SEMICONDUCTOR DEVICES

TUNNEL DIODE

ANKIT KHATRI
2K20/B9/73

ANKIT KUMAR
2K20/B9/74

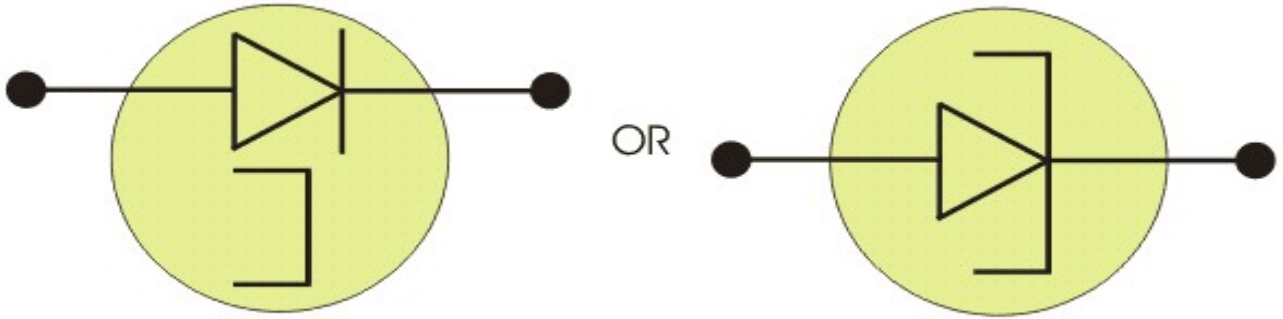
TUNNEL DIODE

Tunnel Diode is the P-N junction device that exhibits negative resistance. When the voltage is increased than the current flowing through it decreases. It works on the principle of the *Tunneling effect*.

Tunnel diodes have a heavily doped positive-to-negative (P-N) junction that is about 100 Å wide.The tunnel diode is a two-terminal device with n-type semiconductor as the cathode and p-type semiconductor as an anode.

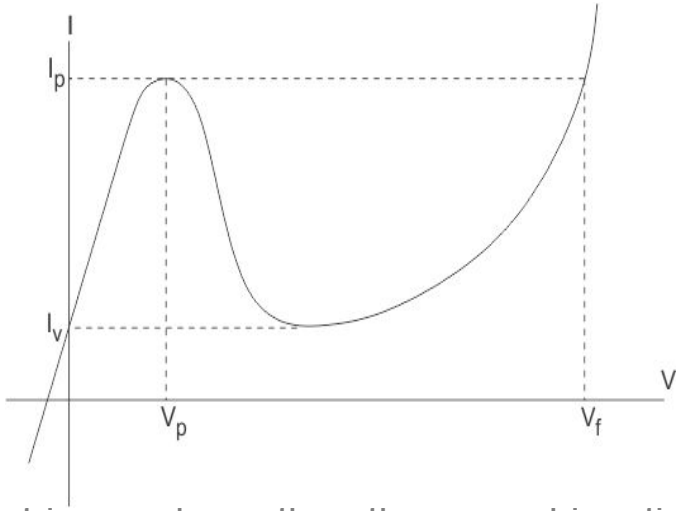
Invented by Leo Esaki a scientist at Sony Corporation.

Tunnel Diode Symbol



Characteristics of Tunnel Diode

When reverse bias is applied the Fermi level of the p-side becomes higher than the Fermi level of n-side. Hence, the tunneling of electrons from the balance band of p-side to the conduction band of n-side takes place. With the interments of the reverse bias the tunnel current also increases.When forward bias is applied the Fermi level of n-side becomes higher that the Fermi level of p-side, thus the tunneling of electrons from the n-side to p-side takes place.



The amount of the tunnel current is very large than the normal junction current. When the forward bias is increased, the tunnel current is increased up to certain limit.

When the band edge of n-side is the same as the Fermi level in p-side, the tunnel current is maximum with the further increment in the forward bias the tunnel current decreases and we get the desired negative conduction region. When the forward bias is raised further, normal pn junction current is obtained which is exponentially proportional to the applied voltage. The V-I characteristics of the tunnel diode is given,

The negative resistance is used to achieve oscillation and often Ck+ function is of very high frequency frequencies.

Tunnel Diode Working Phenomenon

Based on the classical mechanics' theory, a particle must acquire energy which is equal to the potential energy barrier height, if it has to move from one side of the barrier to the other. Otherwise, energy has to be supplied from some external source, so the N-sided electrons of the junction can jump over the junction barrier to reach the P-side of the junction.If the barrier is thin such as in tunnel diode, according to the Schrodinger equation implies that there is a large amount of probability and then an electron will penetrate through the barrier.

This process will happen without any energy loss on the part of the electron. The behavior of the quantum mechanical indicates tunneling. The high-impurity **P-N junction devices** are called as tunnel-diodes. The tunneling phenomenon provides a majority carrier effect.

$$P \propto \exp(-A^* E_b * W)$$

Where,

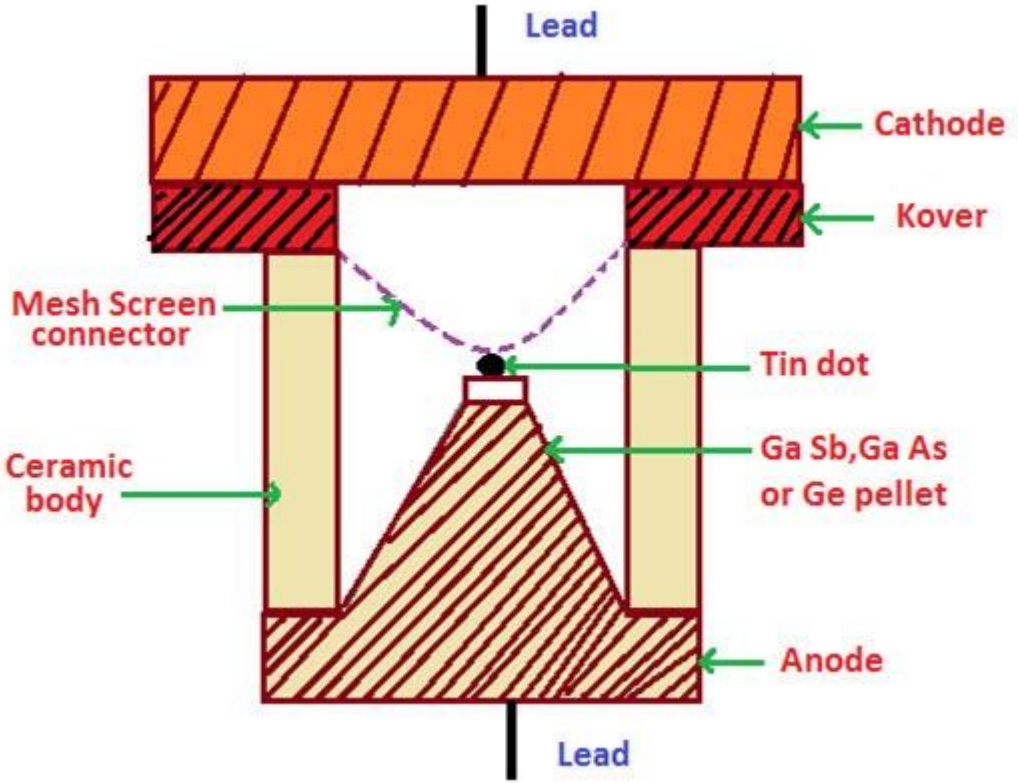
‘E’ is the energy of the barrier,

‘P’ is the probability that the particle crosses the barrier,

‘W’ is the width of the barrier

Construction of Tunnel Diode

The diode has a ceramic body and a hermetically sealing lid on top. A small tin dot is alloyed or soldered to a heavily doped pellet of n-type Ge. The pellet is soldered to anode contact which is used for heat dissipation. The tin-dot is connected to the cathode contact via a mesh screen which is used to reduce the inductance.



Construction of Tunnel Diode

Operation and its Characteristics

The operation of the tunnel diode mainly includes two biasing methods such as forward and reverse.

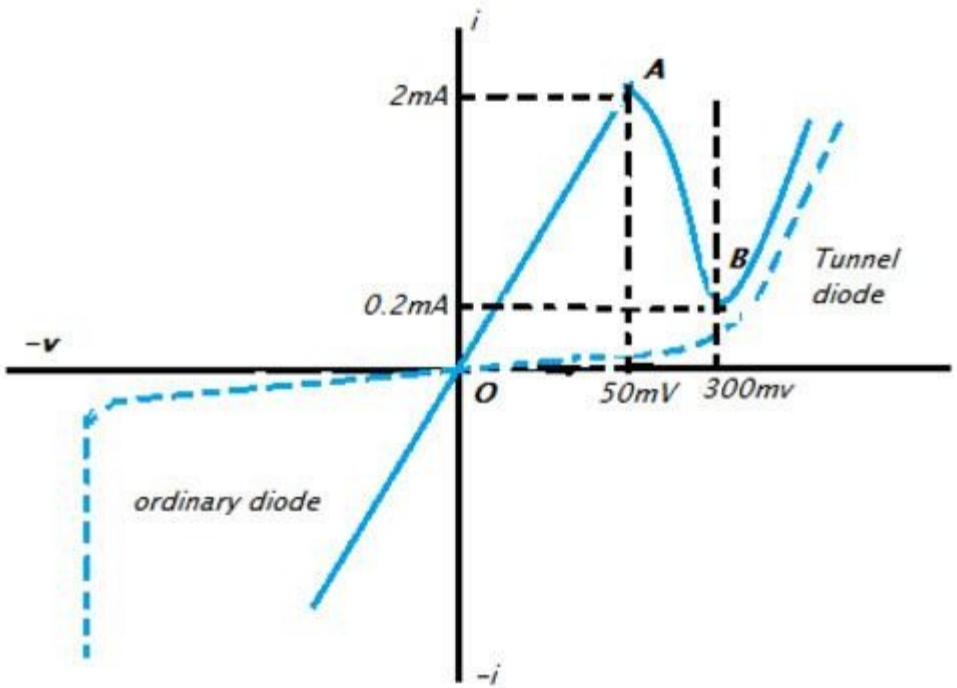
Forward Bias Condition

Under the forward bias condition, as voltage increases, then-current decreases and thus become increasingly misaligned, known as negative resistance. An increase in voltage will lead to operating as a normal diode where the conduction of electrons travels across the P-N junction diode.

The negative resistance region is the most important operating region for a Tunnel diode. The Tunnel diode and normal P-N junction diode characteristics are different from each other.

Reverse Bias Condition :

Under the reverse condition, the tunnel diode acts as a back diode or backward diode. With zero offset voltage, it can act as a fast rectifier. In reverse bias condition, the empty states on the n-side aligned with the filled states on the p-side. In the reverse direction, the electrons will tunnel through a potential barrier. Because of its high doping concentrations, tunnel diode acts as an excellent conductor.The forward resistance is very small because of its tunneling effect. An increase in voltage will lead to an increase in the current until it reaches peak current. But if the voltage increased beyond the peak voltage then current will decrease automatically. This negative resistance region prevails till the valley point. The current through the diode is minimum at valley point. The tunnel diode acts as a normal diode if it is beyond the valley point.



Tunnel Diode Characteristics

Tunnel Diode Applications

- Due to the tunneling mechanism, it is used as an ultra high speed switch.
- The switching time is of the order of nanoseconds or even picoseconds.
- Due to the triple valued feature of its curve from current, it is used as a logic memory storage device.
- Due to extremely small capacitance, inductance and negative resistance, it is used as a microwave oscillator at a frequency of about 10 GHz.
- Due to its negative resistance, it is used as a relaxation oscillator circuit.

Advantages of Tunnel Diode

- Low cost
- Low noise
- Ease of operation
- High speed
- Low power
- Insensitive to nuclear radiations

Disadvantages of Tunnel Diode

- Being a two-terminal device, it provides no isolation between output and input circuits.
- The voltage range, which can be operated properly in 1 volt or below.

Reference

- https://www.electrical4u.com/tunnel-diode/
- https://en.wikipedia.org/wiki/Tunnel_diode
- https://www.physics-and-radio-electronics.com/electronic-devices-and-circuits/semiconductor-diodes/tunneldiode-howitworks.html