UNIT IV

Optical properties of Materials

4.3.Absorption In Semiconductors , Insulators And Metals

4.3.1Absorption in Semi conductor:

In intrinsic semi conductors light energy is absorbed to produce electron hole pair. Electrons can go to conduction band if the photon energy is greater than the band gap energy.

That is $h\upsilon > E_g$

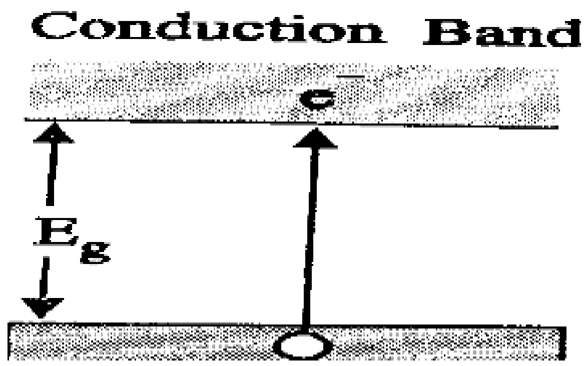

Fig4.3.1Absorption

For extrinsic semiconductor , electron transition is between donor and conduction band in n type semiconductor and for p type it is between acceptor and valence band

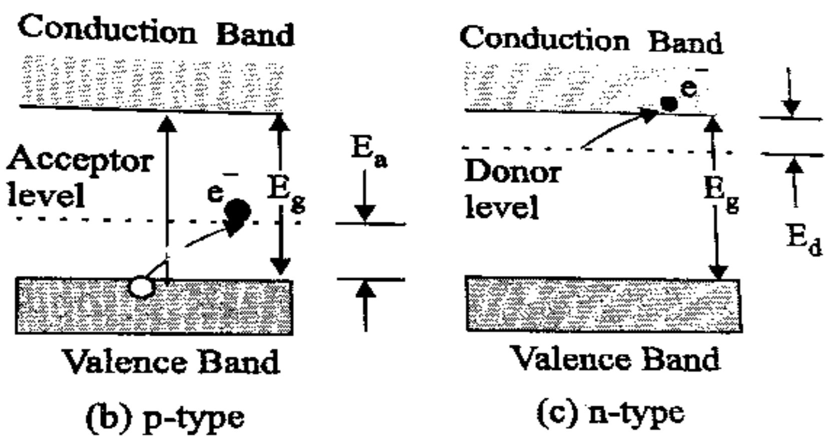

Fig 4.3.2.Absorption & emission in semiconductors

So visible light is not absorbed by materials having energy greater than 3.1ev

Emission:

When the electron moves from conduction band to valence band they emit light.

4.3.2Absorption and emission of light in metals

Incident light will be absorbed when the thickness of metal film is less than 0.1µm.

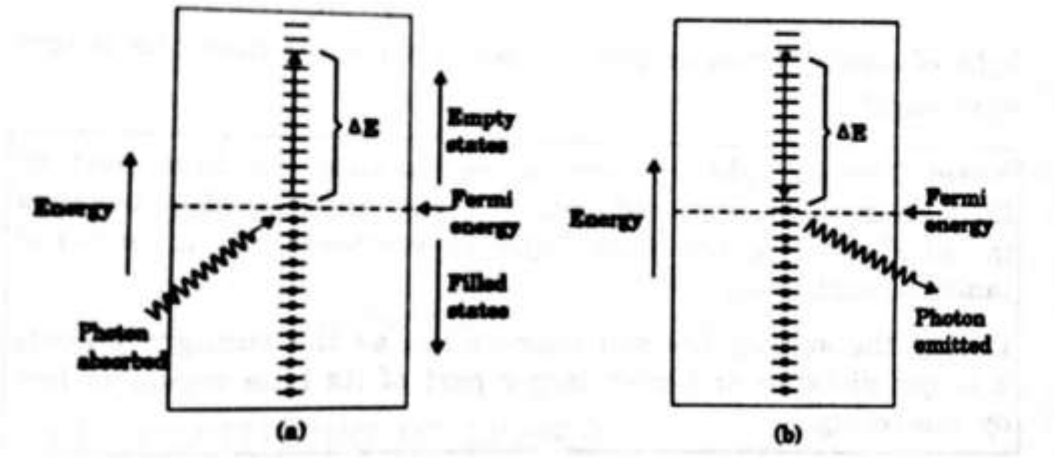

Fig 4.3.3.Absorption and emission in metals

Metals are opaque to radio waves,infra red visible and middle of uv radiation. It is transparent to x-rays and gamma rays.Thus elctron absorbs and move to higher energy state.

Emission:

Most of the absorbed radiation is emitted from the surface in the form of visible light.Reflectivity of metals is between 0.9 to 0 .95.

4.3.3.Absorption and emission in Insulators

Absorption:

In Insulator, an electron can move from valence band to conduction band if the energy of absorbed light is greater than the band gap energy

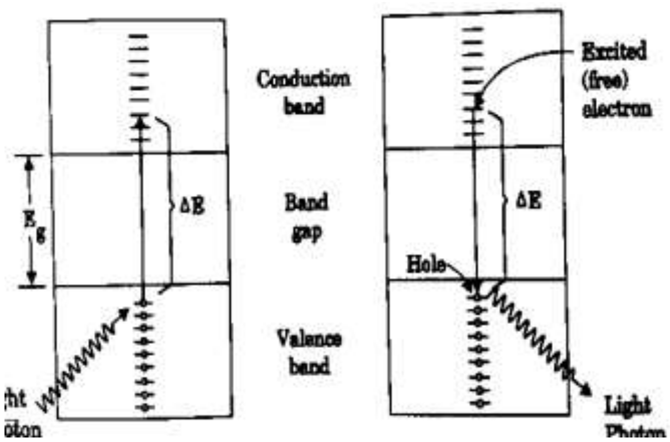

Fig 4.3.4.Absorption and emission in insulators

Emission:

When the electron moves from conduction band to valence band they emit light.

UNIT IV

Optical properties of Materials

4.8 LASER Diodes(GaAs)

Characteristics

Active medium - P-N junction diode

Active centre - Recombination of electrons and

holesPumping method - Direct pumping

Optical Resonator - Junction of diodes - polishedPower

output - 1 mW

Nature of output - Pulsed or Continuous

waveformWavelength - 8400A^0 – 8600A^0

Band gap - 1.44 eV

Principle:

The electron in conduction band combines with a hole in the valence band and hence the recombination of electron and hole produces energy in the form of light. This

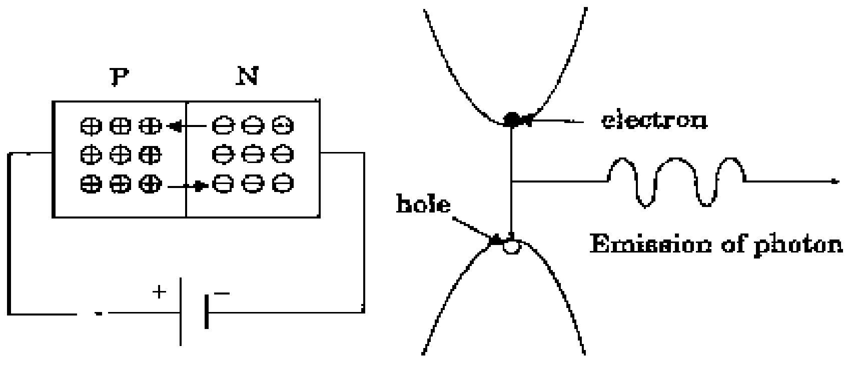

Fig:4.8.1 (a)semiconductor laser principle,(b)Emission of photon

photon, in turn may induce another electron in the conduction band (CB) to valence band(VB) and thereby stimulate the emission of another photon.

Construction:

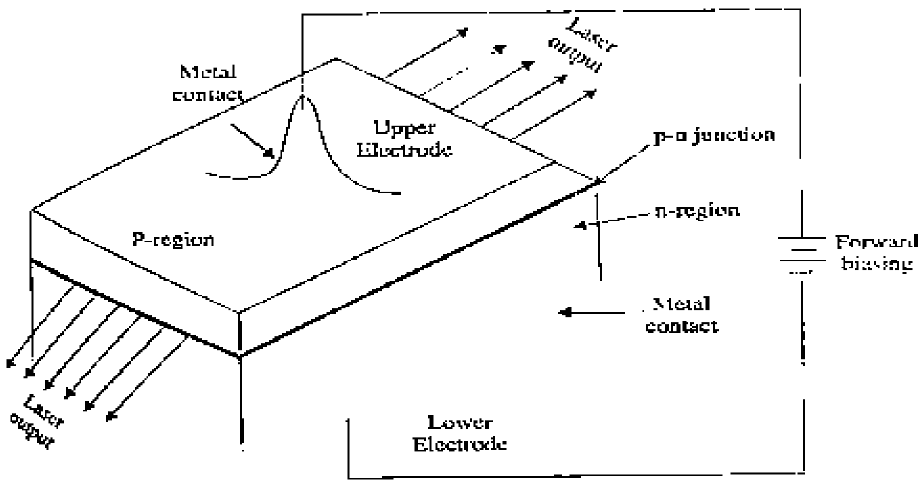

Fig 4.8.2. Laser Diode

The active medium is a p-n junction diode made from a single crystalline material i.e. Gallium Arsenide in which p-region is doped with germanium and n-region with Tellurium. The thickness of the p-n junction layer is very narrow so that the emitted laser radiation has large divergence. The junctions of the 'p' and 'n' are well polished and are parallel to each other as shown in figure. Since the refractive index of GaAs is high, it acts as optical resonator so that the external mirrors are not needed. The upper and lower electrodes fixed in the 'p' and 'n' region helps for the flow of current to the diode whilebiasing.

Working

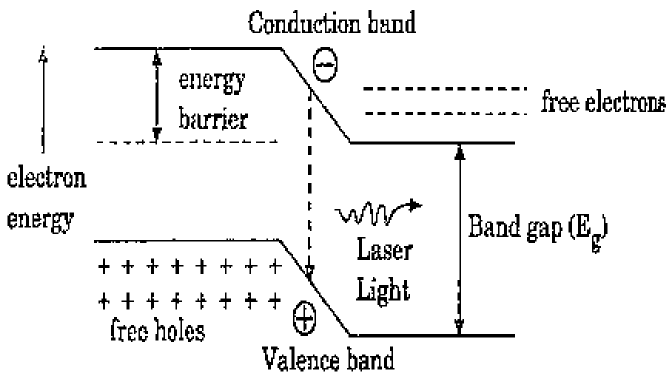

Fig 4.8.3.Energy band diagram

1. The population inversion in a p-n junction is achieved by heavily doping 'p' and 'n' materials, so that the Fermi level lies within the conduction band of n type and within the valence band of 'p' type as shown in figure.

2. If, the junction is forward biased with an applied voltage nearly equal to the band gap

voltage, direct conduction takes place. Due to high current density, active region is generated near the depletion region.

3. At this junction, if a radiation having frequency (v) is made to incident on the p-n junctionthen the photon emission is produced as shown in figure.

4. Thus the frequency of the incident radiation should be in the range

5. Further, the emitted photons increase the rate of recombination of injection electrons from the n region and holes in p region by inducing more recombination.

6. Hence the emitted photons have the same phase and frequency as that of original inducingphotons and will be amplified to get intense beam of LASER.

7. The wavelength of emitted radiation depends on i) the band gap and ii) the concentration ofdonor and acceptor atoms in GaAs.

Advantages

i) It is easy to manufacture the diode.

ii) The cost is low.

Disadvantages

i) It produces low power output.

ii) The output wave is pulsed and will be continuous only for some time.

iii) The beam has large divergence.

iv) They have high threshold current density.

Applications

1. It is widely used in fibre optic communications

2. It is used to heal the wounds by IR radiation.

3. I t is also used as a pain killer.

4. It is used in printers, CD writing and reading.

UNIT IV

Optical properties of Materials

4.7. Light emitting diode

It is a p-n junction diode which emits light when it is forward biased.

4.7.1 Principle

The injection of electrons into the p-region from n-region makes direct transition from the conduction band to valance band. Then, the electrons recombine with holes and emits photons of energy E_g,

The forbidden gap energy is given by

$$E_g = hv$$

Where h – Plank's constant

v- Frequency of the emitted radiation.

$$\text{But } v = c/\lambda$$

Where c – velocity of the light

λ - wave length of the light

$$\therefore E_g = (hc) / \lambda$$

Hence, the wave length of the emitted photon is given by the relation

$$\lambda = (hc) / E_g$$

The wave length of the light emitted purely depends on the band gap energy.

4.7.2 Construction

Figure shows cross section view of a LED.

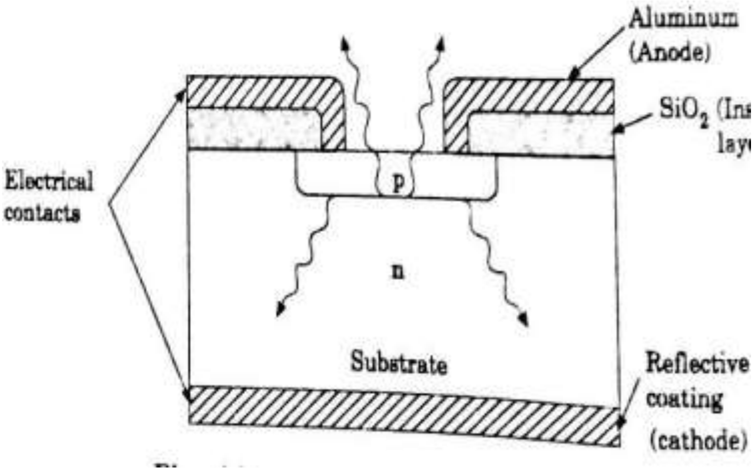

Fig 4.7.1 LED

A n-type layer is grown on a substrate and a p-type layer is deposited on it by diffusion. Since carrier recombination takes place in the p-layer , it is deposited on the top.

For maximum light emission, a metal film anode is deposited at the outer edges of the p-type layer. The bottom of the substrate is coated with a metal (gold) film. It reflects most of the light to the surface of the device and also provides cathode connection. Figure shows circuit and symbol of LED.

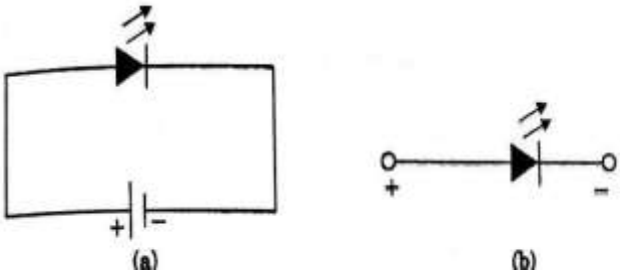

Fig 4.7.2 Symbol

4.7.3 Working

When the p-n junction diode is forward biased, the barrier width is reduced, raising the potential energy on the n-side and lowering that of the p-side.

The free electrons and holes have sufficient energy to move into the junction region. If a free electron meets a hole, it recombines with each other resulting in the release of a light photon.

Thus, light radiation from LED is caused by the recombination of holes and electrons that are injected into the junction by a forward bias voltage (Fig.).

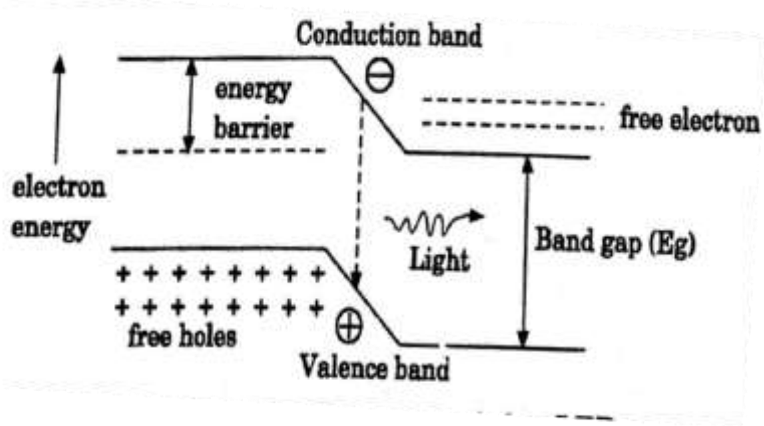

Fig 4.7.2.Energy band

4.7.4 Advantages of LED Lights

- Long life. The components of an **LED** and the way that they generate light significantly extend the lifespan of these bulbs. ...
- Energy efficiency. ...
- High brightness and intensity. ...
- Exceptional color range. ...
- Low radiated heat. ...
- Reliability. ...

4.8. ORGANIC LIGHT EMITTING DIODE

4.8.1 Construction

Organic light emitting diodes (OLEDs) are solid state devices made up of thin films or organic molecules that produce light with the application of electricity.

The organic light emitting diode (OLED) is also called light emitting polymer (LEP) or Organic Electro Luminescence (OEL) and it consists of a film of organic compounds.

Specially fabricated diode which is made up of organic materials which emits light when it is forward biased.

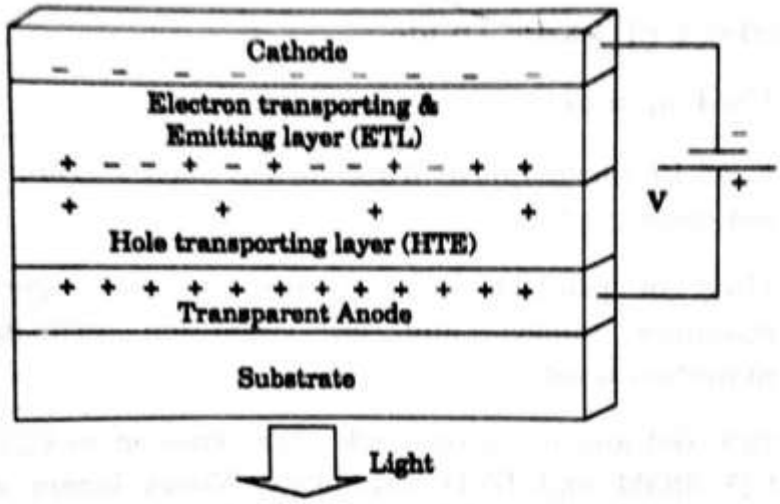

Fig 4.8.1.OLED

It consists of two layers. One is emissive layer and another one is conductive layer. Both are made of organic molecules. It has Metal cathode above emissive layer and anode below conductive layer

4.8.2.Working

An organic film is contacted by a metal electrodes on both sides. When a voltage is applied, positive charges (holes) are injected into the organic material (conducting layer) from one contact.

The negative charges (electrons) are injected from the other side into emissive layer.

When two different charge carriers meet, they recombine each other produce energy in the form of light photon

Types of OLEDs

(i) PLED

(ii) POLED

(iii) TOLED

(iv) SOLED

(v) IOLED

(i) PLED:Polymer Light Emitting Diodes (PLED) involve an electroluminescent conductive polymer that emits light when it is subjected to an electric current.

(ii) POLED

Patternable Organic Light Emitting Device (POLED) uses a light or heat activated electro active layer.

iii) TOLED

Transparent Organic Light Emitting Device (TOLED) uses a transparent contact to create displays.

iv) SOLED

Stacked OLED (SOLED) uses a novel pixel architecture that is based on stacking the red, green and blue sub pixels on top of one another.

(v) IOLED

Inverted OLED (IOLED) uses a bottom cathode that can be connected to the drain end of n-channel TFT.

UNIT IV

Optical properties of Materials

4.1. Introduction:

The materials which are sensitive to the light are called optical materials.

4.1.1 Types of optical materials:

1. Transparent materials:

Materials which allow light with little absorption and refelection are called transparent materials.

Eg:Glass

2.Opaque materials:

Materials which does not allow light through them are called opaque materials.

Eg:Wood

3. Translucent materials:

Materials which allow only small amount of light are called translucent materials.

Eg:Plastic cover

4.2. Carrier Generation And Recombination

Definition:The process of creating electron-hole pair is called carrier generation

Types:

- Photo generation
- Phonon generation
- Impact ionization

Photo Generation

In this Light photon is absorbed by an electron ,then the electron moves from valence band to conduction band to produce electron hole pair. Figure shows the absorption of light of energy hγ.Here the energy of photon is greater than the energy gap of the semiconductor

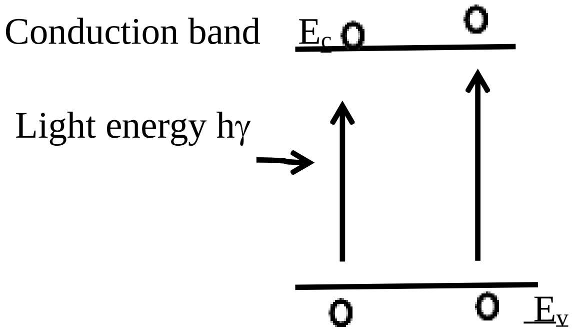

Fig 4.2 .1.Photo Generation

Phonon Regeneration

When the temperature of the semiconductor is increased ,lattice vibration is increased. Then the covalent bond breaks and electron hole pair is created.

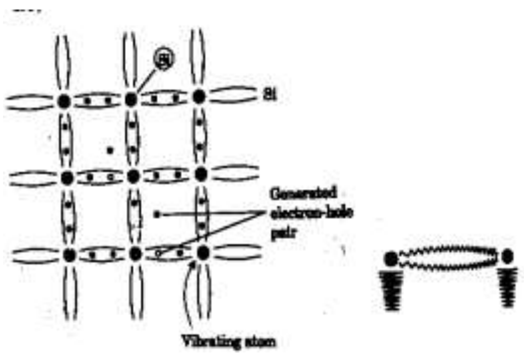

Fig 4.2.2 Phonon Regeneration

Impact Ionization

When an electric field is applied to a semiconductor an electron gain energy.Then it hits other Si atom to break the covalent bond. Thus electron hole pair is created.For a very high electric field , an avalanche breakdown occurs.

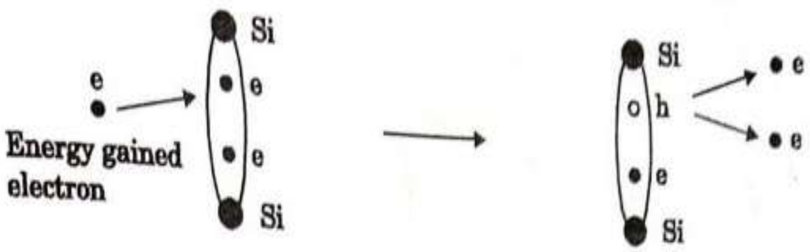

Fig 4.2.3. Impact Ionization

Carrier Recombination

Definition:When a free electron in the conduction band falls to valence band and recombine with a hole to produce light it is called Recombination.

Types:

- Radiative Recombination
- Shockley read hall Recombination
- Auger Recombination

Radiative Recombination

Electrons in higher energy states of conduction band will move to lowest level of conduction band by emitting heat. From this lowest level they fall to valence to emit light. This is called direct recombination.It is produced in direct band gap semiconductor.(GaAs)

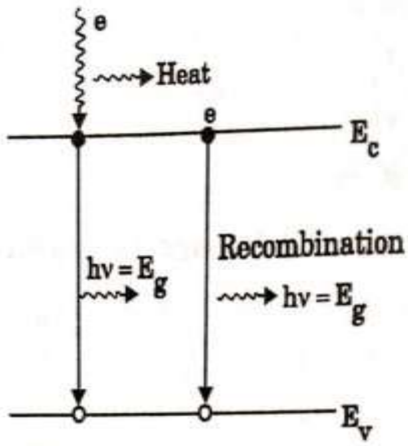

Fig 4.2.4. Radiative Recombination

Schockley-Read-Hall Recombination

Electrons from conduction band move to intermediate level between E_c and E_v by emitting photon or phonon.From this level they move to valence band to emit photon.It is produced in impure semiconductor which has defect.

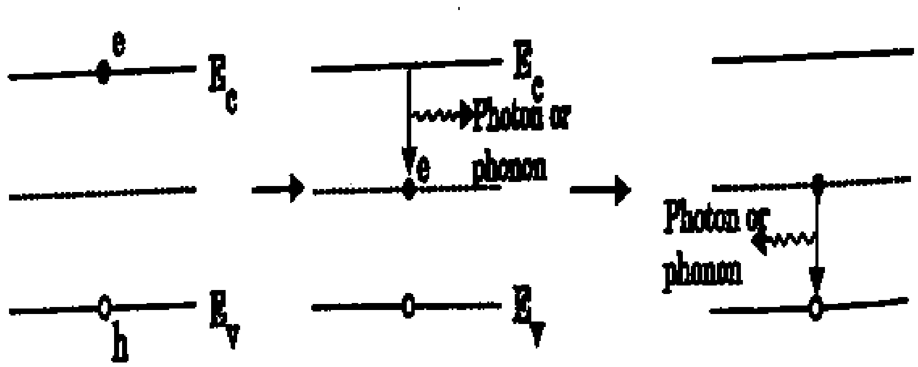

Fig 4.2.5. Schockley-Read-Hall Recombination

Auger Recombination

In this ,first an elecron and hole recombine with each other to produce light. This light is given to an electron in Ec and it moves to highest level of conduction band. From this it moves to E_c by emitting heat. Then it returns to E_v to produce light.

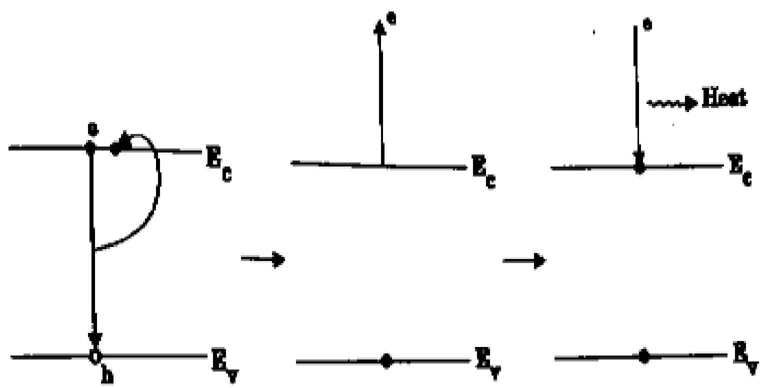

Fig 4.2.6. Auger Recombination

UNIT IV

Optical properties of Materials

4.4.Photo Current In PN Diode

It is reversed biased P-N junction diode which responds to light radiation Light (hυ)

4.4.1 Principle:

When light is incident on the reversed biased P-N junction the concentration of minority carriers increases. Thus it increases the reverse current.

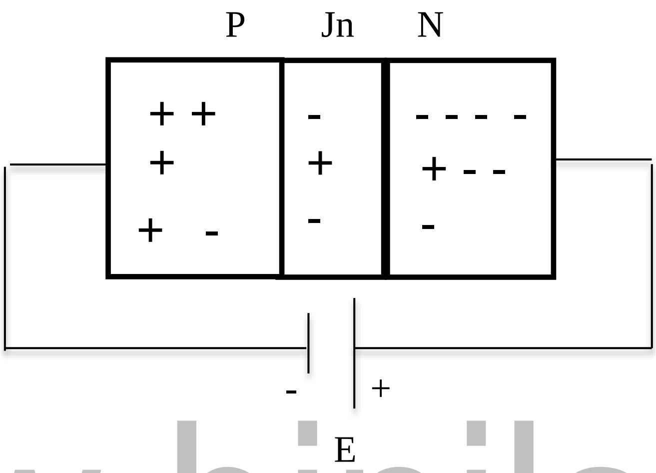

Fig 4.4.1 PN junction diode (reversed biased)

4.4.2 Construction:

It consists of P-N junction diode which is placed in a transparent capsule. Light is allowed to fall on the surface of the junction as shown in fig a.The symbol is shown in the below figureb

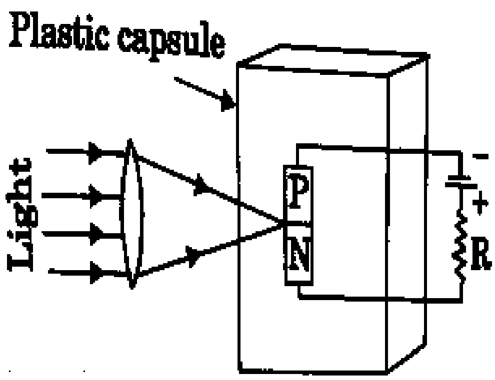

Fig 4.4.2.Photo diode diode

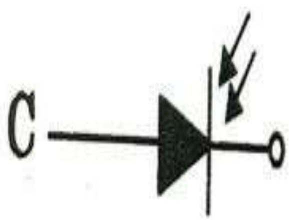

Fig 4.4.3.Symbol

4.4.3.Working:

Initially the diode is placed in a dark room and reversed biased. It produces a reverse saturation current due to thermally generated minority carriers.It is called dark current(I_d).

Now the light is allowed to fall on the junction to produce electron hole pair. This produces an additional current.

Under reverse bias condition

Total current $I=I_s+I_d$

Is -Short circuit current and is proportional to intensity of light.

4.4.5. Voltage current characteristics(V-I)

The volt ampere characteristics of the photo diode is shown in the fig

(i) The current increases with the illumination of light.

(ii) Only for dark current at zero voltage the current Is zero.

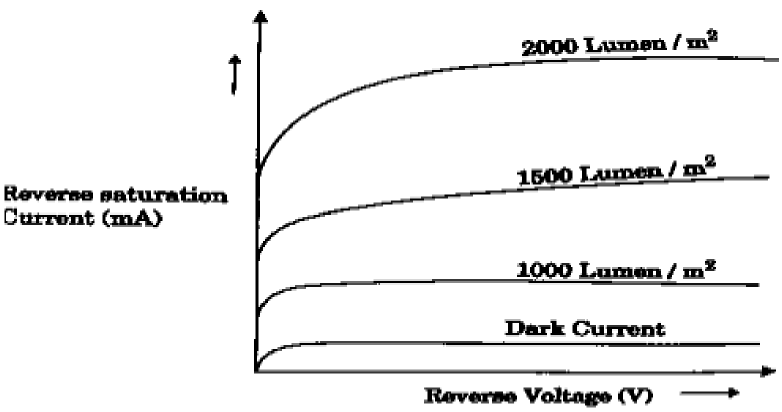

Fig 4.4.5.V-I characteristics

Applications:

It is Used in

1.Light detection system

2.Reading of sound track in film

3.light operated switches.

4.High speed reading of computer

UNIT IV

Optical properties of Materials

4.5. Solar cell

It is a P-N junction diode which coverts solar energy (light energy) into electrical energy.

4.5.1 Construction

It consists of P-N junction diode made of Silicon The P-N diode is packed in a can with glass window on top such that light may fall upon P and N type materials.

The thickness of the P-region is kept very small. Therefore, electrons generated in P region can diffuse to the junction before recombination takes place.

The thickness of N region is also kept small to allow holes generated near the surface to diffuse to the junction before they recombine.

The nickel ring is provided around the P-layer which acts as the positive output terminal. A metal contact at the bottom serves as the negative output terminal.

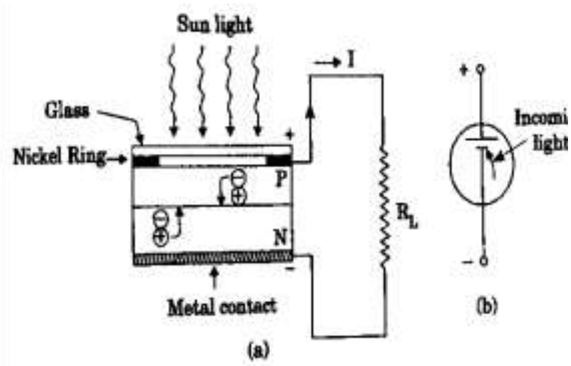

Fig 5.5.1 Solar cell

4.5.2 Working

When light radiation from sun falls on the P-N junction diode, produce electron hole pair. Thus, electron hole pairs are generated in both P and N sides of the junction.

The majority carrier electrons in the P-side cross the barrier potential to reach N side and the holes in N-side move to the P-side (Fig. b). Their flow constitute the minority current.

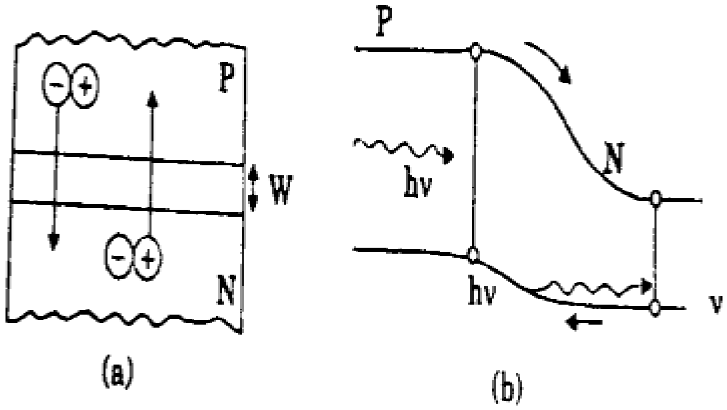

Fig 4.5.2.Energy band

The electrons and holes are accumulated on the two sides of the junction. This leads to an open circuit voltage V_{oc} which is a function of illumination.

4.5.3 V-I Characteristics

The V-I characteristics of the solar cell, corresponding to different levels of illumination is shown in figure. The maximum power output is obtained when the solar cell is opened at the knee of the curve.

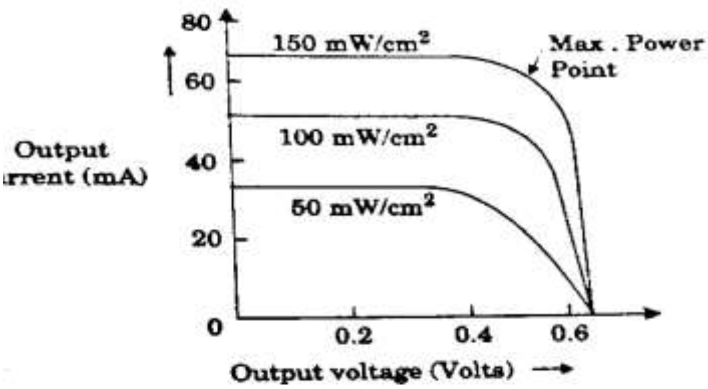

Fig 4.5.3 V-I characteristics

4.5.4Advantages of Solar Energy

- Renewable Energy Source. Among all the benefits of **solar panels**, the most important thing is that **solar** energy is a truly renewable energy source. ...
- Reduces Electricity Bills. ...
- Diverse Applications. ...
- Low Maintenance Costs. ...

- Technology Development.

4.5.5 Dis advantages

- Solar energy is somewhat more expensive to produce than conventional sources of energy
- Solar power is a variable energy source, with energy production dependent on the sun.