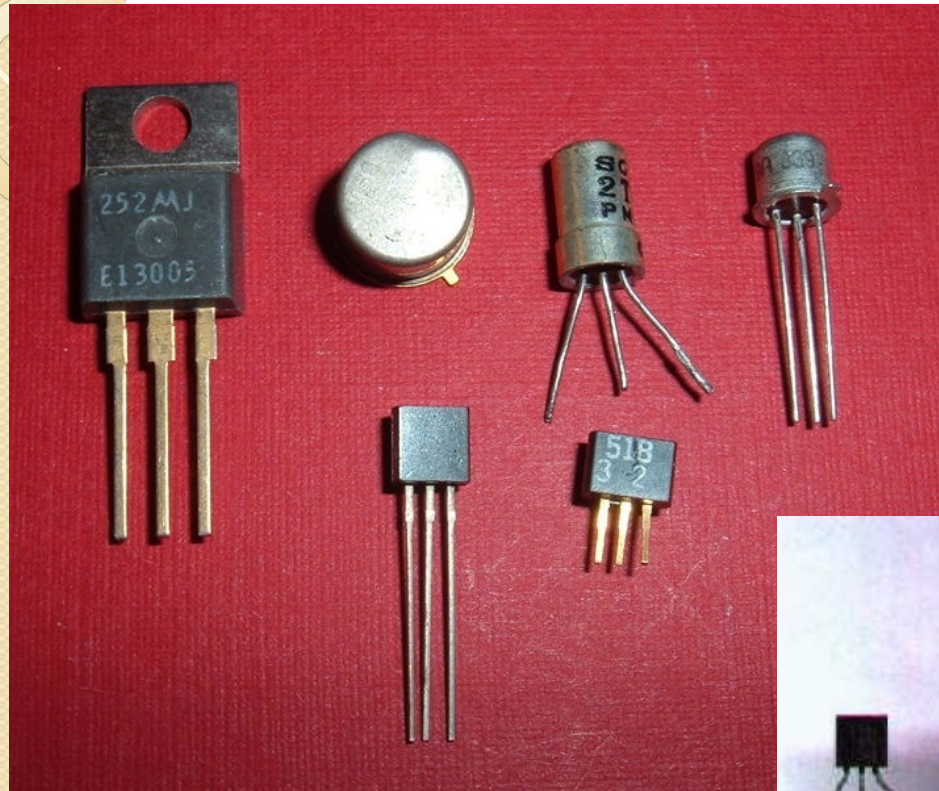
# Topics to be covered

- BJT

# Transistors

- Two main categories of transistors:
  - bipolar junction transistors (BJTs) and
  - field effect transistors (FETs).
- Transistors have 3 terminals where the application of **current (BJT)** or **voltage (FET)** to the input terminal increases the amount of charge in the active region.
- The physics of "**transistor action**" is quite different for the BJT and FET.
- In analog circuits, transistors are used in **amplifiers and linear regulated power supplies**.
- In digital circuits they function as electrical **switches**, including **logic gates, random access memory (RAM), and microprocessors**.

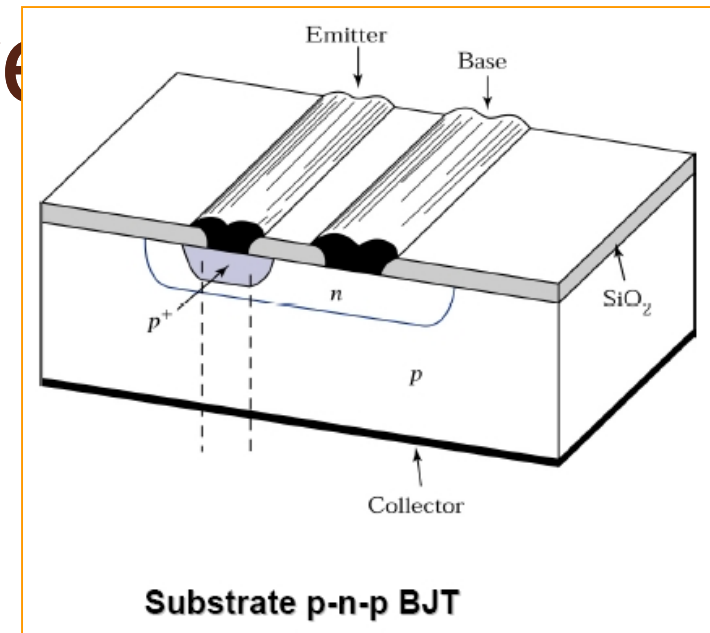
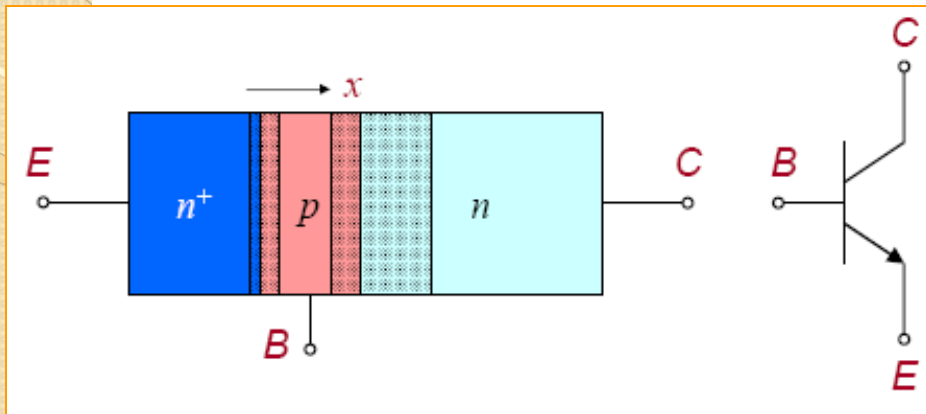
# Modern Transistors



# BJT Fabrication

- BJT can be made either as **discrete devices** or in **planar integrated** form.
- In discrete, the **substrate can be used for one connection**, typically the collector.
- In integrated version, all **3 contacts appear on the top surface**.
  - The E-B diode is closer to the surface than the B-C junction because it is easier to make the heavier doping at the top.

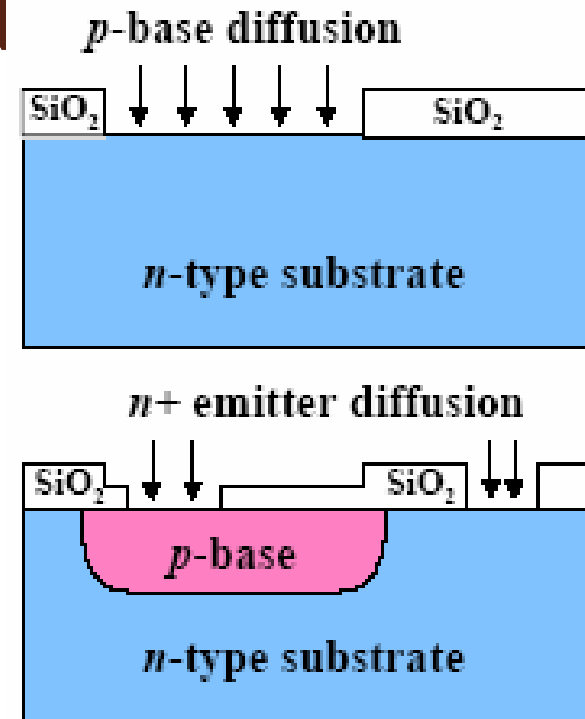
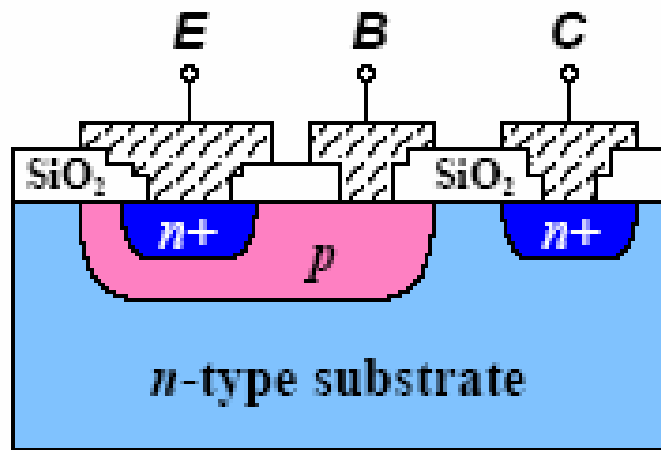
# BJT Structure - Discrete



- Early BJTs were fabricated using **alloying** - an complicated and unreliable process.
- The structure contains **two p-n diodes**, one between the base and the emitter, and one between the base and the collector.



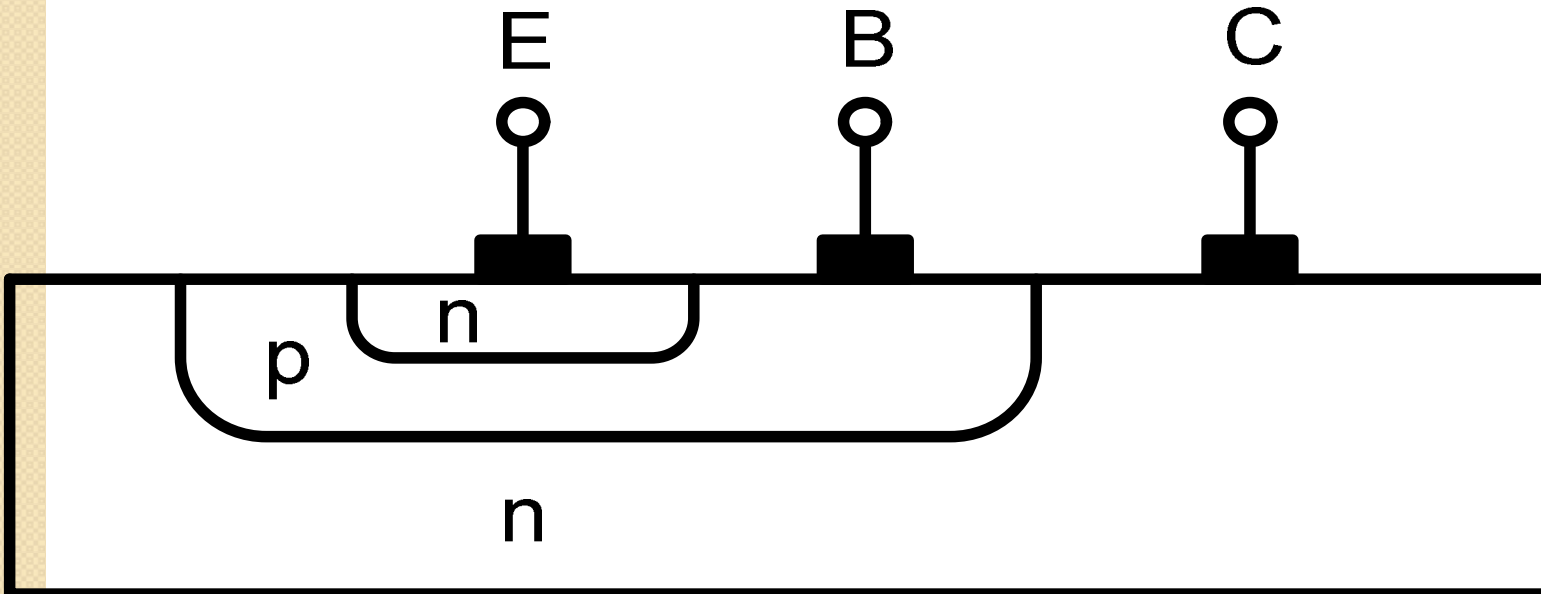
# BJT Structure - Planar



The “**Planar Structure**” developed by Fairchild in the late 50s shaped the basic structure of the BJT, even up to the present day.

- In the planar process, all steps are performed from the surface of the wafer

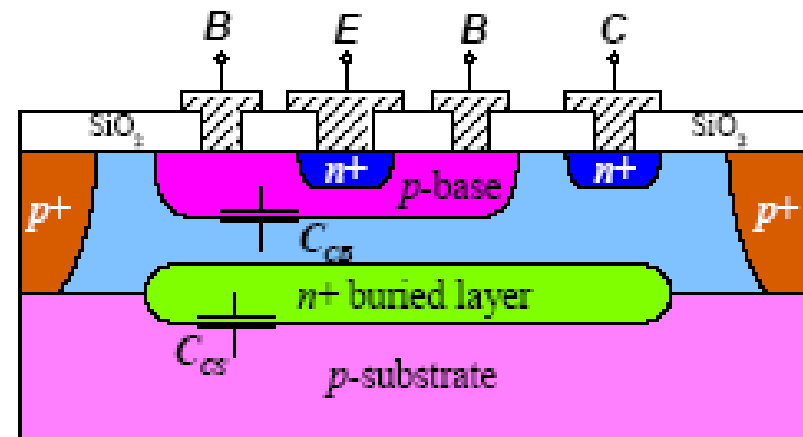
- BJTs are usually constructed vertically
  - Controlling depth of the emitter's n doping sets the base width





# Advanced BJT Structures

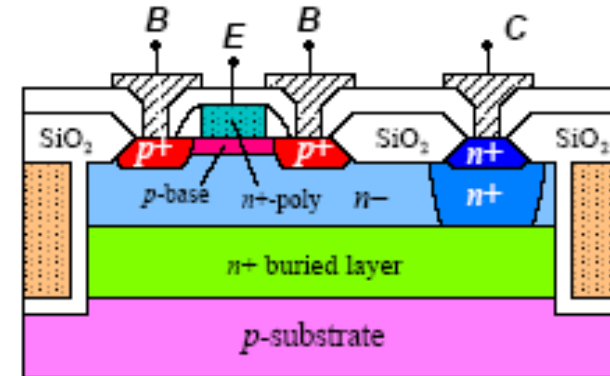
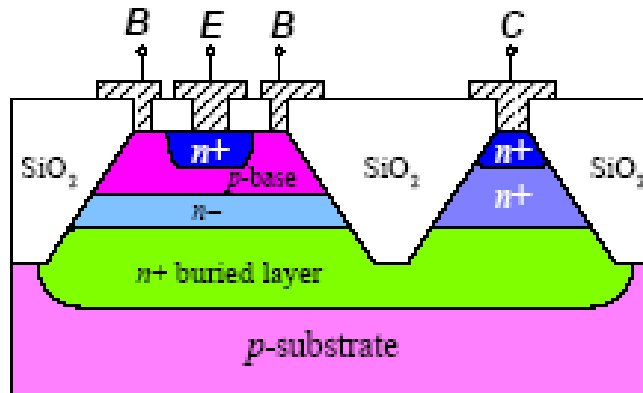
- The original BJT structure survived, practically unchanged, since the mid 60's.
- As the advances in MOS development appears, some of the fabrication technology are also applied to the BJT.
  - Low defect epitaxy
  - Ion implant
  - Plasma etching (dry etch)
  - LOCOS (local oxidation of Si)
  - Polysilicon layers
  - Improved lithography



# Isolation Methods

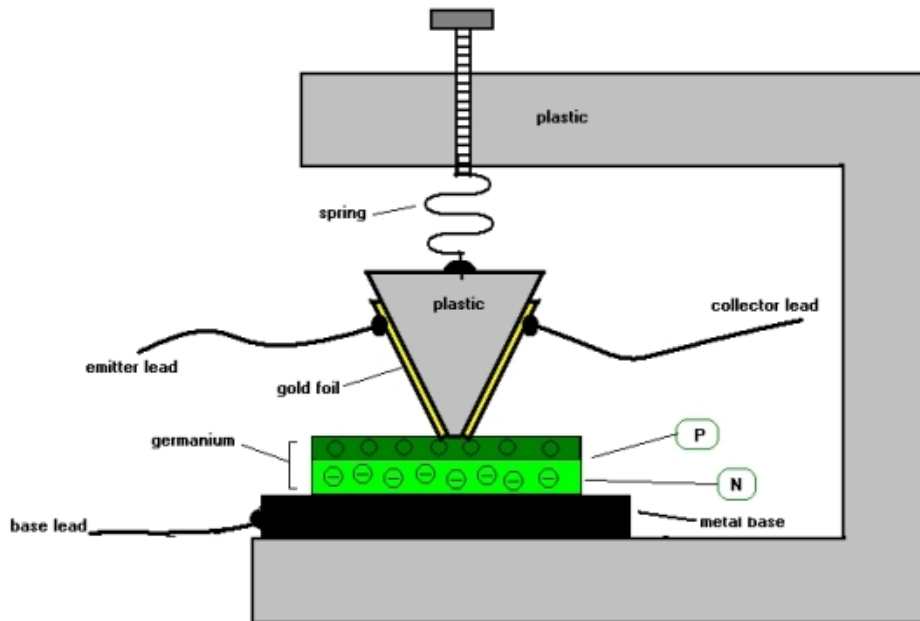
- The most significant advances in reducing overall device size and packing density have come from improved isolation methods.
- The traditional **junction isolation** technique requires the p+ deep diffusion to be aligned to the n+ buried layer that is covered by a thick epitaxial layer.
- The area (and hence junction capacitance) is determined by alignment tolerance, area for side diffusion, and allowance for the spread of the depletion region.
- Modern isolation techniques: *oxide isolation*, and *trench isolation*.

# Oxide & Trench Isolation



- Oxide isolation processes were introduced in the late 70's. They utilize wet anisotropic etch (KOH) of the  $\langle 100 \rangle$  Si wafer with Si<sub>3</sub>N<sub>4</sub> as mask.
- The KOH etch will erode the  $\langle 111 \rangle$  plane. Oxide is either deposited or grown to fill the V-grooves.
- The base and emitter are formed on the large **mesa** and the collector on the small **mesa**.
- To further reduce the area between adjacent mesa, trench isolation can be used, making use of trench etching.
- The trench is typically 2 $\mu$ m wide and 5 $\mu$ m deep. The trench walls are oxidized and the remaining volume is filled with polysilicon.

# The First Transistor: Point-contact transistor

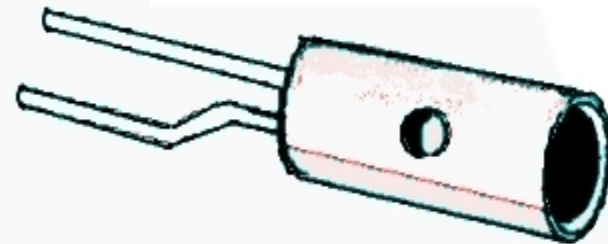


The point-contact transistor was commercialized and sold by Western Electric and others but was rather quickly superseded by the junction transistor.

A point-contact transistor was the first type of **solid state electronic transistor** ever constructed.

← It was made by researchers John Bardeen & Walter Houser Brattain at Bell Laboratories in December 1947.

First commercially available point-contact transistor



# The Junction Transistor

- First **BJT** was invented early in 1948, only weeks after the point contact transistor.
- Initially known simply as the **junction transistor**.
- It did not become practical until the early 1950s.
- The term “**bipolar**” was tagged onto the name to distinguish the fact that **both carrier types play important roles in the operation**.
- **Field Effect Transistors (FETs)** are “**unipolar**” transistors since their operation depends primarily on a single carrier type.

# Bipolar Junction Transistors (BJT)

- A bipolar transistor essentially consists of a pair of **PN Junction diodes** that are joined back-to-back.
- There are therefore two kinds of BJT, the **NPN** and **PNP** varieties.
- The three layers of the sandwich are conventionally called the **Collector**, **Base**, and **Emitter**.

