5.10 LIGHT EMITTING DIODE (LED)

Light Emitting Diode (LED) works only in forward bias condition. When Light Emitting Diode (LED) is forward biased, the free electrons from n-side and the holes from p-side are pushed towards the junction.

When free electrons reach the junction or depletion region, some of the free electrons recombine with the holes in the positive ions. We know that positive ions have less number of electrons than protons. Therefore, they are ready to accept electrons. Thus, free electrons recombine with holes in the depletion region. In the similar way, holes from p-side recombine with electrons in the depletion region.

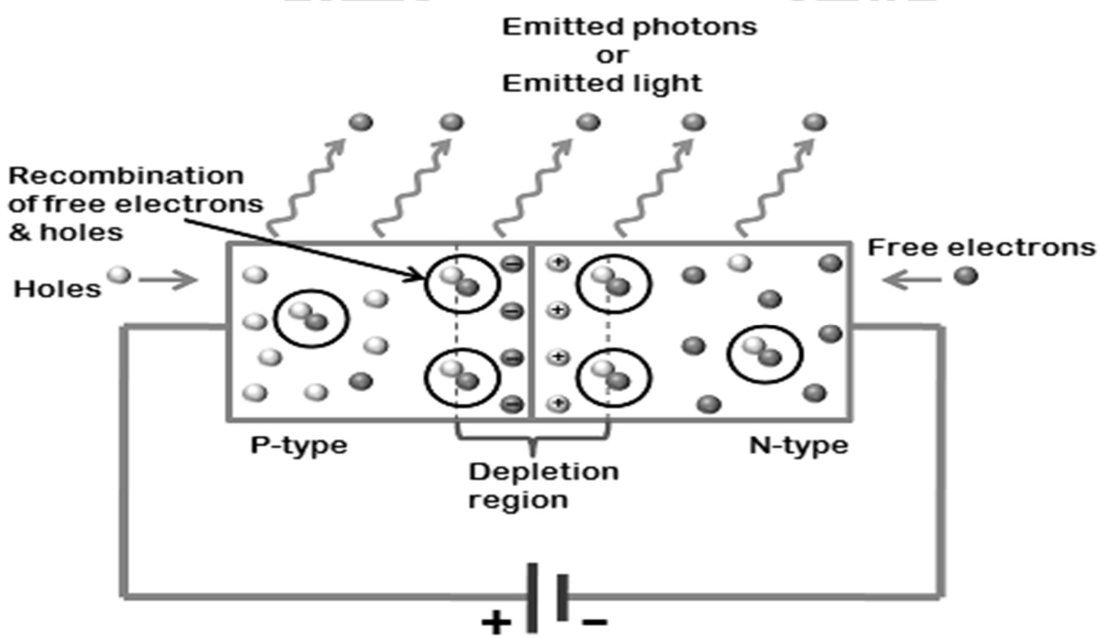

Fig:5.10.1 Working of Light Emitting Diode

Because of the recombination of free electrons and holes in the depletion region, the width of depletion region decreases. As a result, more charge carriers will cross the p-n junction.

Some of the charge carriers from p-side and n-side will cross the p-n junction before they recombine in the depletion region. For example, some free electrons from n-type semiconductor cross the p-n junction and recombines with holes in p-type semiconductor. In the similar way, holes from p-type semiconductor cross the p-n junction and recombines with free electrons in the n-type semiconductor.

Thus, recombination takes place in depletion region as well as in p-type and n-type semiconductor.

The free electrons in the conduction band releases energy in the form of light before they recombine with holes in the valence band.

In silicon and germanium diodes, most of the energy is released in the form of heat and emitted light is too small.

However, in materials like gallium arsenide and gallium phosphide the emitted photons have sufficient energy to produce intense visible light.

When external voltage is applied to the valence electrons, they gain sufficient energy and breaks the bonding with the parent atom. The valence electrons which breaks bonding with the parent atom are called free electrons.

When the valence electron left the parent atom, they leave an empty space in the valence shell at which valence electron left. This empty space in the valence shell is called a hole.

The energy level of all the valence electrons is almost same. Grouping the range of energy levels of all the valence electrons is called valence band.

In the similar way, energy level of all the free electrons is almost same. Grouping the range of energy levels of all the free electrons is called conduction band.

The energy level of free electrons in the conduction band is high compared to the energy level of valence electrons or holes in the valence band. Therefore, free electrons in the conduction band need to lose energy in order to recombine with the holes in the valence band.

The free electrons in the conduction band do not stay for long period. After a short period, the free electrons lose energy in the form of light and recombine with the holes in the valence band. Each recombination of charge carrier will emit some light energy.

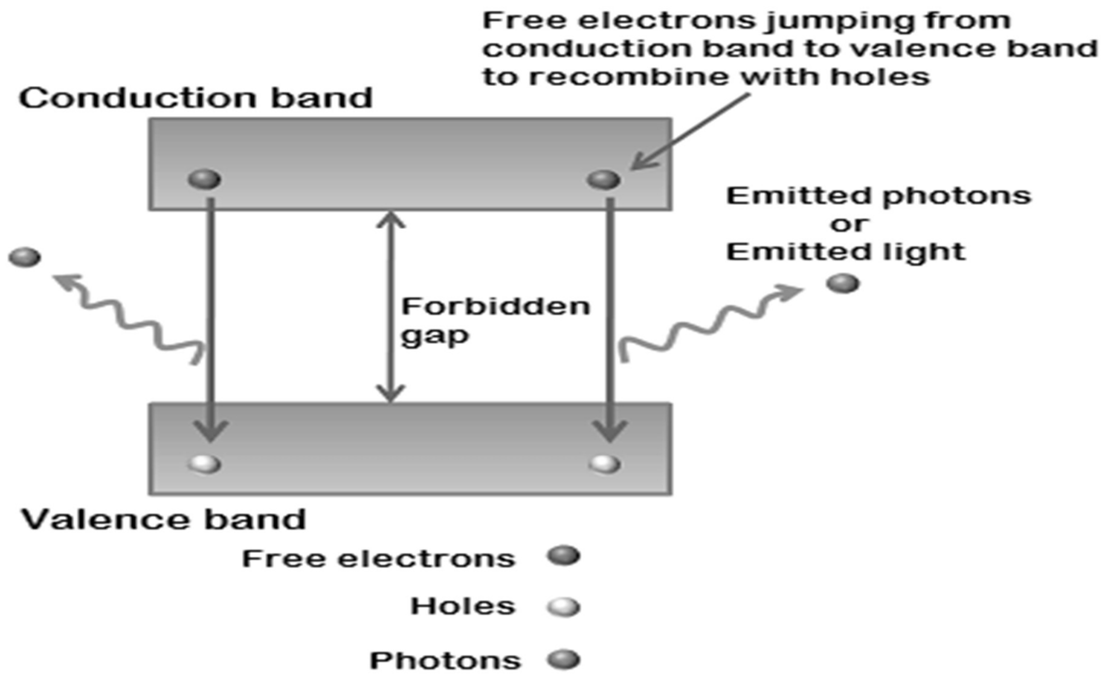

Fig:5.10.2 Process of Light Emission in LED

The energy lose of free electrons or the intensity of emitted light is depends on the forbidden gap or energy gap between conduction band and valence band.

The semiconductor device with large forbidden gap emits high intensity light whereas the semiconductor device with small forbidden gap emits low intensity light.

In other words, the brightness of the emitted light is depends on the material used for constructing LED and forward current flow through the LED.

In normal silicon diodes, the energy gap between conduction band and valence band is less. Hence, the electrons fall only a short distance. As a result, low energy photons are released. These low energy photons have low frequency which is invisible to human eye.

In LEDs, the energy gap between conduction band and valence band is very large so the free electrons in LEDs have greater energy than the free electrons in silicon diodes. Hence, the free electrons fall to a large distance. As a result, high energy photons are released. These high energy photons have high frequency which is visible to human eye.

The efficiency of generation of light in LED increases with increase in injected current and with a decrease in temperature.

In light emitting diodes, light is produced due to recombination process. Recombination of charge carriers takes place only under forward bias condition. Hence, LEDs operate only in forward bias condition.

When light emitting diode is reverse biased, the free electrons (majority carriers) from n-side and holes (majority carriers) from p-side moves away from the junction. As a result, the width of depletion region increases and no recombination of charge carriers occur. Thus, no light is produced.

If the reverse bias voltage applied to the LED is highly increased, the device may also be damaged.

All diodes emit photons or light but not all diodes emit visible light. The material in an LED is selected in such a way that the wavelength of the released photons falls within the visible portion of the light spectrum.

Light emitting diodes can be switched ON and OFF at a very fast speed of 1 ns.

Light emitting diode (LED) symbol

The symbol of LED is similar to the normal p-n junction diode except that it contains arrows pointing away from the diode indicating that light is being emitted by the diode.

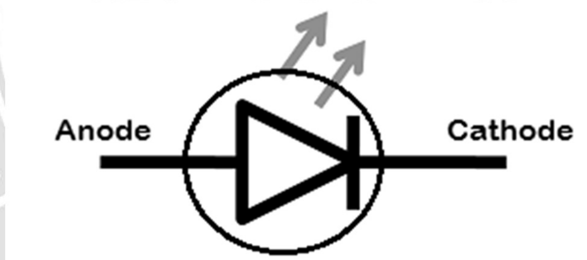

Fig:5.10.3 Symbol of Light Emitting Diode

LEDs are available in different colors. The most common colors of LEDs are orange, yellow, green and red.

The schematic symbol of LED does not represent the color of light. The schematic symbol is same for all colors of LEDs. Hence, it is not possible to identify the color of LED by seeing its symbol.

LED construction

One of the methods used to construct LED is to deposit three semiconductor layers on the substrate. The three semiconductor layers deposited on the substrate are n-type semiconductor, p-type semiconductor and active region. Active region is present in between the n-type and p-type semiconductor layers.

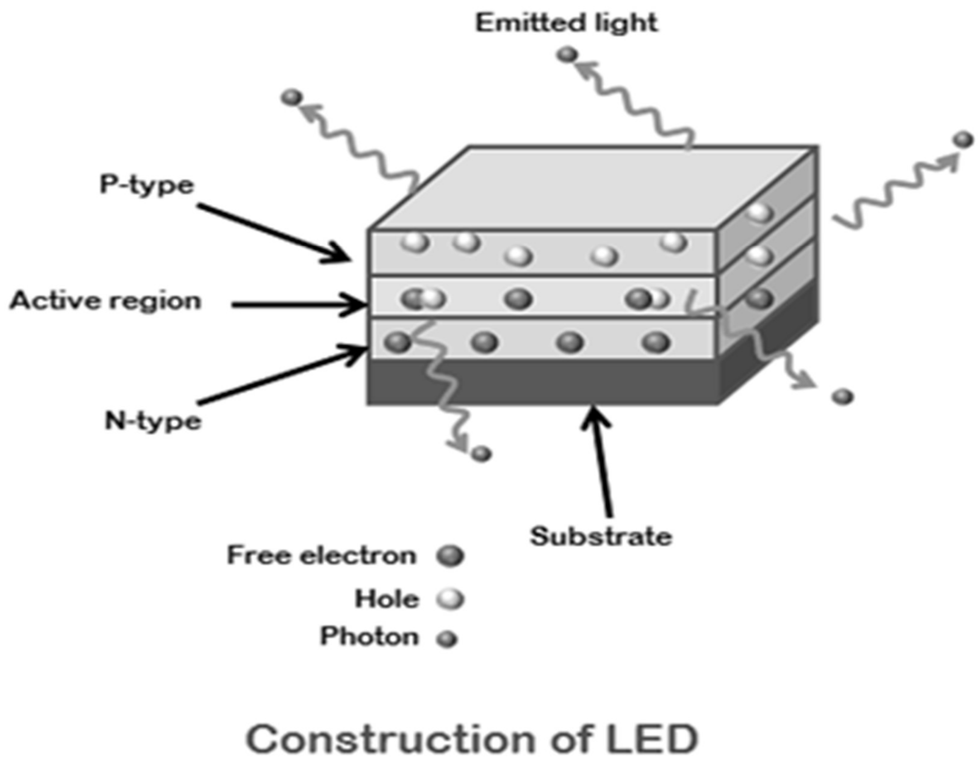

Fig:5.10.4 Construction of Light Emitting Diode

When LED is forward biased, free electrons from n-type semiconductor and holes from p-type semiconductor are pushed towards the active region.

When free electrons from n-side and holes from p-side recombine with the opposite charge carriers (free electrons with holes or holes with free electrons) in active region, an invisible or visible light is emitted.

In LED, most of the charge carriers recombine at active region. Therefore, most of the light is emitted by the active region. The active region is also called as depletion region.

Biasing of LED

The safe forward voltage ratings of most LEDs is from 1V to 3 V and forward current ratings is from 200 mA to 100 mA.

If the voltage applied to LED is in between 1V to 3V, LED works perfectly because the current flow for the applied voltage is in the operating range. However, if the voltage applied to LED is increased to a value greater than 3 volts. The depletion region in the LED breaks down and the electric current suddenly rises. This sudden rise in current may destroy the device.

To avoid this we need to place a resistor (Rs) in series with the LED. The resistor (Rs) must be placed in between voltage source (Vs) and LED.

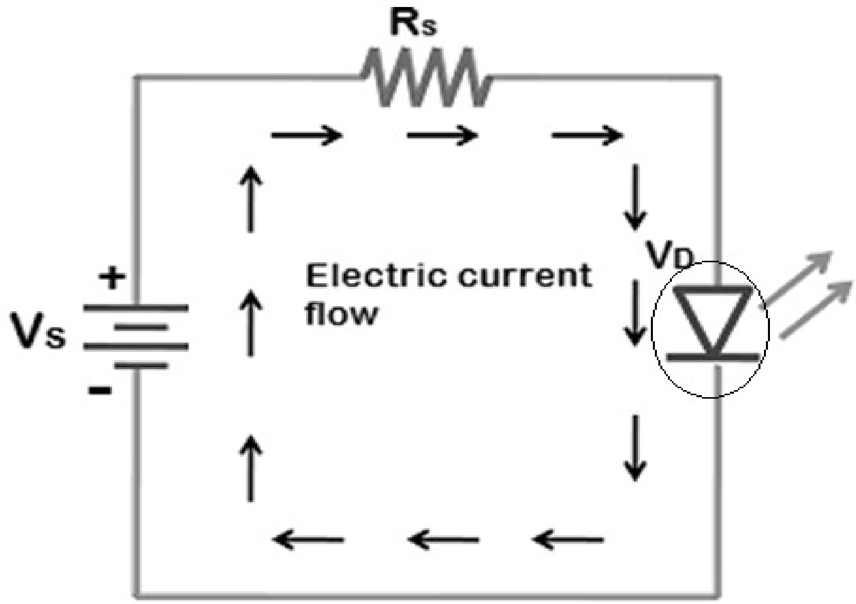

Fig:5.10.5 Biasing of Light Emitting Diode

The resistor placed between LED and voltage source is called current limiting resistor. This resistor restricts extra current which may destroy the LED. Thus, current limiting resistor protects LED from damage.

The current flowing through the LED is mathematically written as

$$I_F = \frac{V_s - V_D}{R_s}$$

Where,

IF = Forward current

VS = Source voltage or supply voltage

VD = Voltage drop across LED

RS = Resistor or current limiting resistor

Voltage drop is the amount of voltage wasted to overcome the depletion region barrier (which leads to electric current flow).

The voltage drop of LED is 2 to 3V whereas silicon or germanium diode is 0.3 or 0.7 V. Therefore, to operate LED we need to apply greater voltage than silicon or germanium diodes.

Light emitting diodes consume more energy than silicon or germanium diodes to operate.

Output characteristics of LED

The amount of output light emitted by the LED is directly proportional to the amount of forward current flowing through the LED. More the forward current, the greater is the emitted output light. The graph of forward current vs output light is shown in the figure.

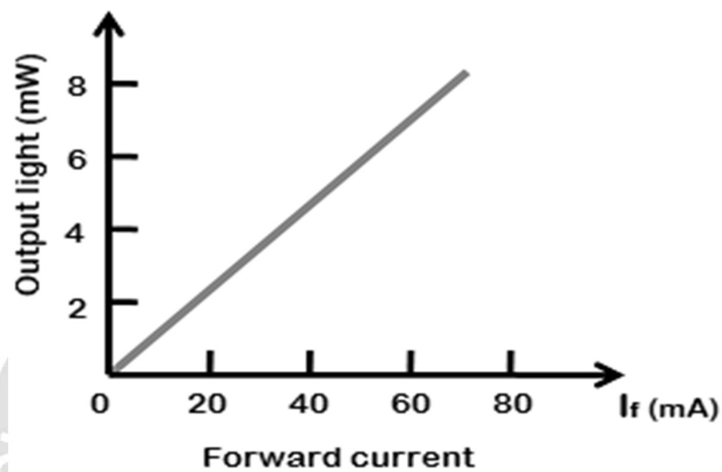

Fig:5.10.6 Characteristics of Light Emitting Diode

Visible LEDs and invisible LEDs

LEDs are mainly classified into two types: visible LEDs and invisible LEDs.

Visible LED is a type of LED that emits visible light. These LEDs are mainly used for display or illumination where LEDs are used individually without photosensors.

Invisible LED is a type of LED that emits invisible light (infrared light). These LEDs are mainly used with photosensors such as photodiodes.

Determines the color of an LED

The material used for constructing LED determines its color. In other words, the wavelength or color of the emitted light depends on the forbidden gap or energy gap of the material.

Different materials emit different colors of light.

Gallium arsenide LEDs emit red and infrared light.

Gallium nitride LEDs emit bright blue light.

Yttrium aluminium garnet LEDs emit white light.

Gallium phosphide LEDs emit red, yellow and green light.

Aluminium gallium nitride LEDs emit ultraviolet light.

Aluminum gallium phosphide LEDs emit green light.

Advantages of LED

1. The brightness of light emitted by LED is depends on the current flowing through the LED. Hence, the brightness of LED can be easily controlled by varying the current. This makes possible to operate LED displays under different ambient lighting conditions.
2. Light emitting diodes consume low energy.
3. LEDs are very cheap and readily available.
4. LEDs are light in weight.
5. Smaller size.
6. LEDs have longer lifetime.
7. LEDs operates very fast. They can be turned on and off in very less time.
8. LEDs do not contain toxic material like mercury which is used in fluorescent lamps.
9. LEDs can emit different colors of light.

Disadvantages of LED

1. LEDs need more power to operate than normal p-n junction diodes.
2. Luminous efficiency of LEDs is low.

Applications of LED

The various applications of LEDs are as follows

1. Burglar alarms systems
2. Calculators
3. Picture phones
4. Traffic signals
5. Digital computers
6. Multimeters
7. Microprocessors
8. Digital watches
9. Automotive heat lamps
10. Camera flashes
11. Aviation lighting