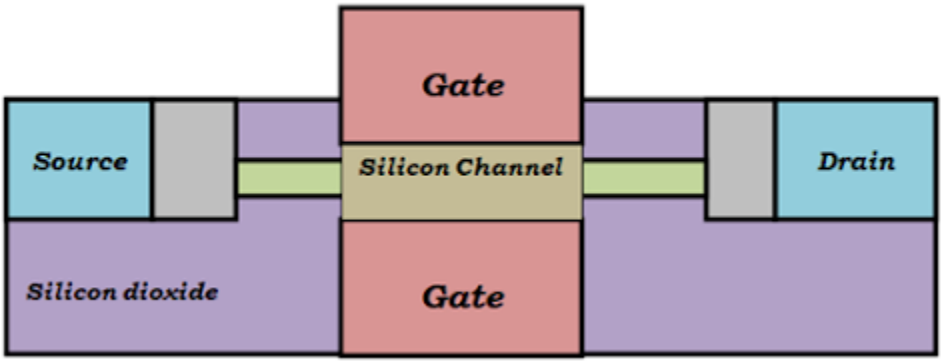
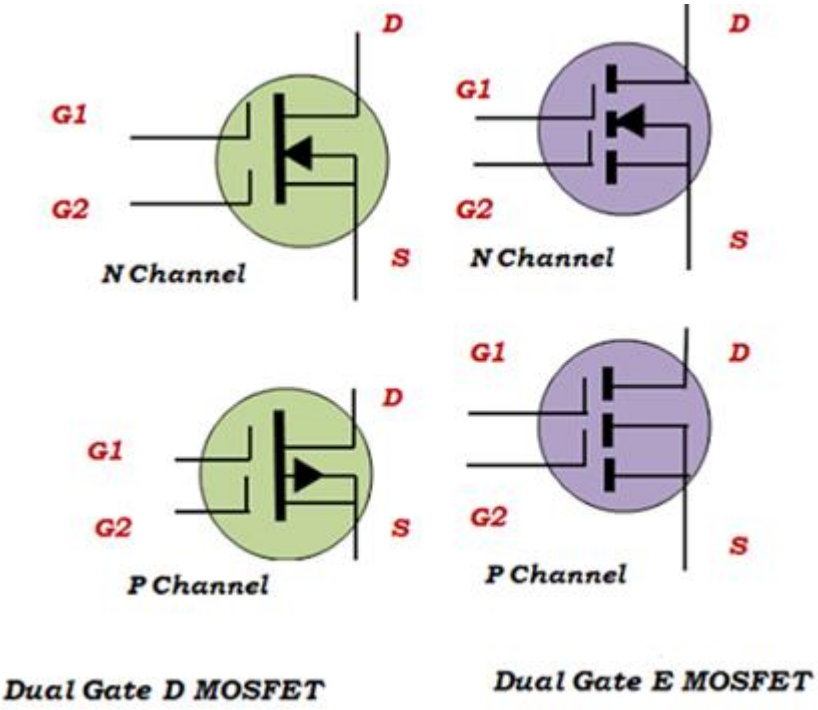
DUAL GATE MOSFET

In dual gate MOSFET as the name says two gate terminals are used. The second gate terminal is used to control and reduce the feedback capacitance between input and output and thus the amplifiers become more stable. It is mostly used in high frequency RF amplifier applications. The disadvantage of normal FET is high capacitance so that it cannot be used at higher frequencies.



Dual Gate MOSFET

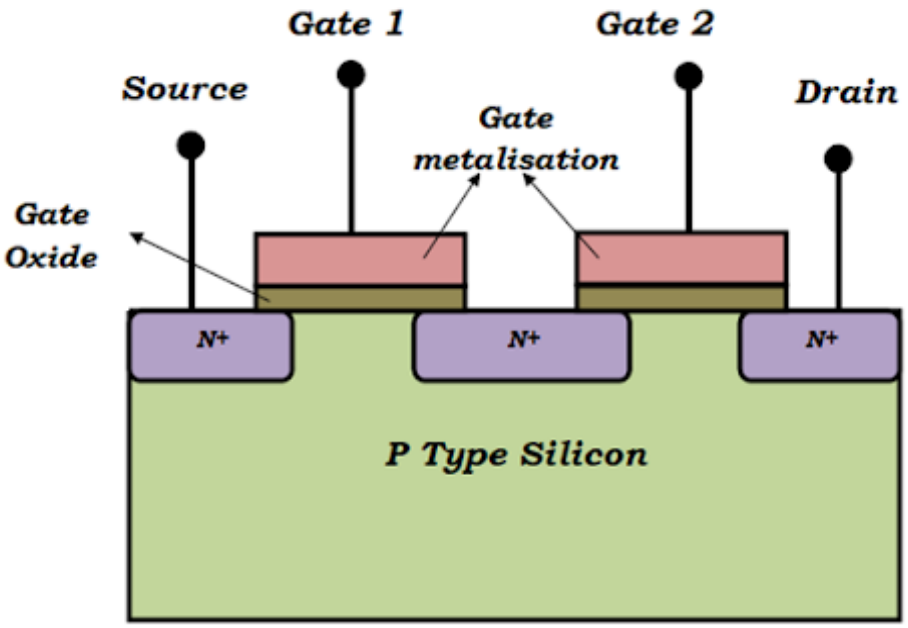
Symbol of Dual gate MOSFET:



Symbol of Dual Gate MOSFET

In the above diagram the symbol of depletion and enhancement dual gate MOSFET is given. N channel and P channel in each mode is given. But P channel is not used mostly because the mobility of holes is very low than the mobility of electrons.

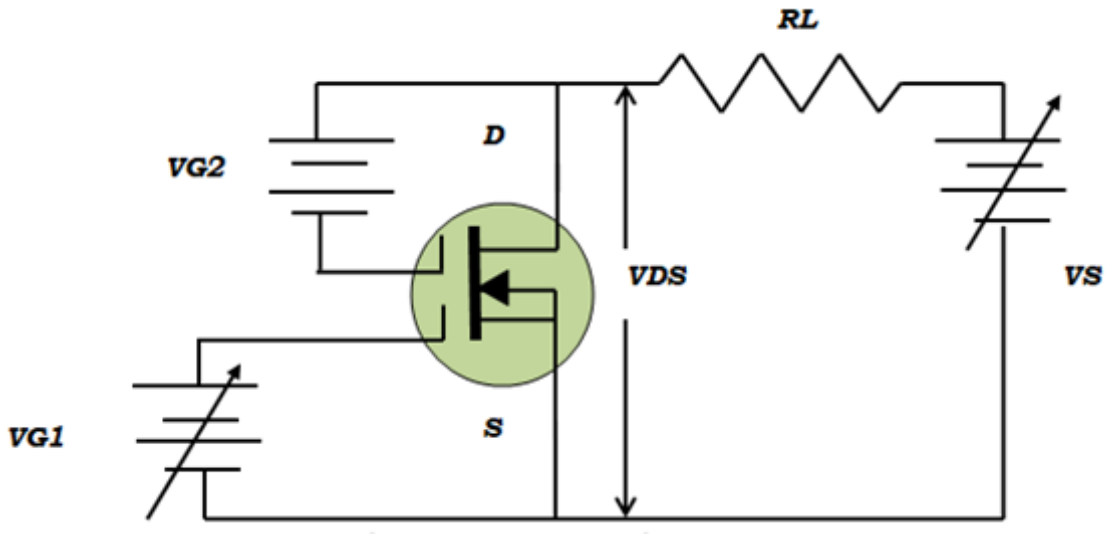
Construction of Dual gate MOSFET:



Construction of Dual Gate MOSFET

Double Gate MOSFET is manufactured using Silicon On Insulator method. Silicon channel is grown over silicon oxide layer. It is like two FETs connected in series. The highly doped N middle block acts as the drain for the first FET and source for the second FET. The gate oxide between gate and the channel is the dielectric layer and the metal used for gate is conductor and the channel is also conductor, so all these three layers together form the capacitor. So it is like two capacitors connected in series. The total capacitance connected in series is lesser than the individual capacitance. Two gates are used to reduce the feedback capacitance at high frequencies. The voltages at both the gates controls the flow of current in the channel.

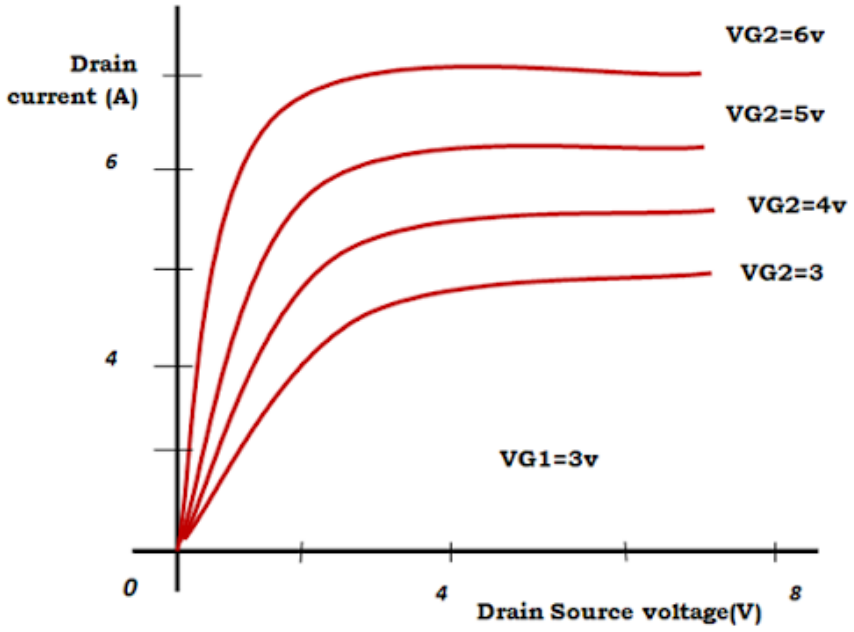
Working of Dual gate MOSFET:



Working of Dual Gate MOSFET

In the above diagram there are two gates and two FETs. They are top gate, bottom gate and top FET and bottom FET. In the top gate voltage is applied and kept constant and the bottom FET is analyzed. It is found that when the applied voltage is above 3V that is the threshold voltage to the top gate, it remains in the saturation region.

V-I Characteristics of Dual gate MOSFET:



V-I Characteristics of Dual Gate MOSFET

The voltage applied at the first gate is kept at 3V and kept as constant. The applied voltage at the second gate is varied and and the drain and source voltage is varied and the drain current is observed. The threshold voltage is 3v. the drain current increases and remains in the saturation region where the current is almost constant.

Advantages of Dual gate MOSFET:

1) Higher drive currents at lower supply voltage and threshold voltage.

2) Reduced channel and gate leakage current at off state which saves power.

3) Separate gate control on voltage saves power and chip area.

Challenges in Dual gate MOSFET:

1) Identically sized gates

2) Self alignment of source and drain to both gates

3) Alignment of both gates to each other

4) Connecting two gates with low resistance path

Application of Dual gate MOSFET:

1) Mixers

2) Demodulators

3) Cascade amplifiers

4) RF amplifier

5) AGC amplifier

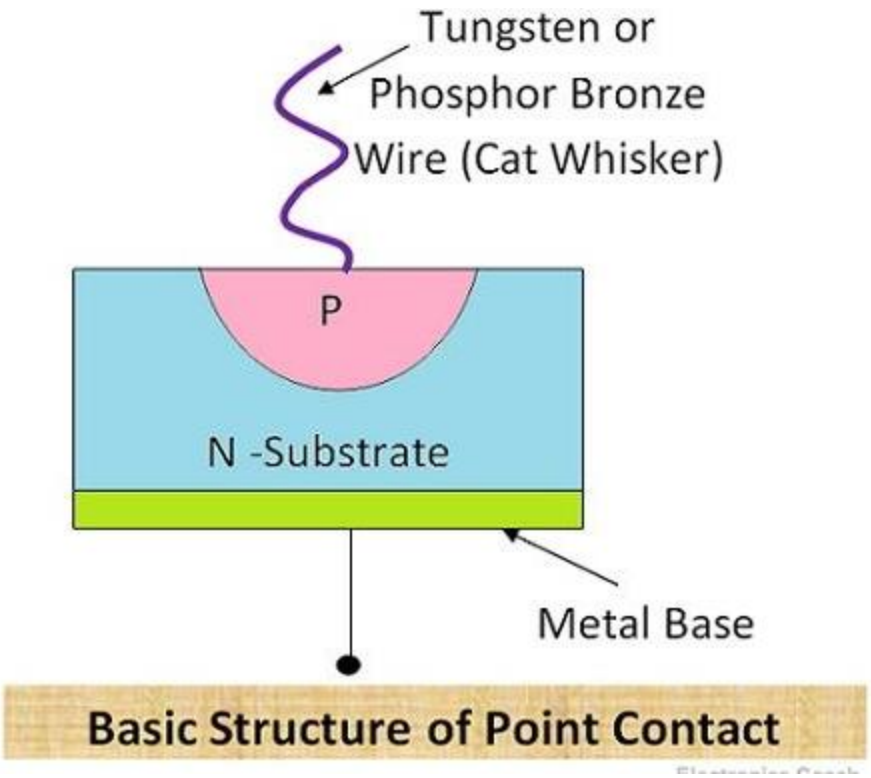
POINT CONTACT DIODE

Definition: Point contact diode is formed by touching a metallic wire with an N-type semiconductor to form a small area of contact. This form a **small point junction.** It is widely used because such a small point junction possesses a small value of junction capacitance. Thus, the charge storage at the junction is low. Due to this, the switching ability of diode is much better than a conventional diode.

Construction of Point Contact Diode

It is formed by a contact of an N-type semiconductor substrate and tungsten or **phosphor bronze wire (Cat whisker)**. The semiconductor used in the construction of point contact diode can be either silicon or germanium but Germanium is used extensively because it possesses higher carrier mobility.

The dimension of the semiconductor substrate is about 1.25 mm square and its thickness is 0.5 mm thick. One phase of the semiconductor substrate is soldered to the metal base by the technique of radio frequency heating.



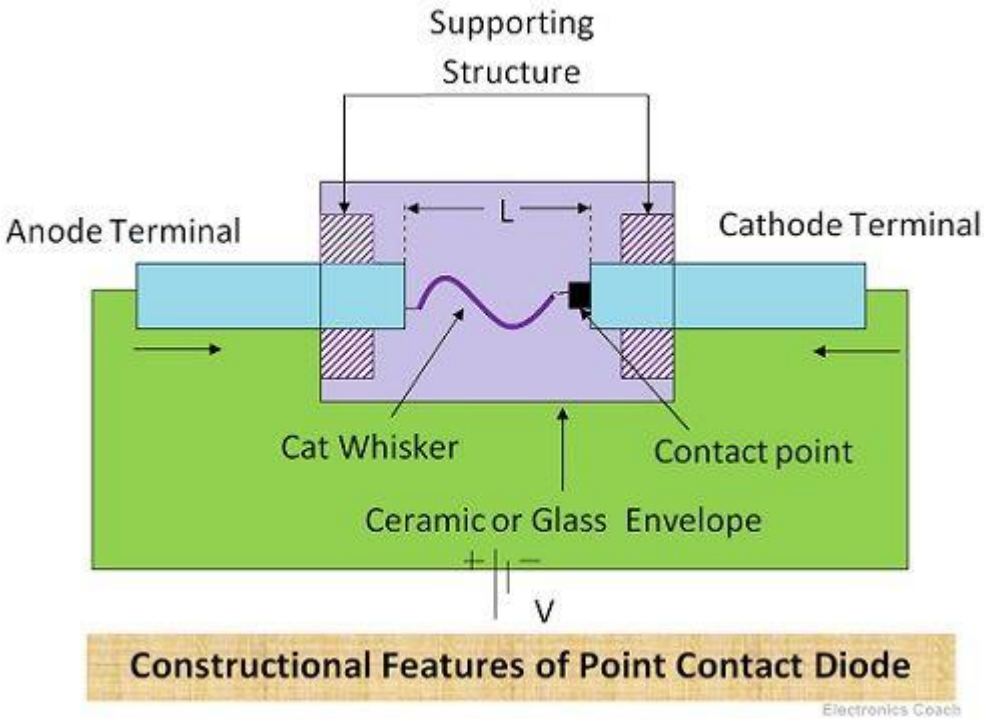
Basic Structure of Point Contact

The cross sectional area of tungsten wire or cat whisker is in few meter. It is joined to N-type semiconductor but the phase of the substrate joined to cat whisker should be opposite to that of metal contact phase. The anode and cathode terminal are connected through metallic contacts.

Working of Point Contact Diode

When forward bias is applied to point contact diode the current produced in the device is passed through the cat whisker. Due to this, the tungsten wire gets heated. Due to this heating, the wire undergoes deformation. Thus, a small gap is deliberately left for the expansion of wire under the large current.

When the wire gets heated, the semiconductor in the contact with the wire also gets heated. Due to this, it gets melted and atoms from whisker are passed to semiconductor crystal. Thus, the whisker acts as a P-type semiconductor. Therefore, a P-N Junction is formed but the area of the junction is very small. It can be assumed as a pointed junction.



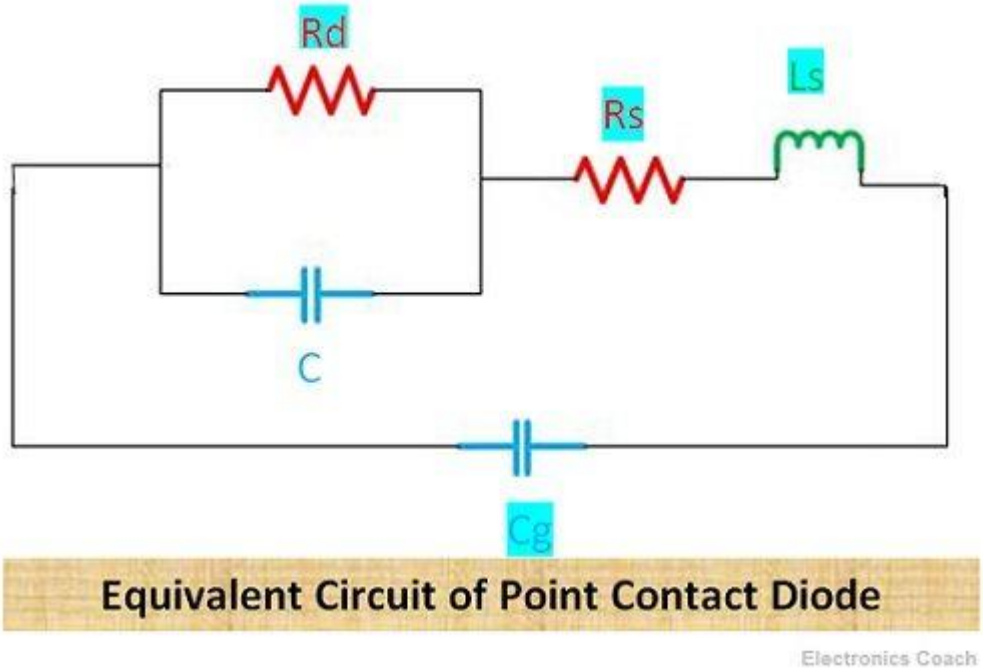
Although the junction cannot be seen clearly because the size of the junction is very small, it can be considered as point junction. The entire device is enclosed in glass or ceramic envelope. Besides, the supporting structure is provided to N-type semiconductor and cat whisker to provide mechanical strength to the device.

The junction capacitance and diffused capacitance in this diode is very small i.e. about 0.1 to 1pF. This is because the area of contact between the wire and the N-type substrate is very small. Due to the small area of junction the density of charge carriers near junction is very low. Thus, the low charge storage imparts it the ability to switch fastly.

Approximate Small Signal Equivalent Circuit

The approximate small signal equivalent circuit is described in the below diagram. The total capacitance is the sum of C_T and C_D.

$C = C_T + C_D$ and $C_g = \varepsilon_0 A/L$



Where Cg is the geometric capacitance

$$R_d = dV/dI$$

Where Rd is the nonlinear resistance of the diode, and series resistance Rs and Inductance Ls represents the effects of ohmic contacts, bulk semiconductor and whisker.

Advantage of Point Contact Diode

Suitable for High Frequency: Due to fast switching, it is suitable for high-frequency applications.

Disadvantages of Point Contact Diode

1. **Lower Current Rating:** The diode has lower current rating due to which the diode resistance is large under forward bias.
2. **Less Reliable:** The small area of contact is not very rugged and thus, it is less reliable than a conventional diode.

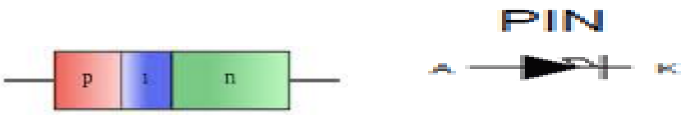
Applications of Point Contact Diode

1. **High-Frequency Circuits:** Due to small junction area and low junction capacitance and diffused capacitance as discussed above, the diode is suitable for high-frequency applications (about 10 GHz).
2. **Radio Frequency Mixers:** In communication, Mixers play a crucial role in circuitry and the point contact diode is used extensively in radio frequency mixers.
3. **Detector Circuits:** For detecting high-frequency signal these diodes play a crucial role in circuitry.
4. **Video Detector:** It also finds application in video detector.
5. **Envelope detector and detector circuits of radio and television:** Point contact diodes are also used in envelope and television detector circuit because it switches rapidly from one state to another state.

These are the applications of Point contact diode. Point contact diode does not involve two semiconductor pieces to form two electrodes but it uses metallic wire and a semiconductor specimen.

PIN diode

A **PIN diode** is a diode with a wide, undoped intrinsic semiconductor region between a p-type semiconductor and an n-type semiconductor region. The p-type and n-type regions are typically heavily doped because they are used for ohmic contacts.



the PIN diode consists of a semiconductor diode with three layers. The usual P and N regions are present, but between them is a layer of intrinsic material a very low level of doping. This may be either N-type or P-type,

The thickness of the intrinsic layer is normally very narrow, typically ranging from 10 to 200 microns. The outer P and N-type regions are then heavily doped

here is very lightly doped wide region between P and N regions. Wide I – region makes them inefficient rectifiers. Under zero or Reverse Bias PIN diode has low capacitance so high resistance to RF signal. Under FB a typical PIN diode will have very low resistance (typical 1 Ω) an RF conductor. It makes a god RF switch

The PIN diode has heavily doped p-type and n-type regions separated by an intrinsic region. When reverse biased, it acts like an almost constant capacitance and when forward biased it behaves as a variable resistor.

The built in field stretches over the intrinsic region, causing minority carriers to be swept out by the field over a larger volume. It is often used for light detectors, and some high efficiency solar cells.

The capacitance between the P and N region decreases because of the increased seperation between P and N region.thid advantage allow the PIN diode to have fast response time. Hence these diode are useful at very high frequencies (above 300MHZ)

There is a great er electron hole pair generation because of the increased electricfield between the P and N region.this advantage allows the PIN diode to process even the weak signal

OPERATION

When P n region is unbiased (no voltage is applied acrossthe diode)ther is a diffusion ofelectron aand holesacross the junction due to the different concentration of atoms in the P I N region

The diffusion of electron s and holes produce a depletion layer across the PI and NI junction as shown in Fig. The depletion layer penetrate to a little distance in the P –type and N –type semiconductor regions but to a larger distance in the I-region. Under such condition , the device has a high value of resistance.

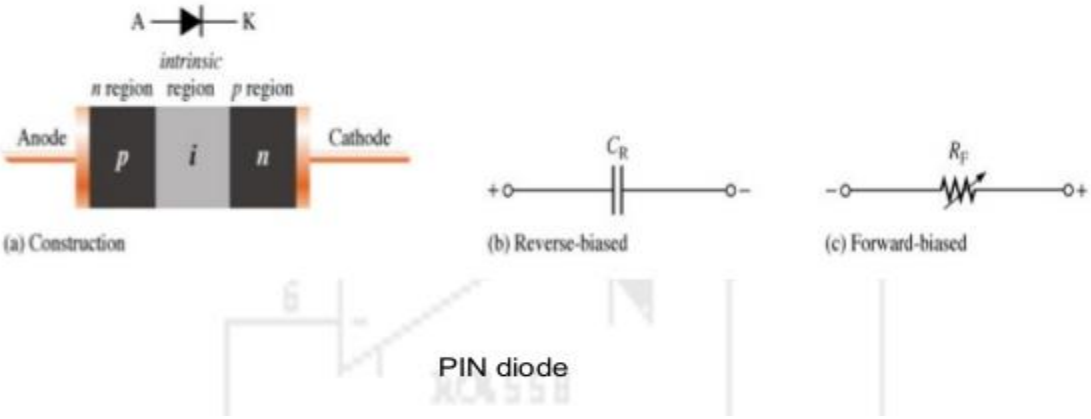


Fig 2

When the PIN diode is forward biased, the width of the depletion layer s decreases. As a result of this, more carriers are injected into the I-region. This reduces the resistance of the I-region. I the depletion layer is not thick, then the I-region becomes flooded with the carriers at a suitable bias. Thus, when a PIN diode is forward biased, it acts like a variable resistance as shown in fig 2 The forward resistance of an intrinsic region decreases with the increasing current.

On the other, when the PIN diode is reverse biased, the depletion layers become thicker. As the reverse bias is increased , the thickness of the depletion layer increases till the I-region becomes free of mobile caries. The reverse bias , at which this happens, is called swept out voltage. At this stage the PIN diode acts like an almost constant capacitance as shown in Fig. 2

APPLICATION

The PIN diode is used in a number of areas as a result of its structure proving some properties which are of particular use.

- **High voltage rectifier:** The PIN diode can be used as a high voltage rectifier. The intrinsic region provides a greater separation between the PN and N regions, allowing higher reverse voltages to be tolerated.
- **RF switch:** The PIN diode makes an ideal RF switch. The intrinsic layer between the P and N regions increases the distance between them. This also decreases the capacitance between them, thereby increasing he level of isolation when the diode is reverse biased.
- **Photodetector:** As the conversion of light into current takes place within the depletion region of a photdiode, increasing the depletion region by adding the intrinsic layer improves the performance by increasing he volume in which light conversion occurs.

These are three of the main applications for PIN diodes, although they can also be used in some other areas as well

AVALANCHE PHOTODIODE

The avalanche photodiode or APD was designed by a Japanese engineer in the year 1952. An APD is a very responsive semiconductor detector that used the photoelectric effect to change light into electricity. In 2020, a graphene layer is added to this diode to avoid degradation eventually to maintain these diodes.

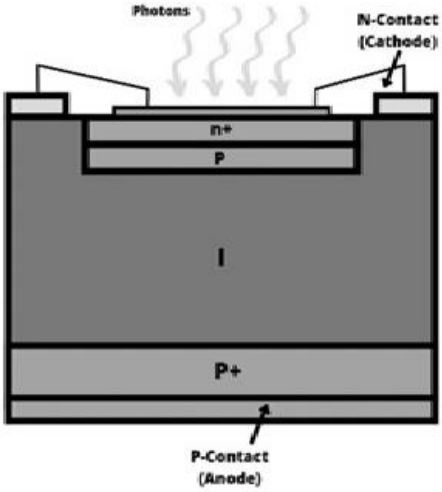
The diode which uses the avalanche method to provide extra performance as compared to other diodes is known as avalanche photodiode.

These diodes are used to change the signals from optical to electrical. These diodes can be operated in high reverse bias. The **avalanche photodiode symbol** is similar to the Zener diode.

Avalanche Photodiode Symbol

Avalanche Photodiode Construction

The construction of both the PIN photodiode and Avalanche photodiode is similar. This diode includes two heavily doped & two lightly doped regions. Here, heavily doped regions are P+ & N+ whereas lightly doped regions are I & P.



Avalanche Photodiode Construction

In the intrinsic region, the depletion layer width is fairly thinner in this diode as compared to the PIN photodiode. Here, the p+ region works like the anode whereas the n+ region acts as the cathode.

As compared to other photodiodes, this diode works in a high reverse bias condition. So this allows avalanche multiplication of the charge carriers formed through the light impact or photon. The avalanche action allows the gain of the photodiode to be enhanced several times to provide a high range of sensitivity.

Working Principle

Avalanche breakdown occurs mainly once the photodiode is subjected to maximum reverse voltage. This voltage enhances the electric field beyond the depletion layer. When incident light penetrates the p+ region then it gets absorbed within the extremely resistive p region then electron-hole pairs are generated.

Charge carriers drift including their saturation velocity to the pn+ region wherever a high electric field exists. When the velocity is highest, then charge carriers will collide through other atoms & produce new electron-hole pairs. A huge charge carrier's pair will result in high photocurrent.

Avalanche Photodiode Operation

This diode operation can be done in a depleted mode completely. However, they can also work in the Geiger mode in addition to the linear avalanche mode. In this type of operation mode, the photodiode can be operated at the above breakdown voltage. At present, another mode is launched namely "Sub-Geiger mode".

Avalanche Photodiode in Optical Fiber Communication

In optical fiber communication (OFC) systems, avalanche photodiodes are generally used for the recognition of weak signals but circuits need to optimize enough so that high Signal to noise ratio (S/N). Here, SNR is

S/N = Power from the photocurrent/photo detector's power + Amplifier noise power

or obtaining the perfect signal-to-noise ratio, quantum efficiency should be high because this value is almost maximum, so most of the signals are noticed.

Avalanche Photodiode Characteristics

Avalanche photodiodes are highly sensitive, high-speed-based diodes which use an internal gain method that works through applying a reverse voltage. As compared to PIN type photodiode, these diodes measure low range light so used in different applications where high sensitivity is required like measurement of optical distance and optical communication for long-distance.

There are different avalanche photodiode families which are designed mainly for detecting short wavelengths otherwise near-infrared.

Advantages & Disadvantages

The **advantages of avalanche photodiode** include the following.

- The sensitivity range is high.
- High performance.
- Quick response time.
- These diodes are applicable here the gain level is very important as the high voltage required, through lower reliability means that they are frequently less convenient to utilize.
- It detects low-intensity light.
- A single-photon generates a huge number of charge carrier pairs.

The **disadvantages of avalanche photodiode** include the following.

- The required operating voltage is high
- The output of this diode is not linear
- High range of noise
- It is not used regularly because of the low reliability
- It uses high reverse bias for its proper operation

Applications

The **applications of avalanche photodiode** include the following.

- LASER scanner
- Analyzer bridge of antenna
- PET scanner
- Barcode reader
- Laser microscopy
- Laser Rangefinders
- Speed gun
- APDs are used in receivers of OFC (optical fiber communications), imaging, finding the range, laser microscopy, laser scanners & OTDR (optical-time domain reflectometers).
- These are used in optical communications like receiving detectors. Their wide bandwidth & high sensitivity will make it very famous with designers. These diodes work through a reverse voltage beyond the junction that allows the formation of charge carrier pairs in reply to the radiation.