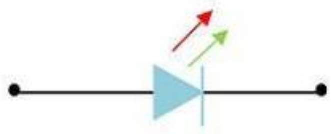
UNIT-III
OPTOELECTRONICS

- **Radiative recombination :** An electron in the conduction band recombines with a hole in the valence band and the excess energy is emitted in the form of a photon.

- **Non Radiative recombination:** An electron in the conduction band recombines with a hole in the valence band and the excess energy is emitted in the form of heat in the semiconductor crystal lattice.

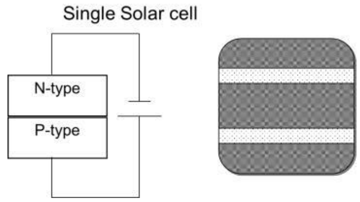
- **LED:** (Light Emitting Diode) is an optoelectronic device which works on the principle of electro-luminance.

- **Symbol of LED:**



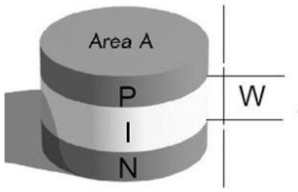
- **Solar cell** It is a photovoltaic device that converts the light energy into electrical energy based on the principles of photovoltaic effect.

- **Symbol of Solar cell:**

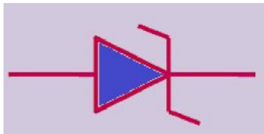


- **PIN diode** is a one type of photo detector, used to convert optical signal into an electrical signal. The PIN diode comprises of three regions, namely P-region, I-region and N-region.

- **Symbol of PIN diode:**



- **Avalanche diode** is a one kind of semiconductor device specially designed to work in the reverse breakdown region.
- **Symbol of Avalanche diode**



1. What is Radiative Recombination?

Ans: Recombination: A process whereby electrons and holes (carriers) are annihilated or destroyed.

Classification:

1. Radiative Recombination: Photon
2. Nonradiative Recombination: Phonon or Lattice vibration

Radiative Recombination occurs when an electron in the conduction band recombines with a hole in the valence band and the excess energy is emitted in the form of a photon.

Optical processes associated with radiative transitions are:

a. spontaneous emission
b. absorption or gain
c. stimulated emission,

- **What is Nonradiative Recombination**

Ans: Nonradiative Recombination

An electron in the conduction band recombines with a hole in the valence band and the excess energy is emitted in the form of heat in the semiconductor crystal lattice.

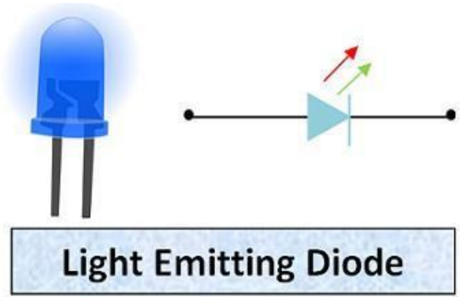
Characterized by the absence of any useful emitted photons in the recombination process.Affecting performance of injection laser by increasing the threshold current

Nonradiative Recombination processes include:

Auger Recombination, Surface Recombination, Recombination at defects

2. Explain the construction, working and I-V characteristics of an LED.

Ans:LED (Light Emitting Diode) is an optoelectronic device which works on the principle of electro-luminance. Electro-luminance is the property of the material to convert electrical energy into light energy and later it radiates this light energy. In the same way, the semiconductor in LED emits light under the influence of electric field.



The symbol of LED is formed by merging the symbol of P-N Junction diode and outward arrows. These outward arrows symbolise the light radiated by the Light emitting diode.

Construction of LED

The semiconductor material used in LED is Gallium Arsenide (GaAs), Gallium Phosphide (GaP) or Gallium Arsenide Phosphide (GaAsP). Any of the above-mentioned compounds can be used for the construction of LED, but the colour of radiated light changes with the change in material. Below are some of the material and their respective colour of light which they emit. In addition to it, the ranges of typical forward voltage are also given below.

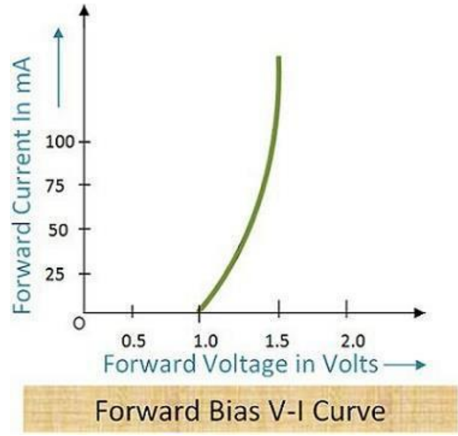
Working of LED

The electrons are majority carriers in N-type and holes are majority carriers in P-type. The electrons of N-type are in the conduction band and holes of P-type are in the valence band. The energy level of the

Conduction band is higher than the energy level of the Valence band. Thus, if electrons tend to recombine with holes they have to lose some part of the energy to fall in lower energy band.

I-V Characteristics of LEDs

The characteristics curve of the LED shows that the forward bias of **1 V** is sufficient to increase the current exponentially.



Applications of LED

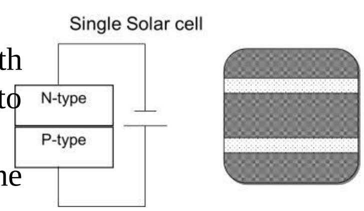
- Indicator in AC circuit
- Display Panel Indicator
- Digital Watches, Calculators & Multimeters
- Remote Control Systems

3. What is a solar cell? Explain its construction and working.

Ans: Solar cell is a photovoltaic device that converts the light energy into electrical energy based on the principles of photovoltaic effect.

Principle: The solar cells are based on the principles of photovoltaic effect. The photovoltaic effect is the photo generation of charge carriers in a light absorbing material as a result of absorption of light radiation**.**

Construction Solar cell (crystalline Silicon) consists of a*n-type semiconductor (emitter)*layer and*p-type semiconductor layer (base).* The two layers are sandwiched and hence there is formation of p-n *junction.* The surface is coated with *anti-refection coating* to avoid the loss of incident light energy due to reflection.



A proper metal contacts are made on the n-type and p-type side of the semiconductor for electrical connection.

Working:

When a solar *panel exposed to sunlight*, the light energies are absorbed by a semi-conduction materials.

Due to this absorbed energy, the electrons are liberated and produce the external DC current.

The DC current is converted into 240-volt AC current using an inverter for different applications.

Mechanism:

First, the sunlight is absorbed by a solar cell in a solar panel.

The absorbed light causes electrons in the material to increase in energy. At the same time they make free to move around in the material.

However, the electrons remain at this higher energy for only a short time before returning to their original lower energy position.

Therefore, to collect the carriers before they lose the energy gained from the light, a PN junction is typically used.

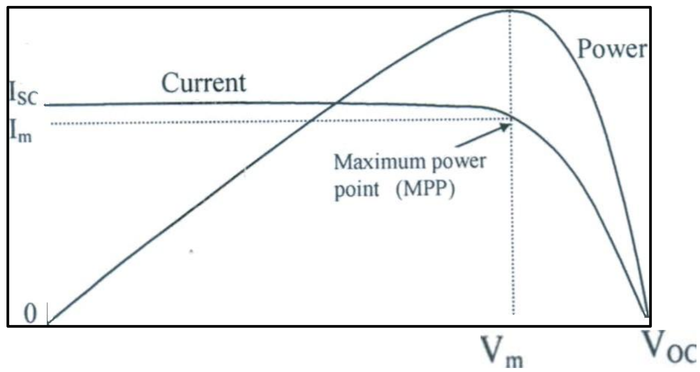
A PN junction consists of two different regions of a semiconductor material (usually silicon), with one side called the p type region and the other the n-type region.

During the incident of light energy, in p-type material, electrons can gain energy and move into the n-type region.

Then they can no longer go back to their original low energy position and remain at a higher energy. The electrons that leave the solar cell as current give up their energy to whatever isconnected to the solar cell, and then re-enter the solar cell. Once back in the solar cell, the process begins again:

The process of moving a light- generated carrier from p-type region to n-type region is called collection. These collections of carriers (electrons) can be either extracted from the device to give a current, or it can remain in the device and gives rise to a voltage

I-V Characteristics of Solar Cell



4. What is a PIN Diode? Explain its construction and working.

Ans: The PIN diode is a one type of photo detector, used to convert optical signal into an electrical signal.

The PIN diode comprises of three regions, namely P-region, I-region and N-region.

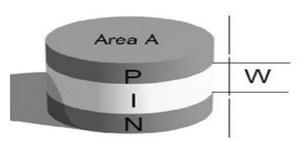
Typically, both the P and N regions are heavily doped due to they are utilized for Ohmic contacts.

The intrinsic region in the diode is in contrast to a PN junction diode.

This region makes the PIN diode a lower rectifier, but it makes it appropriate for fast switches, attenuators, photo detectors and applications of high voltage power electronics.

Structure and Working of PIN Diode

The term PIN diode gets its name from the fact that includes three main layers. Rather than just having a P-type and an N-type layer, it has three layers such as P-type layer

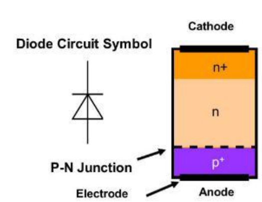


Intrinsic layer

N-type layer

The working principle of the PIN diode exactly same as a normal diode. The main difference is that the depletion region, because that normally exists between both the P & N regions in a reverse biased or unbiased diode is larger. In any PN junction diode, the P region contains holes as it has been doped to make sure that it has a majority of holes. Likewise the N-region has been doped to hold excess electrons.

The layer between the P & N regions includes no charge carriers as any electrons or holes merge. As the depletion region of the diode has no charge carriers it works as an insulator. The depletion region exists within a PIN diode, but if the PIN diode



is forward biased, then the carriers come into the depletion region and as the two carrier types get together, the flow of current will starts.

PIN Diode Characteristics

The PIN diode characteristics include the following

This obeys the typical diode equation for small frequency signals. At higher frequencies, PIN diode appears like an approximately perfect resistor. There is a set of stored charge in the intrinsic region. At small frequencies, the charge can be detached and the diode switched OFF.

At higher frequencies, there is not sufficient time to eliminate the charge, so the PIN diode never switched OFF. The diode has a reduced reverse recovery time. A PIN diode properly biased, therefore performs as a variable resistor. This high-frequency resistance may differ over a broad range (from 0.1 Ω-10 kΩ in some cases; the practical range is slighter, though).

The wider intrinsic area also means the PIN diode will have a low capacitance when reverse-biased. In this diode, the depletion region exists completely in the intrinsic region. This depletion region is much better than in a PN-diode, and nearly constant-size, independent of the reverse bias applied to the PN-diode.

This increases the amount where pairs of electron-hole can be produced by an occurrence photon. Some photo detector devices like photo transistors and PIN photodiodes employ a PIN-junction in their construction.

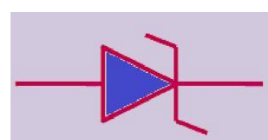
The design of the PIN-diode has some design tradeoffs. Rising the magnitudes of the intrinsic region permits the diode to appear like a resistor at minor frequencies. It harmfully affects the time required to switch off the diode & its shunt capacitance. Therefore, it is essential to choose a device with the most suitable properties for a particular use

5. **What is an Avalanche Diode? Explain its construction and working.**

Ans: An avalanche diode is a one kind of semiconductor device specially designed to work in the reverse breakdown region.

The symbol of this diode is same to as Zener diode. The avalanche diode comprises of two terminals namely anode and cathode.

The avalanche diode symbol is alike to the normal diode but with the turn edges of the vertical bar that is shown in the following figure.



Avalanche Diode Construction

Generally, avalanche diode is made from silicon or other semiconductor materials. The construction of this diode is similar to the Zener diode, except doping level in this diode changes from Zener diode. These diodes are doped heavily. Thus, the depletion region width in this diode is very slight. Because of this region, reverse breakdown happens at lower voltages in this diode.

On the other hand, avalanche diodes are doped lightly. So, the depletion layer width of an avalanche diode is very large evaluated to the Zener diode. Because of this large depletion region, reverse breakdown take place at higher voltages in the diode. The breakdown voltage of this diode is cautiously located by controlling the doping level in the manufacture.

Working of an Avalanche Diode

The main function of the normal diode is to allow electrical current in only one direction i.e., forward direction.

Whereas, avalanche diode allows the current in both the directions. But, this diode is specially designed to work in reverse biased condition when the voltage surpasses the breakdown voltage in the reverse biased condition.

The voltage at which electric current enhances unexpectedly is called breakdown voltage. When the voltage in reverse bias condition applied to this diode then it surpasses the breakdown voltage, a breakdown of the junction will be occurs. This junction breakdown is named as an avalanche breakdown.

Whenever the forward bias voltage is applied to this diode, then it starts working like a regular p-n junction diode by permitting an electric current through it.

When the reverse biased voltage is applied to the avalanche diode, then the majority charge carriers in the P-type and N-type semiconductors are moved away from the PN- junction. As a result, the depletion region's width increases.

So, the majority carriers will not allow electric current. Though, the minority charge carriers knowledge a repulsive force from exterior voltage.

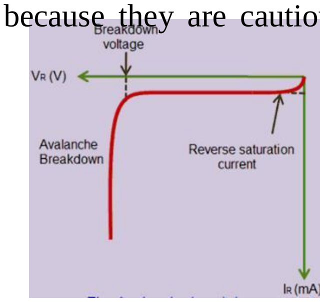
As a result, the flow of minority charge carriers from p-type to n-type & n-type to p-type by moving the electric current.

Though, the current moved by minority charge carriers is very little. The small current passed by minority charge carriers is termed as reverse leakage current.

If the reverse bias voltage is applied to this, further the diode is increased, the minority charge carriers will get a large amount of energy and go faster to better velocities.

The free moving electrons at high speed will crash with the atoms then transfers the energy to the valence electrons. The valence electrons which gets sufficient energy from the rapid electrons will be separated from the parent atom & turn into free electrons. Again, these electrons are accelerated. When these free electrons collide with other atoms, they knock off more electrons. Because of this constant collision with the molecules, a huge number of free electrons or holes are produced. These huge number of free electrons hold overload current in the diode.

Whenever the reverse voltage applied to the diode, then it continuously increases. At some end, the avalanche breakdown and junction breakdown occur. At this point, a tiny increase in voltage will rapidly increase the electric current. This unexpected increase of current may lastingly destroy the regular junction diode. Though, avalanche diodes may not be damaged because they are cautiously designed to function in avalanche breakdown region.



Breakdown Voltage of the Diode

The avalanche diode breakdown voltage depends on the density of doping. Rising the density of doping will reduces the breakdown voltage of the diode.

Applications of Avalanche Diode

- The Avalanche diode is used to protect the circuit.
- Designers employ the diode more for protecting the circuit against unwanted voltages.
- These diodes are used as white noise generators.
- Avalanche diodes produce RF noise, they are generally used as noise sources in radio gears.
- Avalanche diodes are used to generate microwave frequency.