UNIT-IV

OPTOELECTRONIC DEVICES

1. Describe the working of Photo Diode:

A photodiode is a PN-junction diode that consumes light energy to produce electric current. Sometimes it is also called as photo-detector, a light detector, and photo-sensor.

A photodiode is one type of light detector, used to convert the light into current or voltage based on the mode of operation of the device.

Types of Photo diodes: The types of the photodiodes can be classified based on its construction and functions as follows.

- PN Photodiode
- Schottky Photo Diode
- PIN Photodiode
- Avalanche Photodiode

Special Features of Photo diode:

- The linearity of the diode is good with respect to incident light
- Noise is low.
- The response is wide spectral
- Rugged mechanically
- Light weight and compact
- Long life

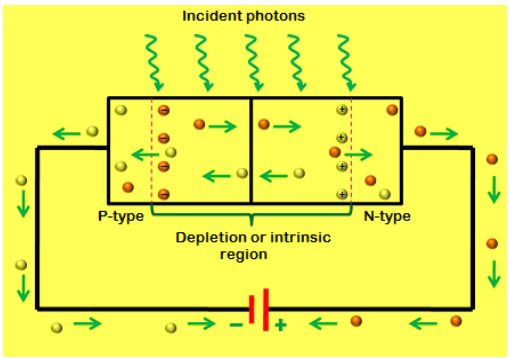
PN Photo Diode:

Prinicple:

Photoelecric effect is the basic principle of photo diode (ie) The light is incident on a reverse biased PN junction diode to produce photo current.

Working of Photodiode:

The working principle of a photodiode is, when a photon of ample energy strikes the diode, it makes a couple of an electron-hole. This mechanism is also called as the inner photoelectric effect. If the absorption arises in the depletion region junction, then the carriers are removed from the junction by the inbuilt electric field of the depletion region. Therefore, holes in the region move toward the anode, and electrons move toward the cathode, and a photocurrent will be generated. The entire current through the diode is the sum of the absence of light and the photocurrent. So the absent current must be reduced to maximize the sensitivity of the device.



Modes of Operation

The operating modes of the photodiode include three modes, namely Photovoltaic mode, Photoconductive mode and avalanche diode mode

Photovoltaic Mode: This mode is also known as zero bias mode, in which a voltage is produced by the lightened photodiode. It gives a very small dynamic range & non-linear necessity of the voltage formed.

Photoconductive Mode: The photodiode used in this photoconductive mode is more usually reverse biased. The reverse voltage application will increase the depletion layer's width, which in turn decreases the response time & the junction capacitance. This mode is too fast and displays electronic noise

Avalanche Diode Mode: Avalanche diodes operate in a high reverse bias condition, which permits multiplication of an avalanche breakdown to each photo-produced electron-hole pair. This outcome in an internal gain in the photodiode, which slowly increases the device response.

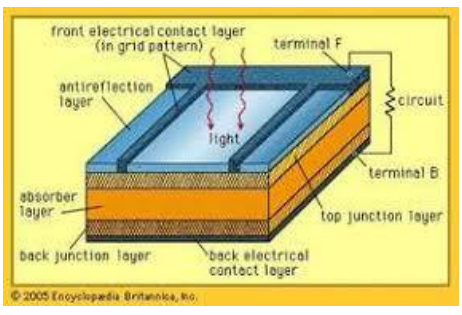
Applications of Photodiode

- The applications of photodiodes involve in similar applications of photodetectors like charge-coupled devices, photoconductors, and photomultiplier tubes.
- These diodes are used in consumer electronics devices like smoke detectors, compact disc players, and televisions and remote controls in VCRs.
- In other consumer devices like clock radios, camera light meters, and street lights, photoconductors are more frequently used rather than photodiodes.
- Photodiodes are frequently used for exact measurement of the intensity of light in science & industry. Generally, they have an enhanced, more linear response than photoconductors.
- Photodiodes are also widely used in numerous medical applications like instruments to analyze samples, detectors for computed tomography and also used in blood gas monitors.
- These diodes are much faster & more complex than normal PN junction diodes and hence are frequently used for lighting regulation and in optical communications.

2. Write a note on Solar cell:

Solar cell also called **photovoltaic cell**, any device that directly converts the energy of light into electrical energy through the photovoltaic effect.

The overwhelming majority of solar cells are fabricated from silicon—with increasing efficiency and lowering cost as the materials range from amorphous (noncrystalline) to polycrystalline to crystalline (single crystal) silicon forms.



Solar Cell Structure and Operation

Light enters the device through an optical coating, or antireflection layer, that minimizes the loss of light by reflection; it effectively traps the light falling on the solar cell by promoting its transmission to the energy-conversion layers below.

The antireflection layer is typically an oxide of silicon, tantalum, or titanium that is formed on the cell surface by spin-coating or a vacuum deposition technique.

The three energy-conversion layers below the antireflection layer are the top junction layer, the absorber layer, which constitutes the core of the device, and the back junction layer.

Two additional electrical contact layers are needed to carry the electric current out to an external load and back into the cell, thus completing an electric circuit.

The electrical contact layer on the face of the cell where light enters is generally present in some grid pattern and is composed of a good conductor such as a metal.

Since metal blocks light, the grid lines are as thin and widely spaced as is possible without impairing collection of the current produced by the cell. The back electrical contact layer has no such diametrically opposed restrictions.

It need simply function as an electrical contact and thus covers the entire back surface of the cell structure.

When light falls on a solar cell, electrons in the absorber layer are excited from a lower-energy "ground state," in which they are bound to specific atoms in the solid, to a higher "excited state," in which they can move through the solid.

In the absence of the junction-forming layers, these "free" electrons are in random motion, and so there can be no oriented direct current.

The addition of junction-forming layers, however, induces a built-in electric field that produces the photovoltaic effect. In effect, the electric field gives a collective motion to the electrons that flow past the electrical contact layers into an external circuit where they can do useful work.

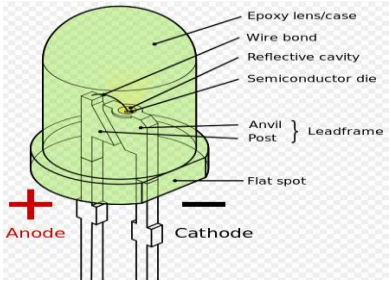
3**. What is LED? Explain the principle, construction and working of LED.**

LED:

The lighting emitting diode is a p-n junction diode. It is a specially doped diode and made up of a special type of semiconductors. When the light emits in the forward biased, then it is called as a light emitting diode.

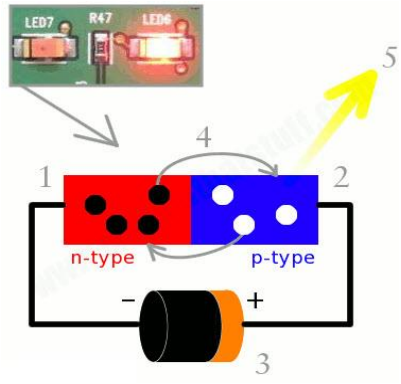
Working Principle of LED:

The working principle of the Light emitting diode is based on the quantum theory. The quantum theory says that when the electron comes down from the higher energy level to the lower energy level then, the energy emits from the photon. The photon energy is equal to the energy gap between these two energy levels. If the PN-junction diode is in the forward biased, then the current flows through the diode.

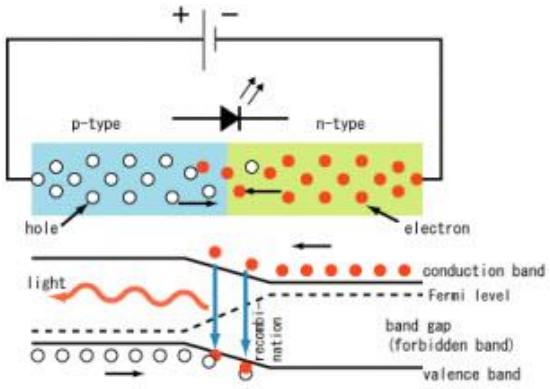


When the diode is forward biased, then the electrons & holes are moving fast across the junction and they are combining constantly, removing one another out. Soon after the electrons are moving from the n-type to the p-type silicon, it combines with the holes, then it disappears. Hence it makes the complete atom & more stable and it gives the little burst of energy in the form of a tiny packet or photon of light.

The above diagram shows how the light emitting diode works and the step by step process of the diagram.



- From the diagram, we can observe that the N-type silicon is in red color and it contains the electrons, they are indicated by the black circles.
- The P- type silicon is in the blue color and it contains holes, they are indicated by the white circles.
- The power supply across the p-n junction makes the diode forward biased and pushing the electrons from n-type to p-type. Pushing the holes in the opposite direction.
- Electron and holes at the junction are combined.
- The photons are given off as the electrons and holes are recombined.
- The flow of current in the semiconductors is caused by the both flow of holes in the opposite direction of current and flow of electrons in the direction of the current. Hence there will be recombination due to the flow of these charge carriers.
- The recombination indicates that the electrons in the conduction band jump down to the valence band. When the electrons jump from one band to another band the electrons will emit the electromagnetic energy in the form of photons and the photon energy is equal to the forbidden energy gap.



Applications of Light Emitting Diodes

There are many applications of the LED and some of them are explained below.

- LED is used as a bulb in the homes and industries
- The light emitting diodes are used in the motorcycles and cars
- These are used in the mobile phones to display the message
- At the traffic light signals led's are used

Advantages of LED's

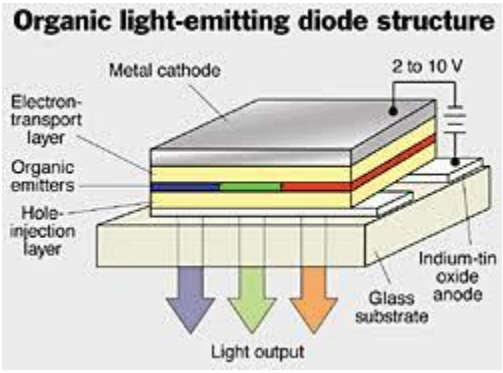
- The cost of LED's is less and they are tiny.
- By using the LED's the electricity is controlled.
- The intensity of the LED differs with the help of the microcontroller.

4. Write a note on Organic Light Emitting Diode:

An **organic light-emitting diode** (**OLED**) is a light-emitting diode (LED) in which the emissive electroluminescent layer is a film of organic compound that emits light in response to an electric current. This organic layer is situated between two electrodes; typically, at least one of these electrodes is transparent.

Uses:

OLEDs are used to create digital displays in devices such as television screens, computer monitors, portable systems such as smartphones, handheld game consoles and PDAs. A major area of research is the development of white OLED devices for use in solid-state lighting applications.



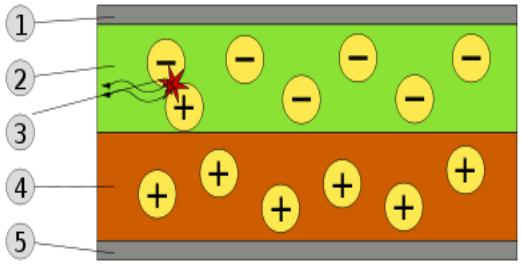
A typical OLED is composed of a layer of organic materials situated between two electrodes, the anode and cathode, all deposited on a substrate.

The organic molecules are electrically conductive as a result of delocalization of pi electrons caused by conjugation over part or the entire molecule.

These materials have conductivity levels ranging from insulators to conductors, and are therefore considered organic semiconductors.

The highest occupied and lowest unoccupied molecular orbitals (HOMO and LUMO) of organic semiconductors are analogous to the valence and conduction bands of inorganic semiconductors.

Working of LED:



During operation, a voltage is applied across the OLED such that the anode is positive with respect to the cathode.

Anodes are picked based upon the quality of their optical transparency, electrical conductivity, and chemical stability.

A current of electrons flows through the device from cathode to anode, as electrons are injected into the LUMO of the organic layer at the cathode and withdrawn from the HOMO at the anode.

This latter process may also be described as the injection of electron holes into the HOMO. Electrostatic forces bring the electrons and the holes towards each other and they recombine forming an exciton, a bound state of the electron and hole.

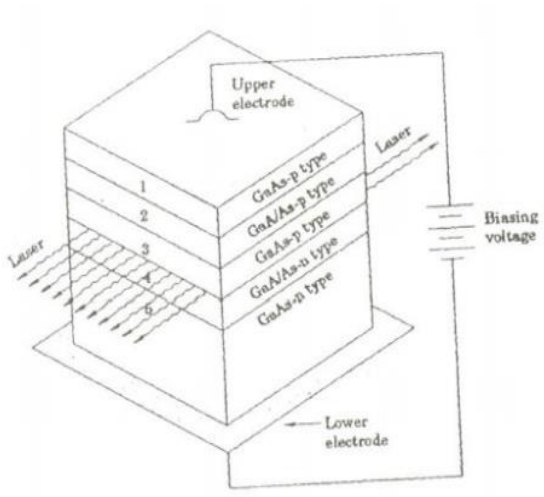
This happens closer to the emissive layer, because in organic semiconductors holes are generally more mobile than electrons. The decay of this excited state results in a relaxation of the energy levels of the electron, accompanied by emission of radiation whose frequency is in the visible region.

The frequency of this radiation depends on the band gap of the material, in this case the difference in energy between the HOMO and LUMO.

5. Describe semiconductor LASER diode

Principle:

When a PN junction diode is forward biased, the electrons from the n region and holes from the p region recombine with each other at the junction. During recombination process, light is released from certain specified direct band gap semiconductors.



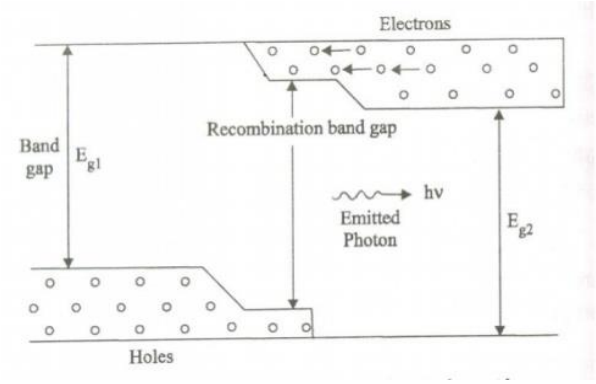
Construction:

This laser consists of five layers as shown in the figure. A layer of Ga-As p – type (3rd layer) will act as the active region. This layer is sand witched between two layers having wider band gap viz GaAlAs-p – type (2nd layer) and GaAlAs-n-type (4th layer).

The end faces of the junctions of 3rd and 4th layer are well polished and parallel to each other. They act as an optical resonator.

Working:

When the PN junction is forward biased, the electrons and holes are injected into the junction region. The region around the junction contains large amount of electrons in the conduction band and holes in the valence band.



Thus the population inversion is achieved. At this stage, some of the injected charge carriers recombines and produce radiation in the form of light.

When the forward biased voltage is increased, more and more light photons are emitted and the light intensity is more. These photons can trigger a chain of stimulated recombination's resulting in the release of photons in phase.

The photons moving at the plane of the junction travels back and forth by reflection between

two sides and grow its strength. A coherent beam of laser having wavelength nearly 8000 A° emerge out from the junction region.

S.No	TITLE		Description
1.	Type	:	It is a heterojunction semiconductor laser
2.	Active medium	:	PN junctions made from different layers.
3.	Pumping method	:	Direct conversion method
4.	Power output	:	The power output of laser beam is 1 mW
5.	Nature of the Output	:	Continuous wave form
6.	Wavelength of the output	:	Nearly 8000 $\overset{0}{A}$

Characteristics:Advantages:

1. It produces continuous wave output.
2. The power output is very high.

Disadvantages:

1. It is very difficult to grow different layers of PN junction.
2. The cost is very high.

Applications:

1.This type of laser is mostly used in optical applications

2. It is widely used in computers, especially on CD-ROMs.