

## Light Emitting Diode materials

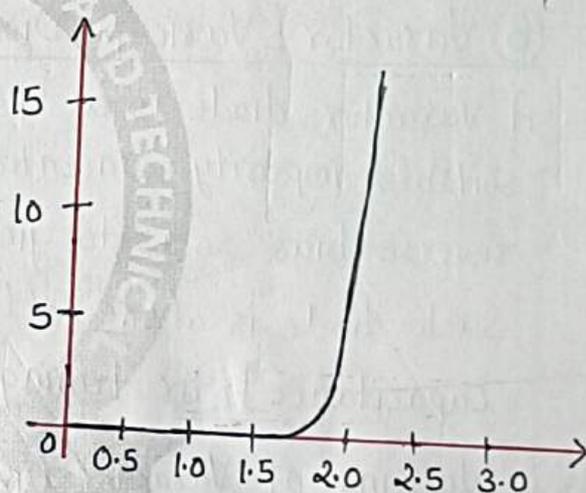
| S.No | Material                   | Symbol | Colour               |
|------|----------------------------|--------|----------------------|
| 1    | Gallium Arsenide           | GaAs   | Infrared [Invisible] |
| 2    | Gallium Phosphide          | GaP    | Red or Green         |
| 3    | Gallium Nitride            | GaN    | Blue or white        |
| 4    | Gallium Arsenide Phosphide | GaAsP  | Red or Yellow        |

### Characteristics of LED

The forward bias characteristics is similar to that of a conventional diode except the higher value of cut-in voltage.

The cut-in voltage of LED is in the range of 1.2V to 3.2V depending on the material used.

Forward Current (mA)



### Advantages of LED

- It has long life
- It is light in weight
- It is cheap and readily available
- It is available in various colours.
- LED is fast operating device i.e., it has high switching speed with switching interval of the order of less than 1  $\mu$ sec [microseconds].

### Disadvantages of LED

- It has extremely low reverse breakdown voltage of the order of 3 to 10V.
- It needs large power for its operation.

© The characteristics are affected by temperature.

Applications of LED

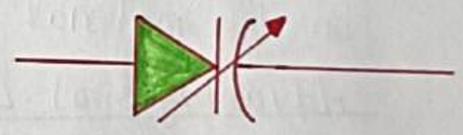
- (a) LED is used in most optical devices.
- (b) It is used as an ON-OFF indicator in various types of electronic circuits and gadgets.
- (c) LEDs are used in remote controls and applications like burglar alarm.
- (d) It is used in all kinds of visual displays like seven segment displays and alpha numeric displays.

(B) Varactor [Varicap] Diode

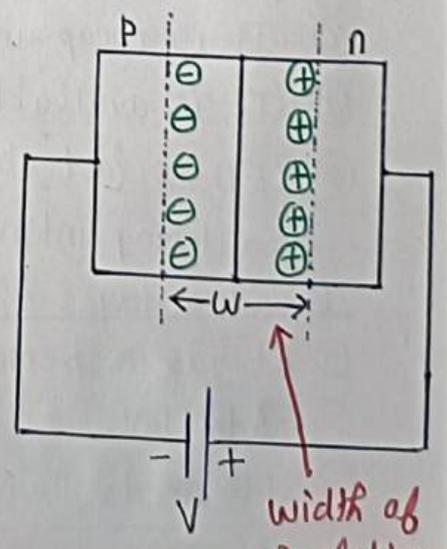
A varactor diode is a specially manufactured p-n junction with suitable impurity concentration profile and operated under reverse-bias so as to yield a variable junction capacitance. Such diode is also called varicap, VVC [Voltage Variable Capacitance] or tuning diode.

Working of Varactor Diode

In a diode, the depletion region exists between p-region and n-region. It forms a barrier which separates the positive and negative charges [holes and electrons] on each side of junction. These charges can be compared to the charges on opposite plates of a capacitor while the depletion region acts like a dielectric medium. Therefore, all the p-n junctions possess junction capacitance.



Varactor diode symbol



Reversed-biased pn-junction  
width of Depletion region

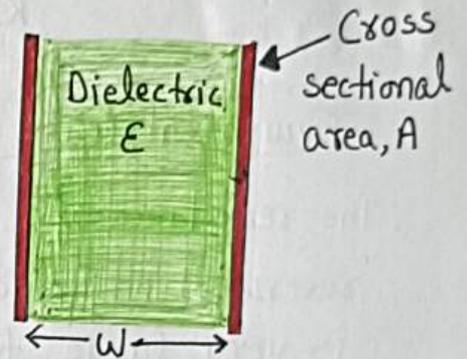
This junction capacitance is also known as transition capacitance, space capacitance, barrier capacitance or depletion region capacitance. It is denoted by  $C_T$

$$C_T = \frac{\epsilon A}{W}$$

where,  $\epsilon$  = Permittivity of semiconductor

$A$  = Area of cross section

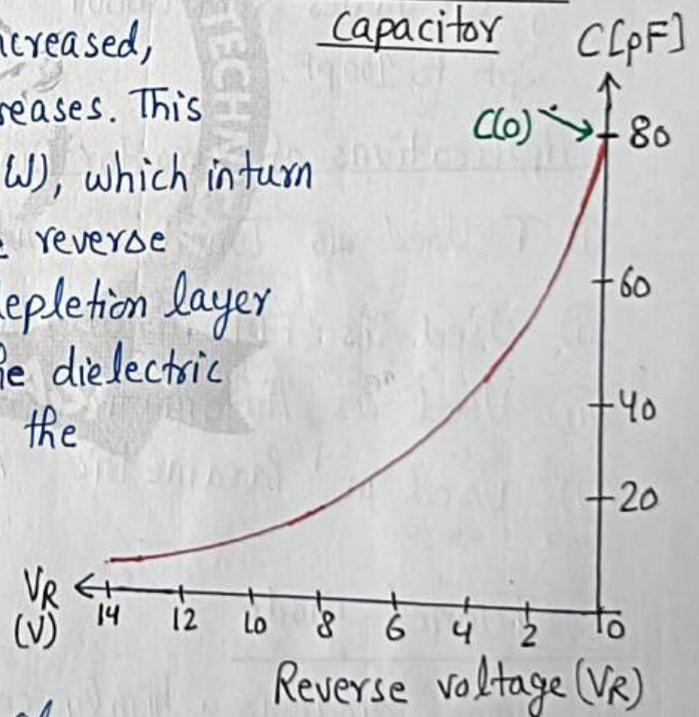
$W$  = width of depletion region.



equivalent effective parallel plate capacitor

When the reverse-bias voltage is increased, the depletion layer widens or increases. This increases the dielectric thickness ( $W$ ), which in turn reduces the capacitance. When the reverse-bias voltage is decreased, the depletion layer becomes narrow. This decreases the dielectric thickness, which in turn increases the capacitance.

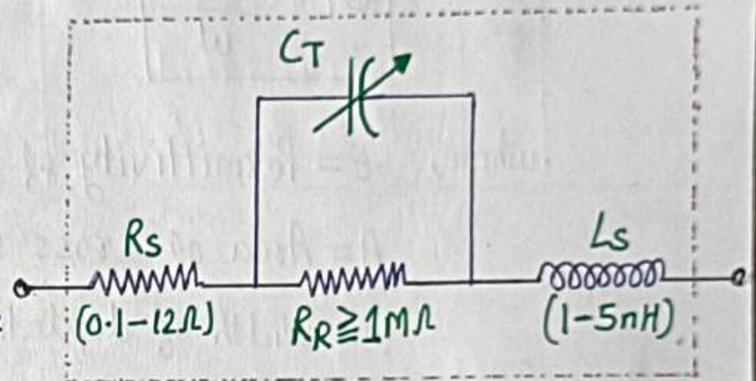
The normal range of reverse bias voltage for a varactor diode is limited to about 20V. The value of capacitance is maximum  $C(0)$ , when reverse bias voltage applied is zero.



Varactor Diode Characteristics

### Equivalent circuit diagram

The resistance of a diode in reverse-bias region ( $R_R$ ) is very large, typically  $1\text{M}\Omega$  or larger. The magnitude of  $C_T$  varies from about  $2\text{pF}$  to  $100\text{pF}$ .



### Applications of Varactor Diode

- (i) Used in Tuned circuits.
- (ii) Used in FM modulators.
- (iii) Used in Automatic frequency control devices.
- (iv) Used in Parametric Amplifiers.

### (C) Tunnel Diode

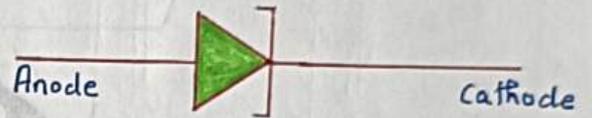
The tunnel diode is a highly conductive, heavily doped PN-junction diode in which the current is produced because of the tunnelling effect.

The tunnelling effect is the phenomenon of conduction in the semiconductor material in which the charge carriers punches the barrier instead of climbing through it. It is also known as esaki diode.

The concentration of impurity in the normal PN-junction diode is about  $1:10^8$ . And in the tunnel diode, the concentration of the impurity is about 1 part in  $10^3$  [ $1:10^3$ ].

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.

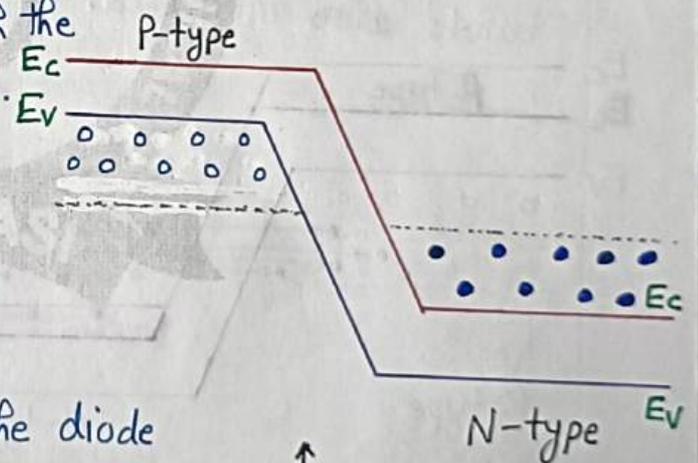


Tunnel Diode Symbol

Tunnel Diode Working

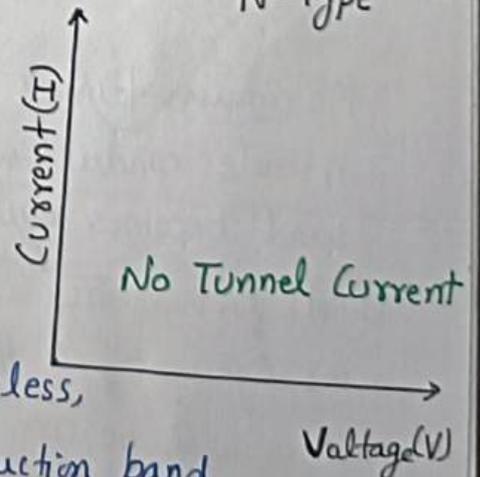
① When the tunnel diode is unbiased i.e., no voltage is applied across the diode in that case the conduction band of the n-type semiconductor material overlaps with the valence band of the p-type material.

This happens because of the heavy doping. The energy levels of the hole and electron in the p- and n-side remains same respectively.



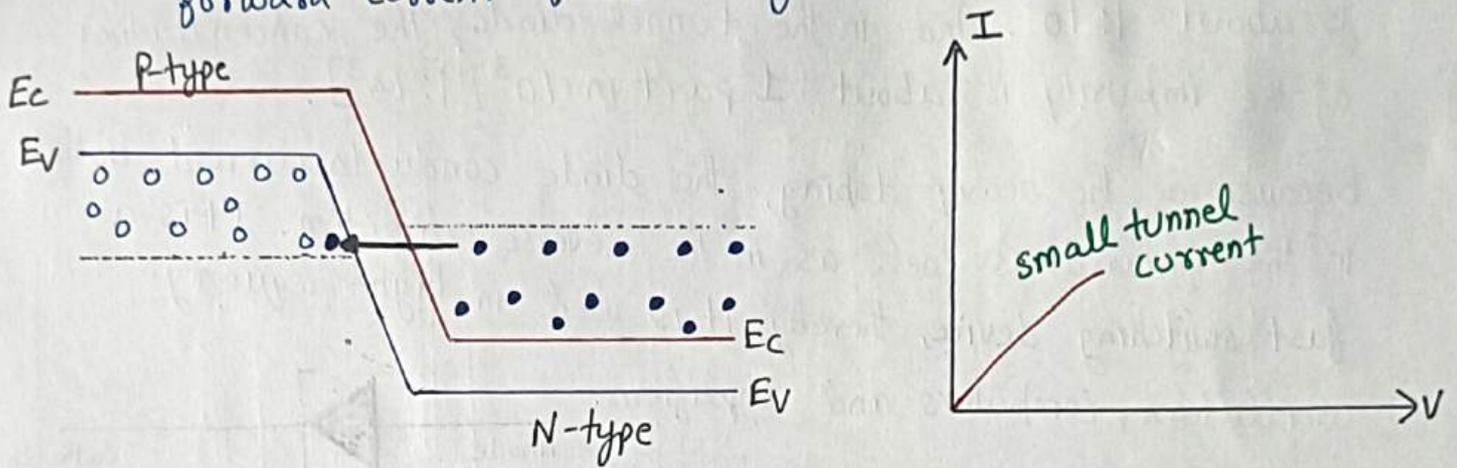
The zero current flows through the diode in the unbiased condition.

② When small voltage is applied across the tunnel diode whose magnitude is less than built-in-depletion region voltage, then no electrons will cross the depletion region and zero current flows through the diode. Nevertheless, a minimal number of electrons from the conduction band

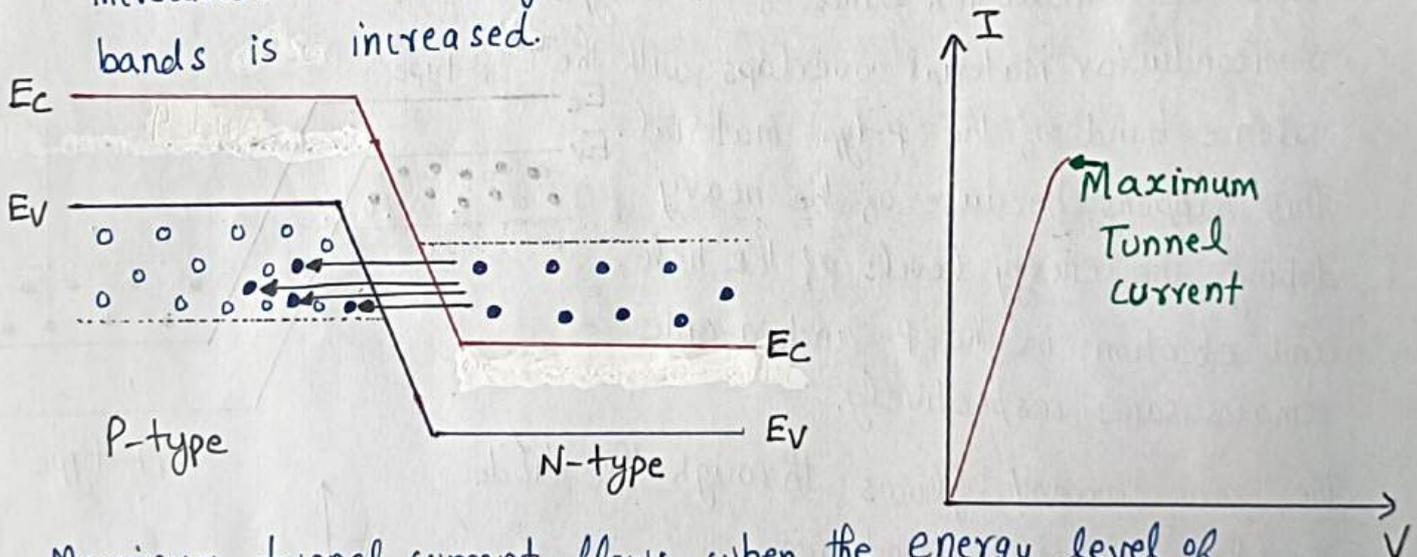


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of n-region will start tunnelling to valence band of p-region. Because of the tunnelling of electrons, a small forward current flows through the depletion region.



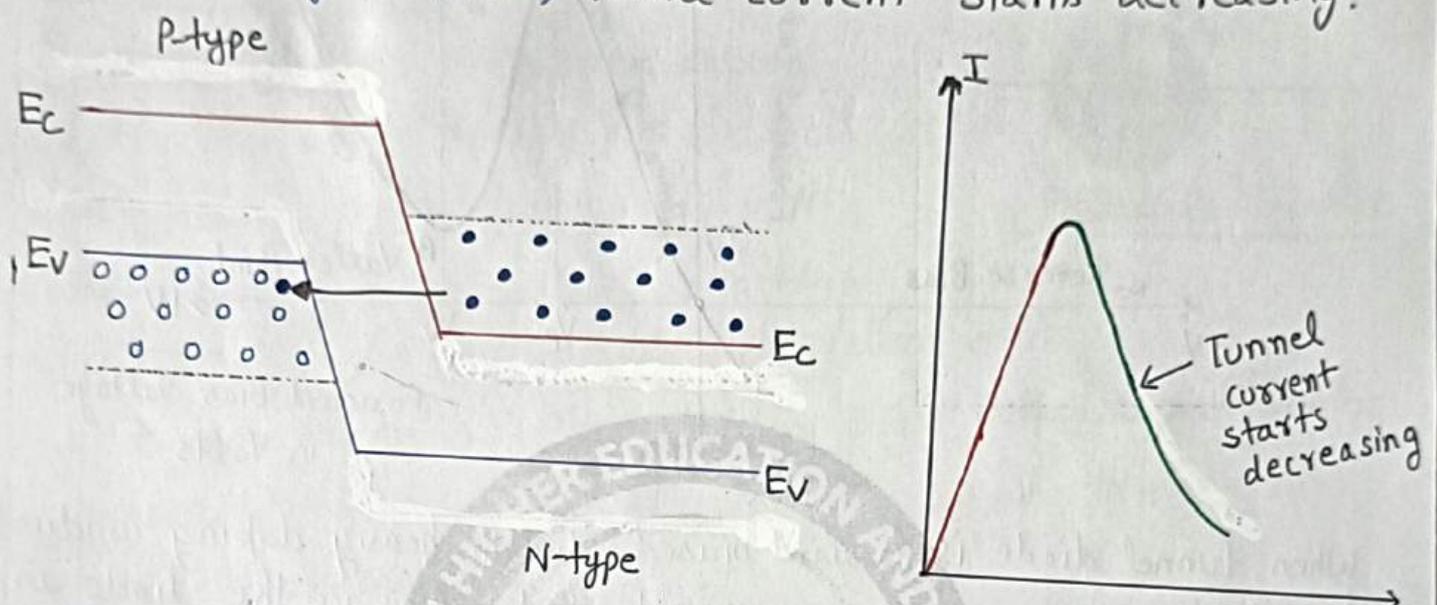
③ When the amount of voltage applied is increased, the number of free electrons generated at n-side and holes at p-side also increases. Due to voltage increase, overlapping between the bands is increased.



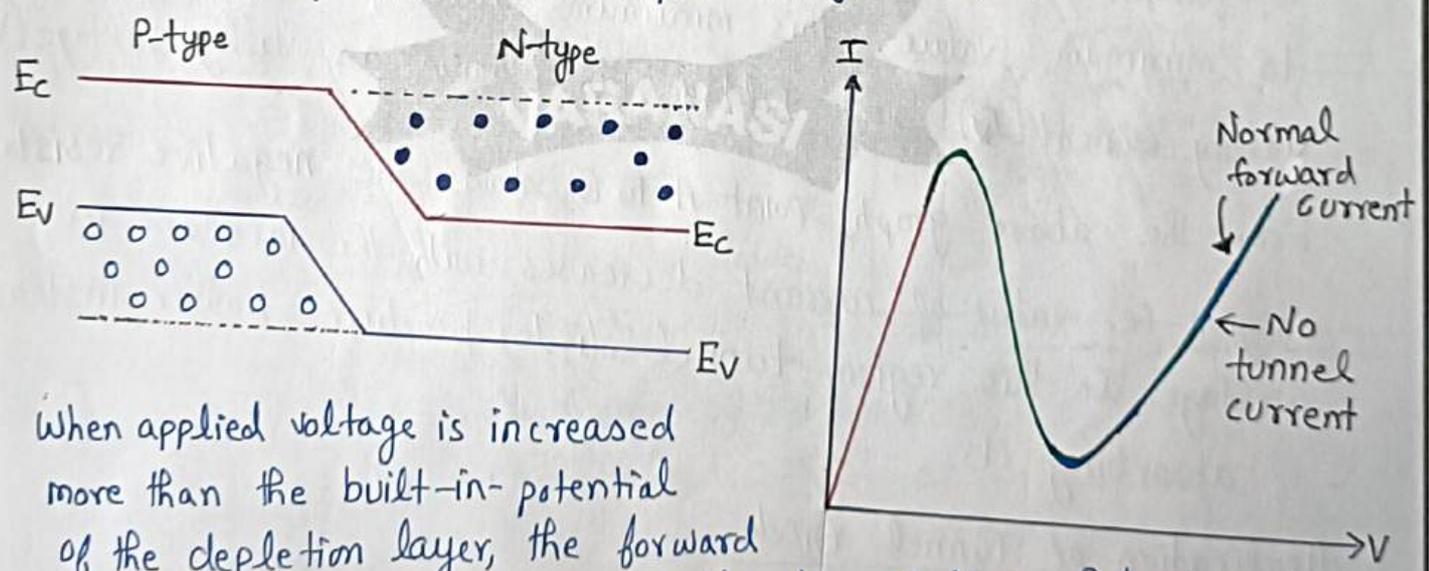
Maximum tunnel current flows when the energy level of n-side conduction band and the energy level of p-side valence band becomes equal.

④ A further increase in the applied voltage will cause a slight misalignment of the conduction band and valence band. Still, there will be an overlap and due to this few number of electrons will tunnel from the conduction band of n-type to the valence band of p-type. Therefore, this causes small

current to flow. Hence, tunnel current starts decreasing.

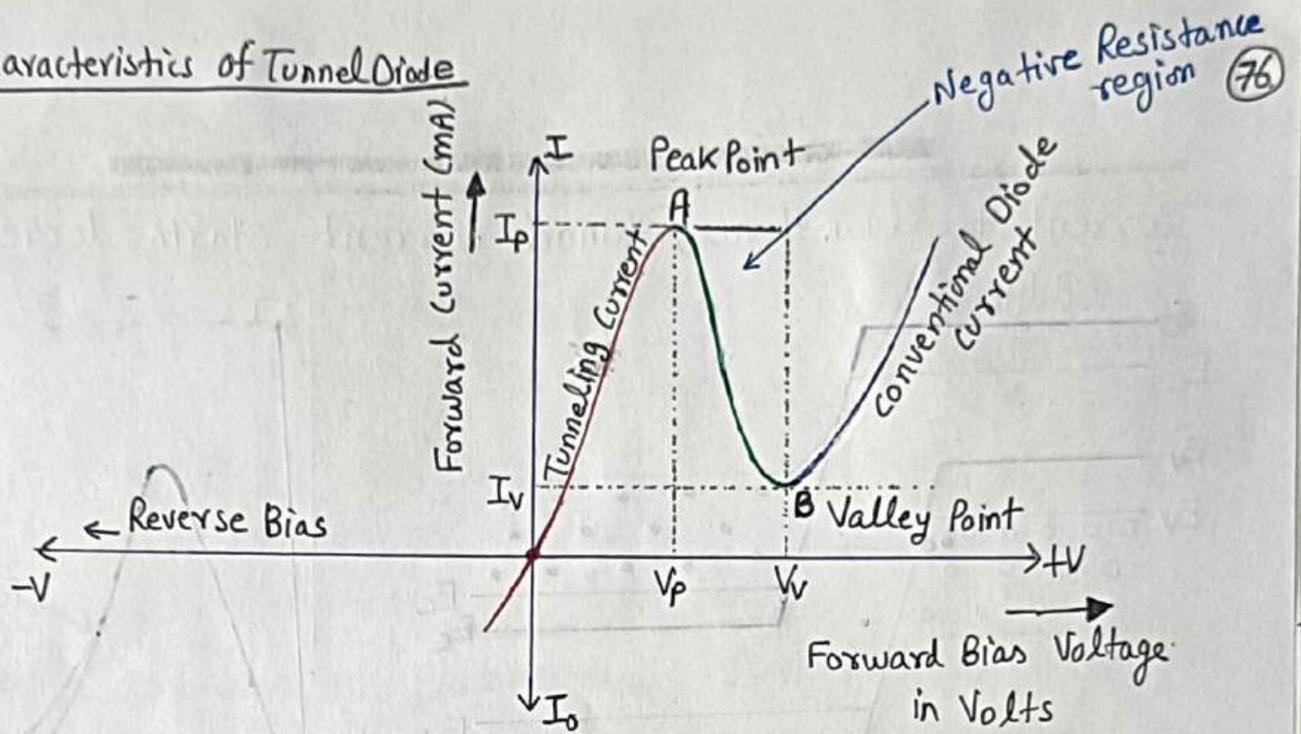


⑤ The tunneling current will be zero when applied voltage is increased further. At this voltage levels, the valence band and the conduction band does not overlap. Now, the tunnel diode will operate as a simple PN-junction diode.



When applied voltage is increased more than the built-in-potential of the depletion layer, the forward current starts flowing through the tunnel diode. Behaviour is very much similar to the forward PN-junction diode [normal].

## V-I Characteristics of Tunnel Diode



When tunnel diode is forward biased, due to heavy doping conduction takes place. The maximum current that flows in the diode is

$I_p$  [peak current] and voltage applied is  $V_p$  [peak voltage].

The current across the terminal decreases when applied voltage is further increased. The current decreases until it reaches its minimum value. This minimum value of current is known as

valley current [ $I_v$ ] and voltage is known as valley voltage [ $V_v$ ]

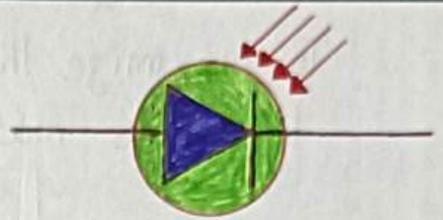
From the above graph, point A to B shows the negative resistance region i.e. value of current decreases with the increase in voltage. In this region, tunnel diode produces power instead of absorbing it.

### Application of Tunnel Diode

- ① It acts as logic memory storage device.
- ② It can be used as a switch, amplifier and oscillator.
- ③ It can be used as a high frequency component as it shows fast response.

### D Photodiodes

A photodiode is a PN-junction diode that converts light energy into electrical energy when incident light falls on it.



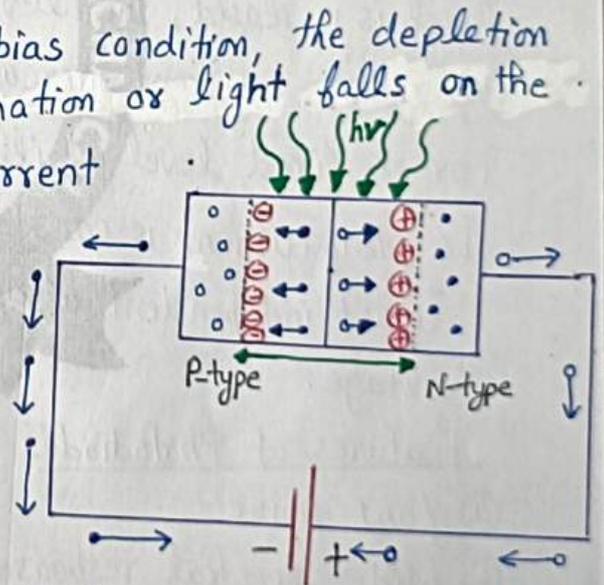
Photodiode Symbol

The amount of current flow is directly proportional to the intensity of light falling on it.

It is also known as photo-detector, light detector and photo-sensor. Photodiodes are particularly designed to work in reverse bias condition.

#### Working Principle of Photodiode

As photodiode operates in the reverse bias condition, the depletion layer width is large. When no illumination or light falls on the photodiode, the reverse saturation current flows due to thermally generated minority carriers. This current is also known as dark current.



When light is incident on the photodiode,

the absorption of photons create electron-hole pairs on both sides of the junction.

In the depletion region, the electric field at the junction accelerates these electrons towards the n-region and the holes towards the p-region. These photo-induced minority charge carriers increases the reverse saturation current. This current is known as **photocurrent**. The commonly used materials for

photodiode are Silicon, Germanium, Indium gallium arsenide (InGaAs) etc.

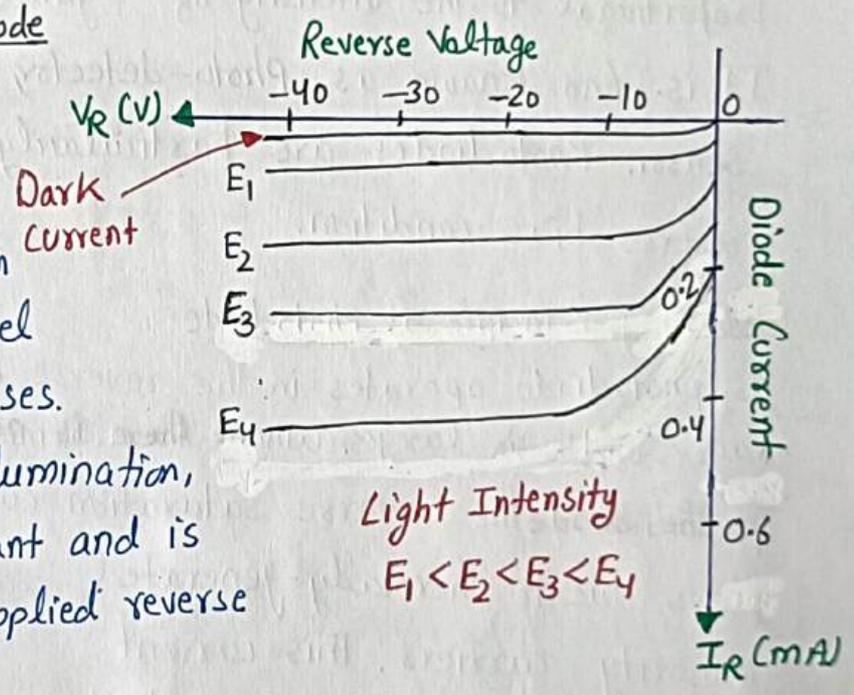
To maximize the sensitivity of photodiode, photocurrent must be made maximum i.e.

Energy of photon > Bandgap Energy  
i.e.  $h\nu > E_g$

Characteristics of Photodiode

For zero illumination, only dark current flows. As the illumination level is increased, the level of reverse current increases.

For a fixed level of illumination, the photocurrent is constant and is almost independent of applied reverse voltage.



Features of Photodiodes

- (a) Low noise
- (b) Wide spectral response
- (c) Long life
- (d) Compact and lightweight
- (e) Excellent linearity with respect to light.

Applications of Photodiode

- (a) Used in Burglar alarm system.
- (b) Used in light detection system.
- (c) Used in light operated system.