B.Sc (H) Electronic Sciences, VI Sem

PHOTONICS

(UPC : 32511603)

TOPIC

Light Emitting Diodes : Working Principle, Construction and Application

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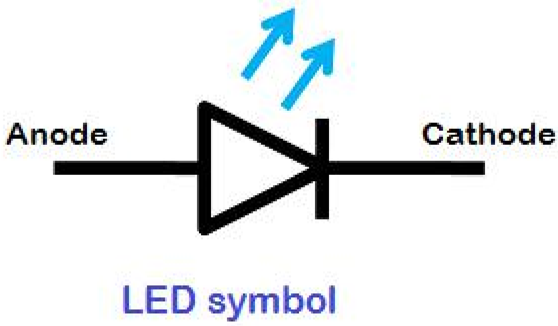
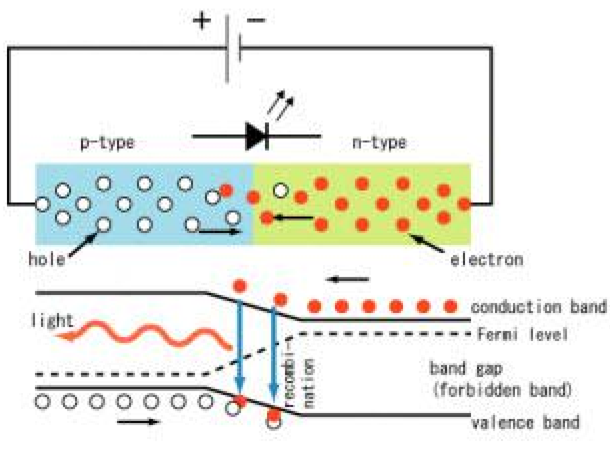
LED (Light Emitting Diode) is an optoelectronic device which works on the principle of electro-luminance. Electro-luminance is the property of the material to convert electrical energy into light energy.

It is specially doped p-n junction diode made up of specific type of semiconductors. When the light emitting diode light is forward biased, then it emits light either in visible region or infra red region.



Working Principle of LED

The light emitting diode works like a normal PN-junction diode. When the diode is forward biased, then the current flows through the diode.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 (Eg).

$$\mathbf{Eg = hf}$$

Where h is known as a Planck constant, and f is the frequency of the emitted electromagnetic radiation.

The frequency of radiation is related to the velocity of light as a

$f = c / \lambda$. where c is the speed of light λ is denoted as a wavelength of an electromagnetic radiation and the above equation will become as

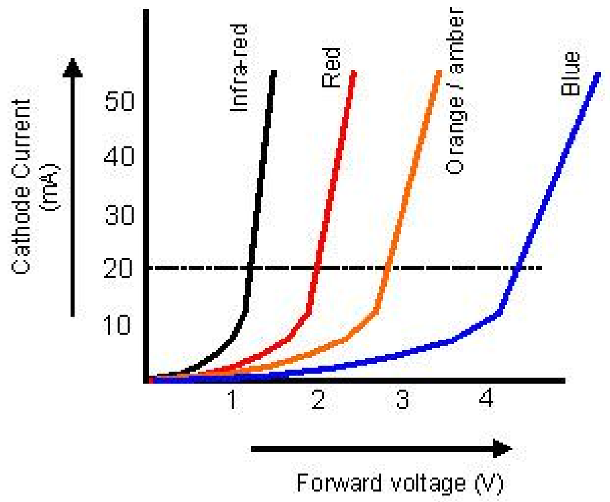
$$\mathbf{Eg = hc / \lambda}$$

From the above equation, we can say that the wavelength of electromagnetic radiation is inversely proportional to the forbidden gap.

For LED the wavelength of the emitted photon, lies in the visible or infrared region.

I-V Characteristics of LED

There are different types of light emitting diodes are available in the market and there are different LED characteristics which include the color light, or wavelength radiation, light intensity. The important characteristic of the LED is color.



The following graph shows the approximate curves between the forward voltage and the current. Each curve in the graph indicates the different color.

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.

Light emitting diodes emit either visible light or invisible infrared light when forward biased. The LEDs which emit invisible infrared light are used for remote controls.

Materials Used in LEDS

Silicon or germanium diodes do not emit energy in the form of light. Instead, they emit energy in the form of heat. Thus, silicon or germanium is not used for constructing LEDs.

In general for silicon and germanium semiconductors, this forbidden energy gap between the condition and valence bands are such that the total radiation of electromagnetic wave during recombination is in the form of the infrared radiation.

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.

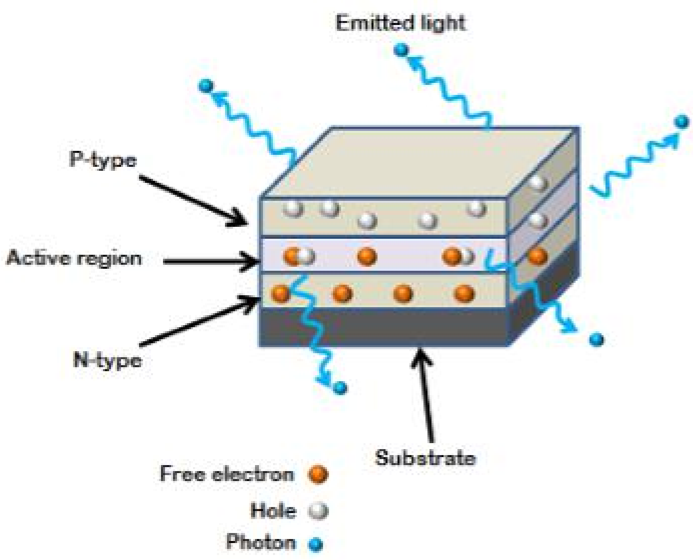
Visible LED is a type of LED that emits visible light. These LEDs are mainly used for display or illumination. Invisible LED is a type of LED that emits invisible light (infrared light). These LEDs are mainly used with photosensors such as photodiodes.

Some commonly used LEDs are mentioned below.

- Gallium Arsenide (GaAs) – infra-red
- Gallium Arsenide Phosphide (GaAsP) – red to infra-red, orange
- Aluminium Gallium Arsenide Phosphide (AlGaAsP) – high-brightness red, orange-red, orange, and yellow
- Gallium Phosphide (GaP) – red, yellow and green
- Aluminium Gallium Phosphide (AlGaP) – green
- Gallium Nitride (GaN) – green, emerald green
- Gallium Indium Nitride (GaInN) – near ultraviolet, bluish-green and blue
- Silicon Carbide (SiC) – blue as a substrate
- Zinc Selenide (ZnSe) – blue
- Aluminium Gallium Nitride (AlGaN) – ultraviolet

Construction:

1. The methods used to construct LED are to deposit three semiconductor layers on the substrate.
2. The three semiconductor layers deposited on the substrate are n-type semiconductor, p-type semiconductor and active region.
3. Active region is present in between the n-type and p-type semiconductor layers.
4. When LED is forward biased, free electrons from n-type semiconductor and holes from p-type semiconductor are pushed towards the active region.



1. 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.
2. 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.

Advantages of LED

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

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. LED is used as a bulb in the homes and industries
2. Burglar alarms systems
3. Calculators
4. Picture phones
5. Traffic signals
6. Digital computers
7. Multimeters
8. Microprocessors
9. Digital watches

Internal Quantum Efficiency of the LED

The fraction of the electrons that are injected into the depletion layer which results in photons getting produced is known as internal quantum efficiency of the LED. It is denoted as η.

If N is the number of electrons injected into the depletion layer every second, the power output of the device is expressed by,

P = η*N*h*v = η*I*h*v/e

Where,
I is forward current
e is the electronic charge

Although internal quantum efficiences of some LED Materials is very high, the external efficiences are much lower.

External Quantum Efficiency (EQE)

The ratio of the number of photons emitted from the LED to the number of electrons passing through the device - in other words, how efficiently the device coverts electrons to photons and allows them to escape.