SUBJECT: BASIC ELECTRONICS

Tunnel Diode: Introduction,Working,V-I Characteristics

Elementrix Classes

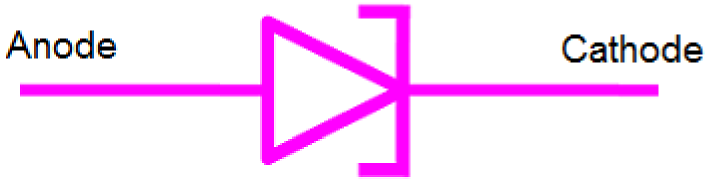
Introduction

- The tunnel diode is a highly conductive, heavily doped PN-junction diode in which the current induces because of the tunnelling. The tunnelling is the phenomenon of conduction in the semiconductor material in which the charge carrier punches the barrier instead of climbing through it.

- The tunnel diode is a heavily doped PN-junction diode. The concentration of impurity in the normal PN-junction diode is about 1 part in 10^8. And in the tunnel diode, the concentration of the impurity is about 1 part in 10^3. Because of the heavy doping, the diode conducts current both in the forward as well as in the reverse direction. It is a fast switching device; thereby it is used in high-frequency oscillators, computers and amplifiers.

Symbol

The circuit symbol of tunnel diode is shown in the below figure. In tunnel diode, the p-type semiconductor act as an anode and the n-type semiconductor act as a cathode.

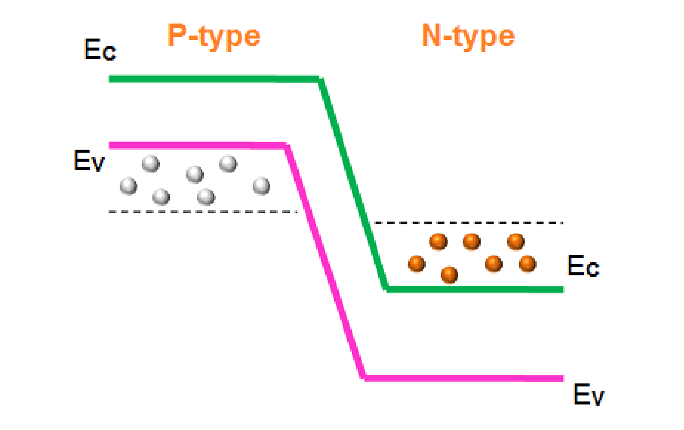


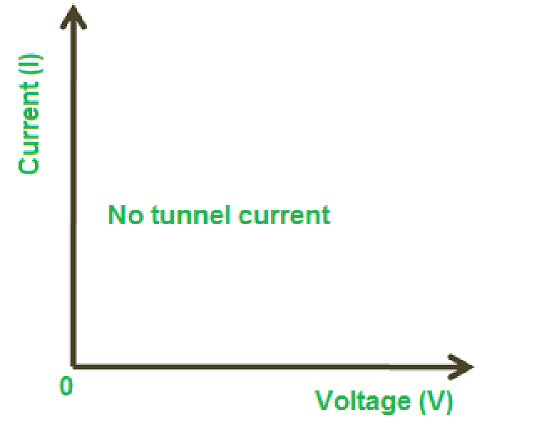
Tunnel diode symbol

Working

Step 1: Unbiased tunnel diode

When no voltage is applied to the tunnel diode, it is said to be an unbiased tunnel diode. In tunnel diode, the conduction band of the n-type material overlaps with the valence band of the p-type material because of the heavy doping.





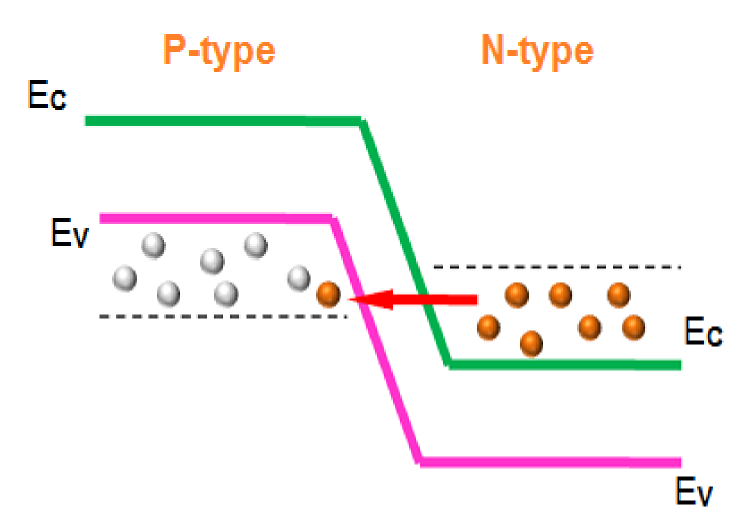
- Because of this overlapping, the conduction band electrons at n-side and valence band holes at p-side are nearly at the same energy level. So when the temperature increases, some electrons tunnel from the conduction band of n-region to the valence band of p-region. In a similar way, holes tunnel from the valence band of p-region to the conduction band of n-region.

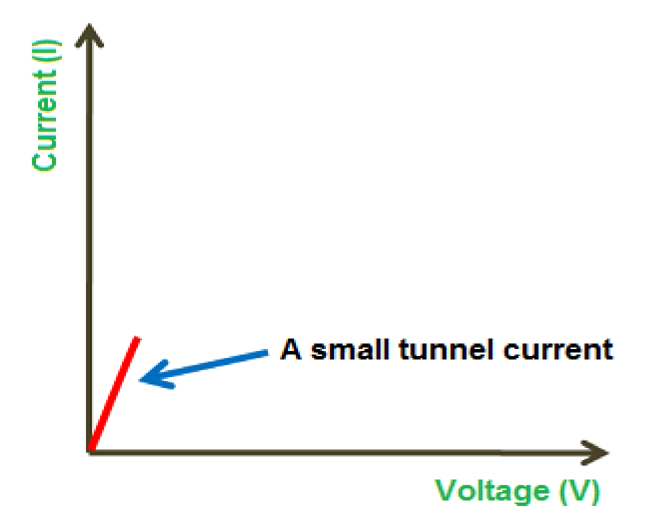
- However, the net current flow will be zero because an equal number of charge carriers (free electrons and holes) flow in opposite directions.

Step 2: Small voltage applied to the tunnel diode

- When a small voltage is applied to the tunnel diode which is less than the built-in voltage of the depletion layer, no forward current flows through the junction.

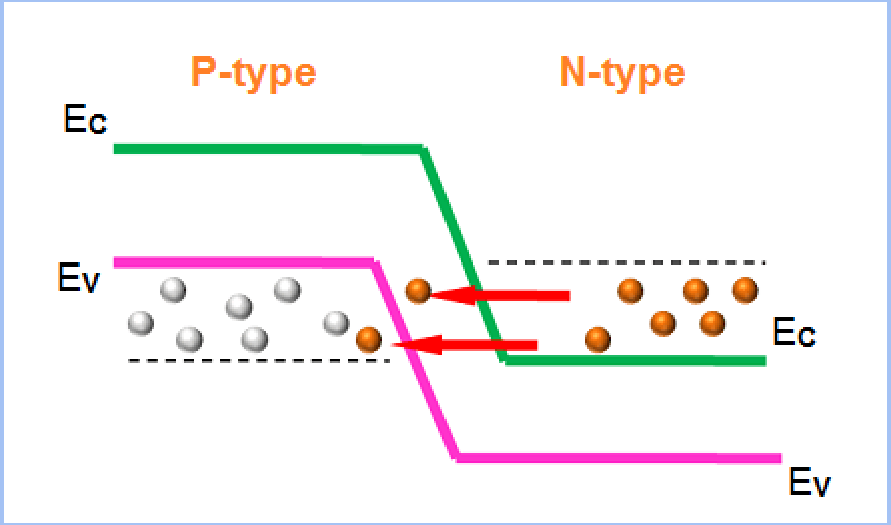
- However, a small number of electrons in the conduction band of the n-region will tunnel to the empty states of the valence band in p-region. This will create a small forward bias tunnel current. Thus, tunnel current starts flowing with a small application of voltage.

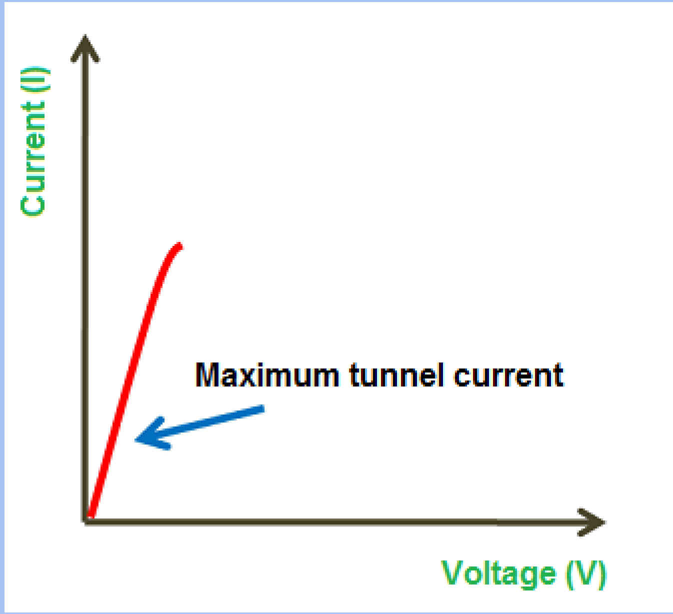

P-type
N-type
Ec
Ev
Ec
Ev


Current (I)
A small tunnel current
Voltage (V)

Step 3: Applied voltage is slightly increased

- When the voltage applied to the tunnel diode is slightly increased, a large number of free electrons at n-side and holes at p-side are generated. Because of the increase in voltage, the overlapping of the conduction band and valence band is increased.

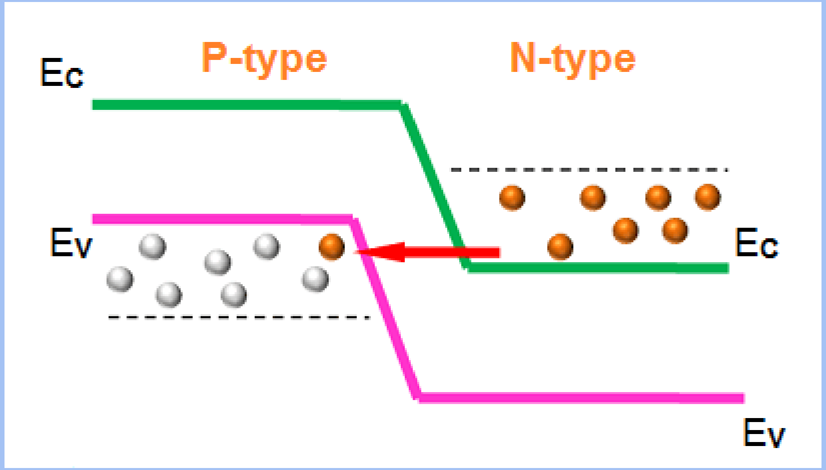


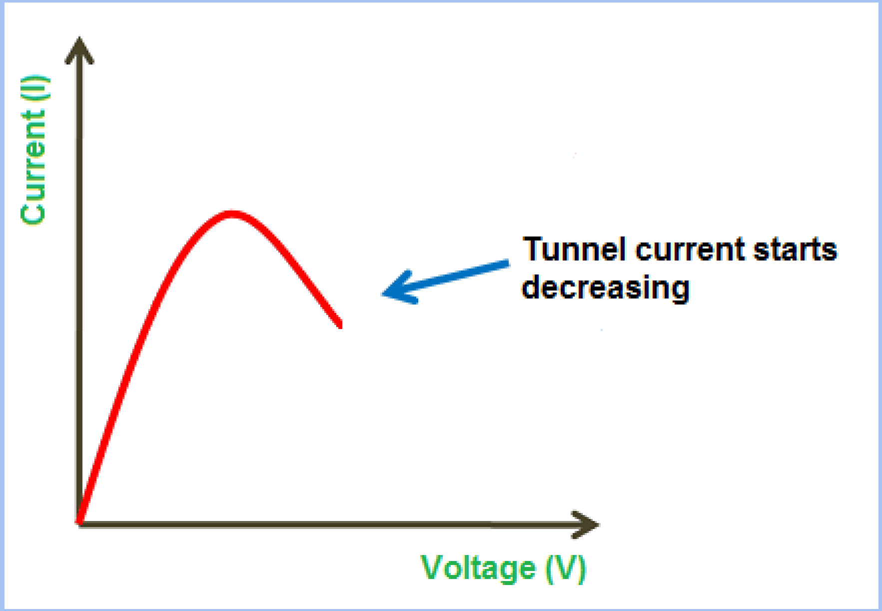


In simple words, the energy level of an n-side conduction band becomes exactly equal to the energy level of a p-side valence band. As a result, maximum tunnel current flows.

Step 4: Applied voltage is further increased

- If the applied voltage is further increased, a slight misalign of the conduction band and valence band takes place.

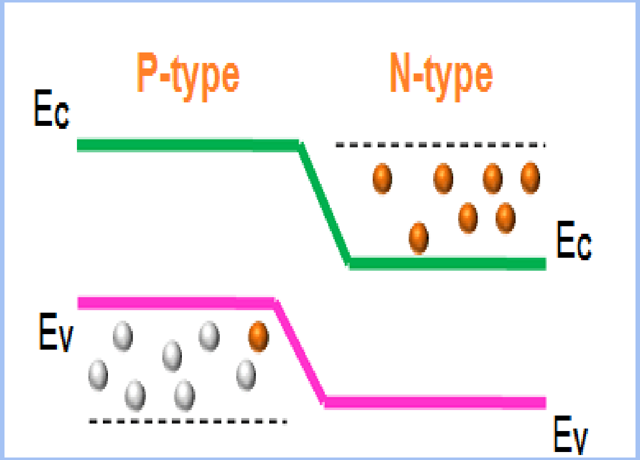


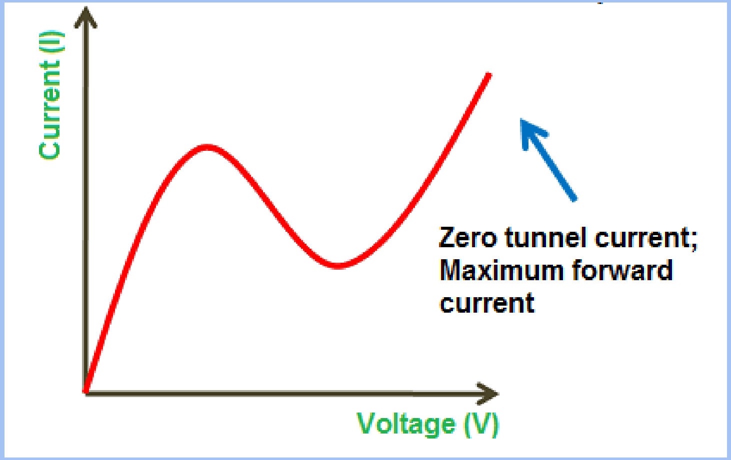


Since the conduction band of the n-type material and the valence band of the p-type material sill overlap. The electrons tunnel from the conduction band of n-region to the valence band of p-region and cause a small current flow. Thus, the tunneling current starts decreasing.

Step 5: Applied voltage is largely increased

- If the applied voltage is largely increased, the tunneling current drops to zero. At this point, the conduction band and valence band no longer overlap and the tunnel diode operates in the same manner as a normal p-n junction diode.



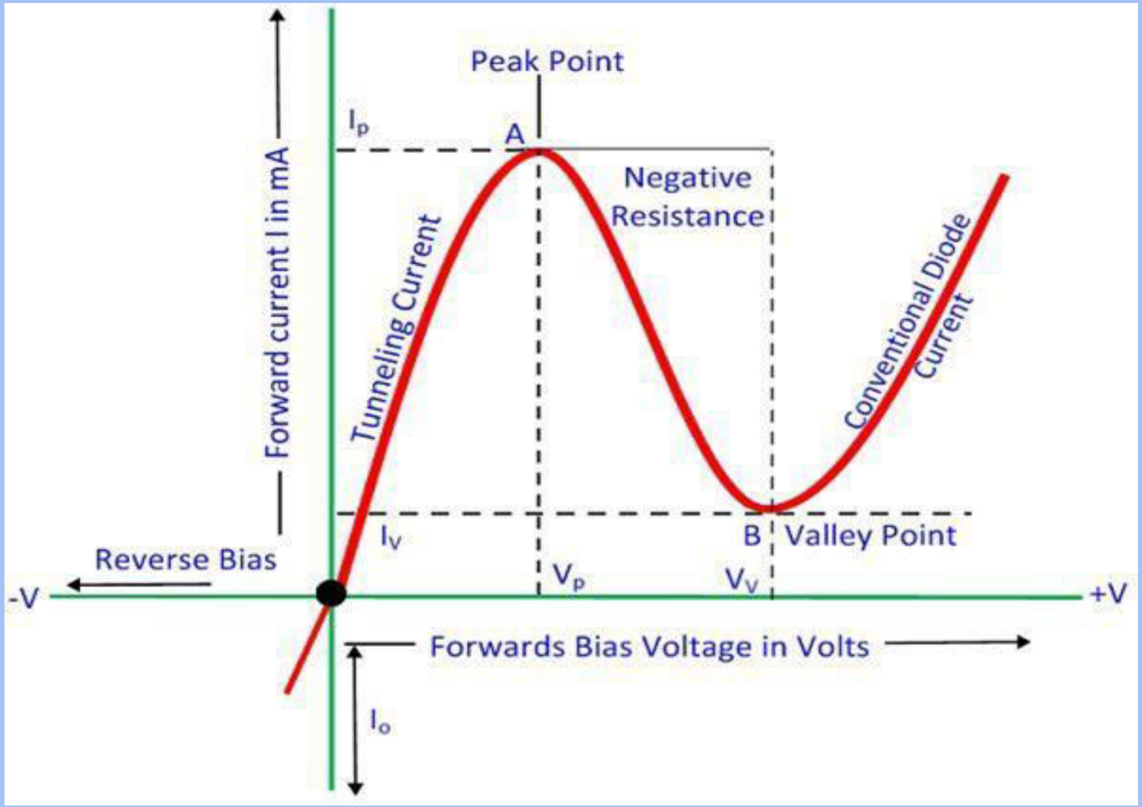


- If this applied voltage is greater than the built-in potential of the depletion layer, the regular forward current starts flowing through the tunnel diode.

- The portion of the curve in which current decreases as the voltage increases is the negative resistance region of the tunnel diode. The negative resistance region is the most important and most widely used characteristic of the tunnel diode.

- A tunnel diode operating in the negative resistance region can be used as an amplifier or an oscillator.

V-I Characteristics of Tunnel Diode



- In forward biasing, the immediate conduction occurs in the diode because of their heavy doping. The current in a diode reached their maximum value I_P when the V_p voltage applied across it. When further the voltage increases, the current across the terminal decreases. And it decreases until it reaches their minimum value. This minimum value of current is called the valley current I_v.

- The graph above shows that from point A to point B the value of current decreases with the increase of voltage. So, from A to B, the graph shows the negative resistance region of the tunnel diode. This region shows the most important property of the diode. Here in this region, the tunnel diode produces the power instead of absorbing it.

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