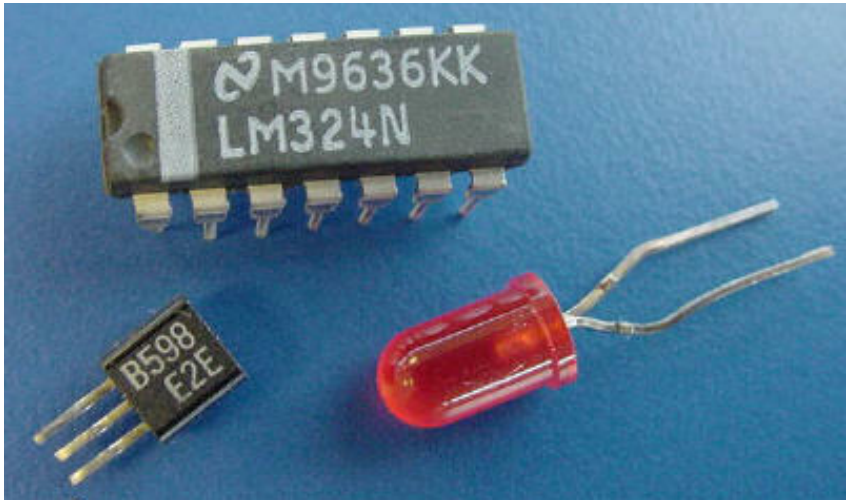
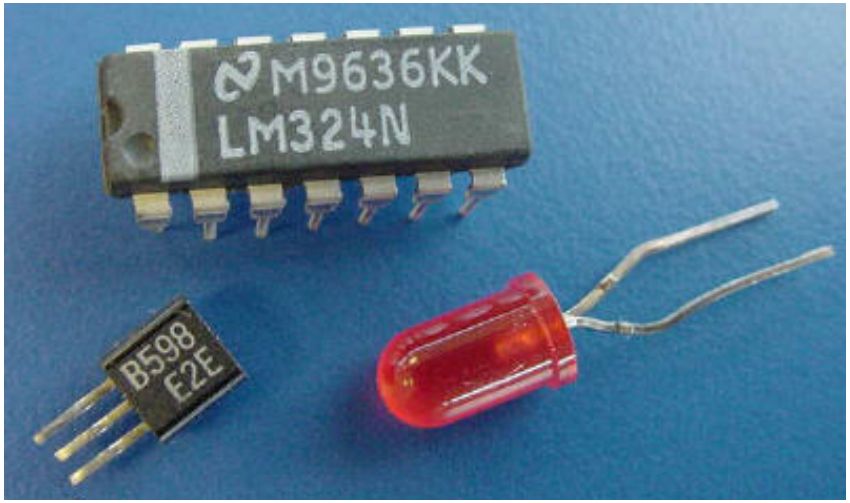
Semiconductors and how they work



Semiconductors are really applied physics and chemistry

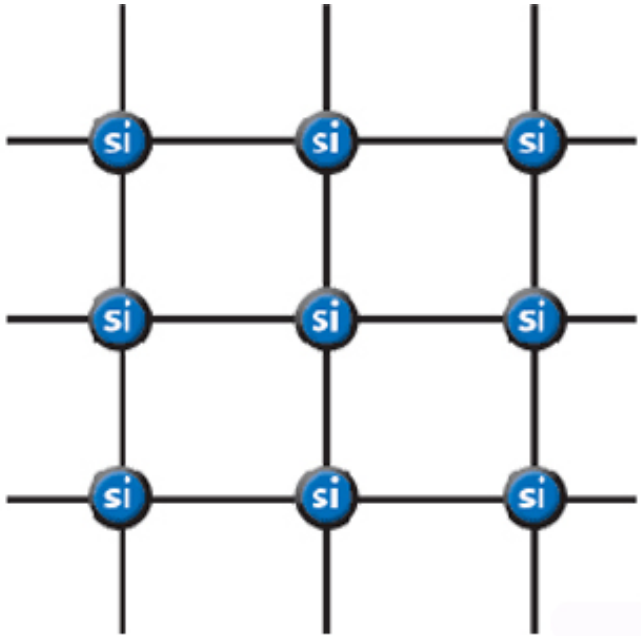


Conductors - permit electrical current to flow (low Resistance)

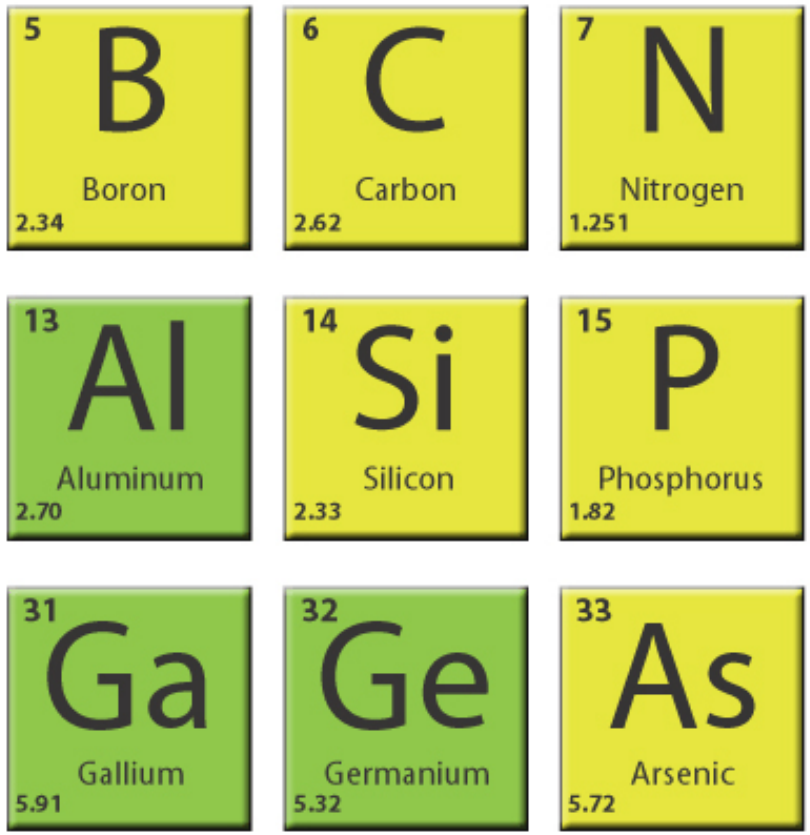
Insulators - do not permit electrical current to flow (high Resistance)

Semi-conductors - permit current to flow- - sometimes

Silicone:



4 electrons in the outer shell of each atom



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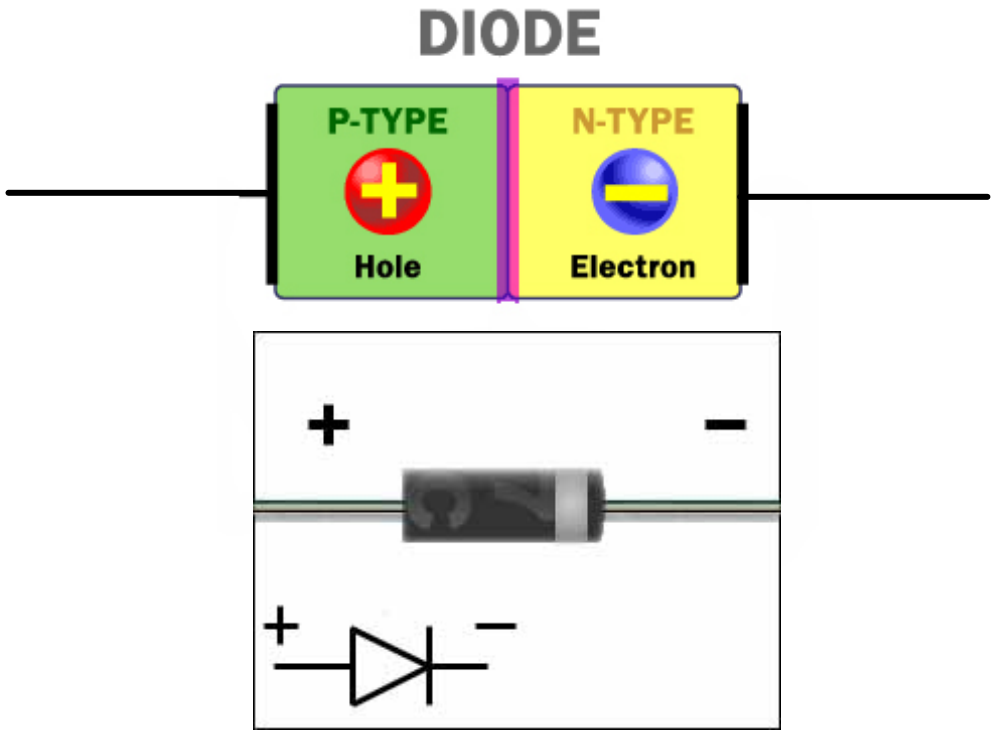
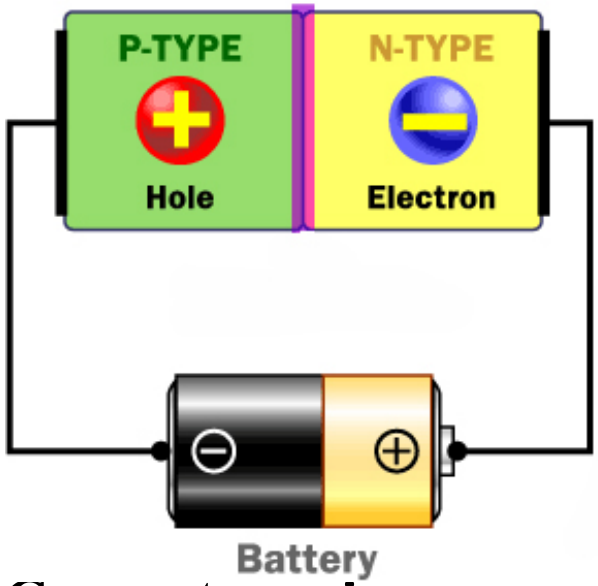
Add a few atoms of phosphorus or arsenic
(outer shell has 5 electrons)
extra electrons => N-type material

Add a few atoms of boron or gallium
(outer shell 3 electrons)
"missing electrons" = "holes"
=> P-type material



P-Type material and N-Type material in close contact

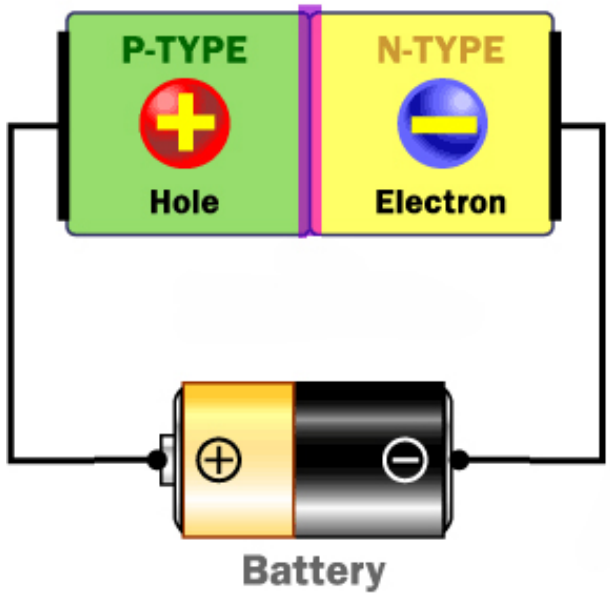
Reverse Biased Diode



Current carriers separate

Current will not flow

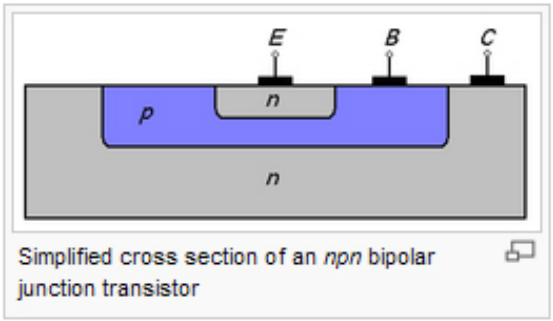
Forward Biased Diode



Current carriers pushed toward each other.
Electrons fall into holes.

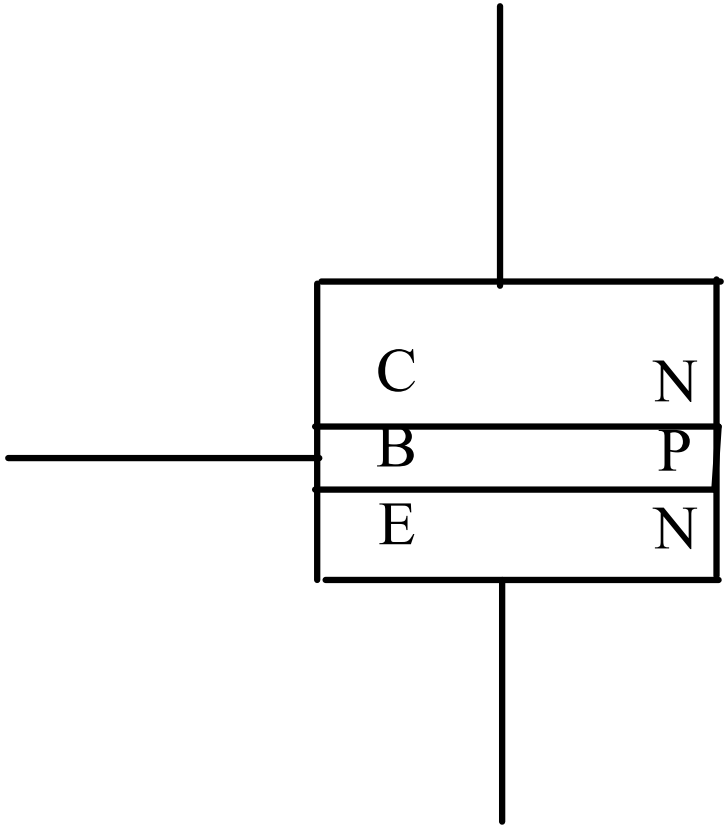
Current continues to flow.

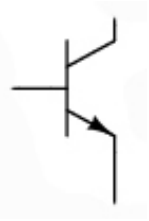
Now consider an N-P-N sandwich



Simplified cross section of an *npn* bipolar junction transistor

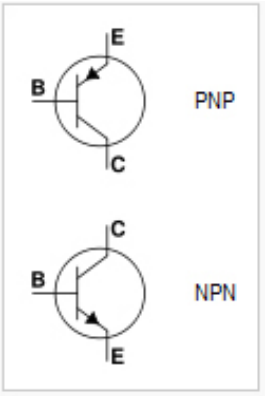
Transistor



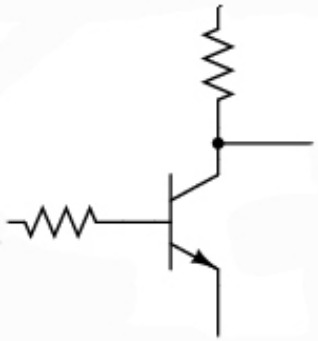


Transistor

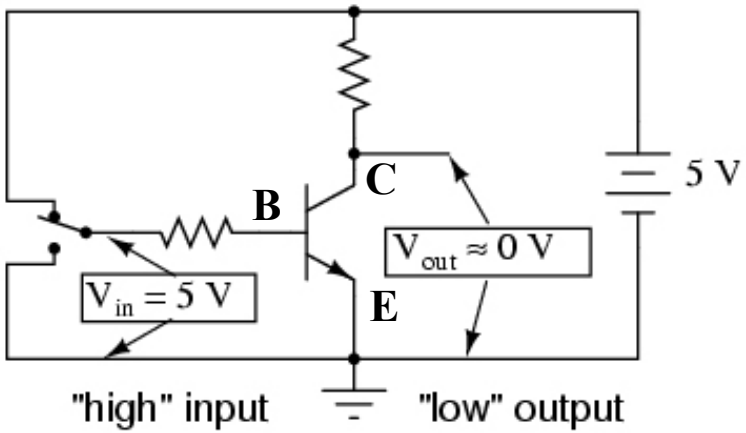
Arrow is located on the emitter.
Arrow points away from the p-type material.



Transistor in circuit



Transistor in saturation

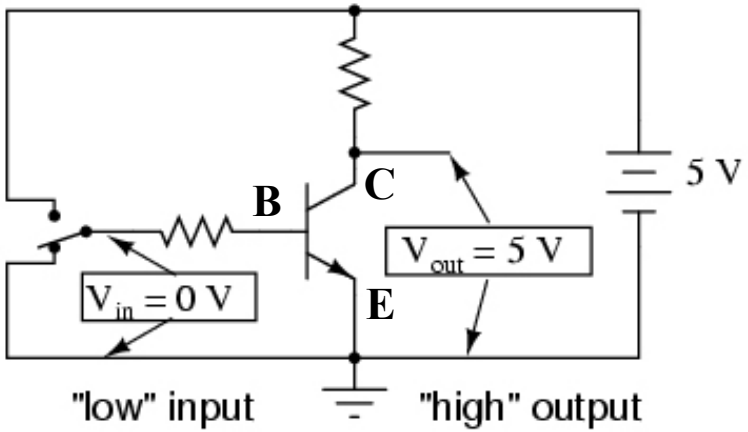


0 V = "low" logic level (0)

5 V = "high" logic level (1)

Little current flows in E-B ckt
More current flows in E-C ckt

Transistor in cutoff



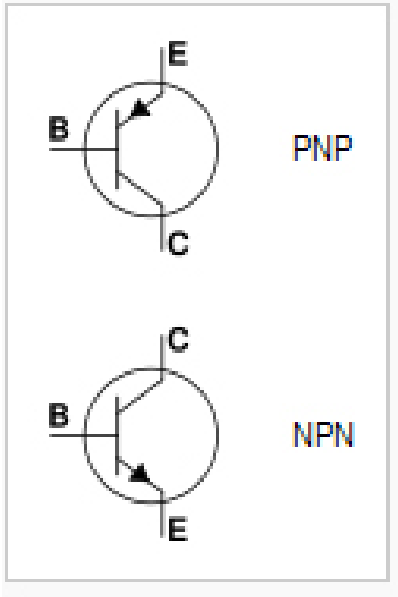
0 V = "low" logic level (0)

5 V = "high" logic level (1)

No current flows in E-B ckt
No current flows in E-C ckt

A transistor can "invert" the logic.
More important: a transistor can amplify the current many times.

Two types of bipolar transistors

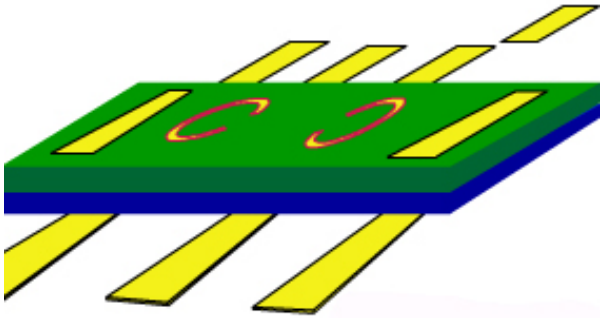


Integrated Circuits

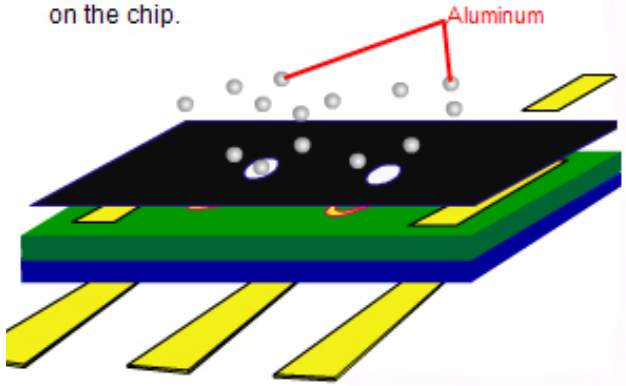
The first step is to prepare a slab of p-type germanium.

In a high temperature oven, the element antimony was diffused into the surface of the slab, creating a thin layer of n-type germanium. The junction between the two types of semiconductor forms one of the two junctions needed to make transistors.

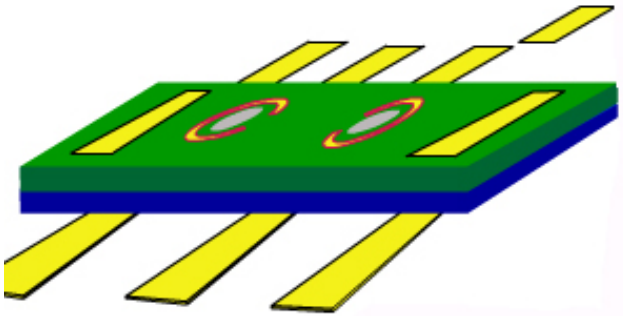
Gold leads were fused to the surfaces in the spots where connections were to be made or where circuit elements would later be formed



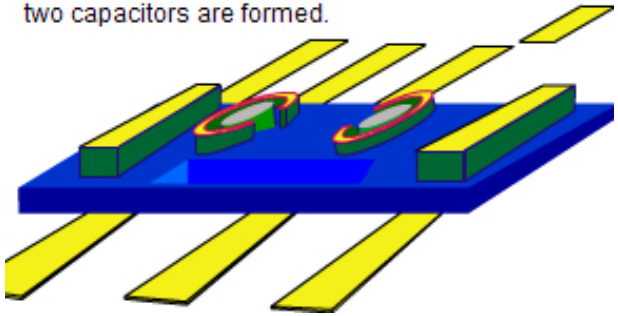
The chip was put in a reactor where aluminum ions are generated at high temperature and voltage. A mask protected some parts of the surface but let aluminum deposit in a pattern on the chip.



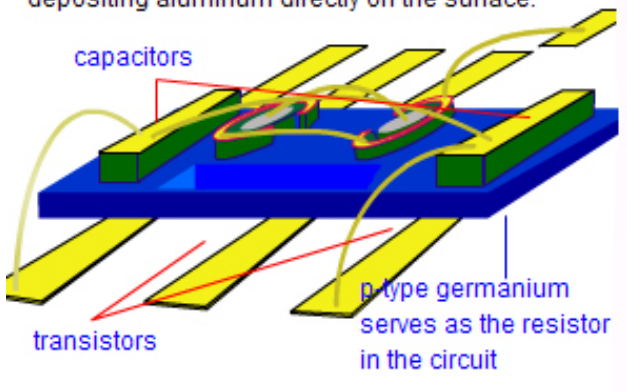
The aluminum left on the surface formed a semiconductor junction with the n-germanium surface.



Protective coatings were applied to certain areas, while other areas were left unprotected. Then the chip was plunged into an etching bath. Unprotected areas were eaten away, leaving "mesas." This process isolate areas where two transistors and two capacitors are formed.



The final step was to attach wires to interconnect some of the components. Later, interconnections were made by depositing aluminum directly on the surface.



The completed chip is a simple electronic circuit, with two transistors, two capacitors, and several resistors. A diagram of the circuit is shown below.