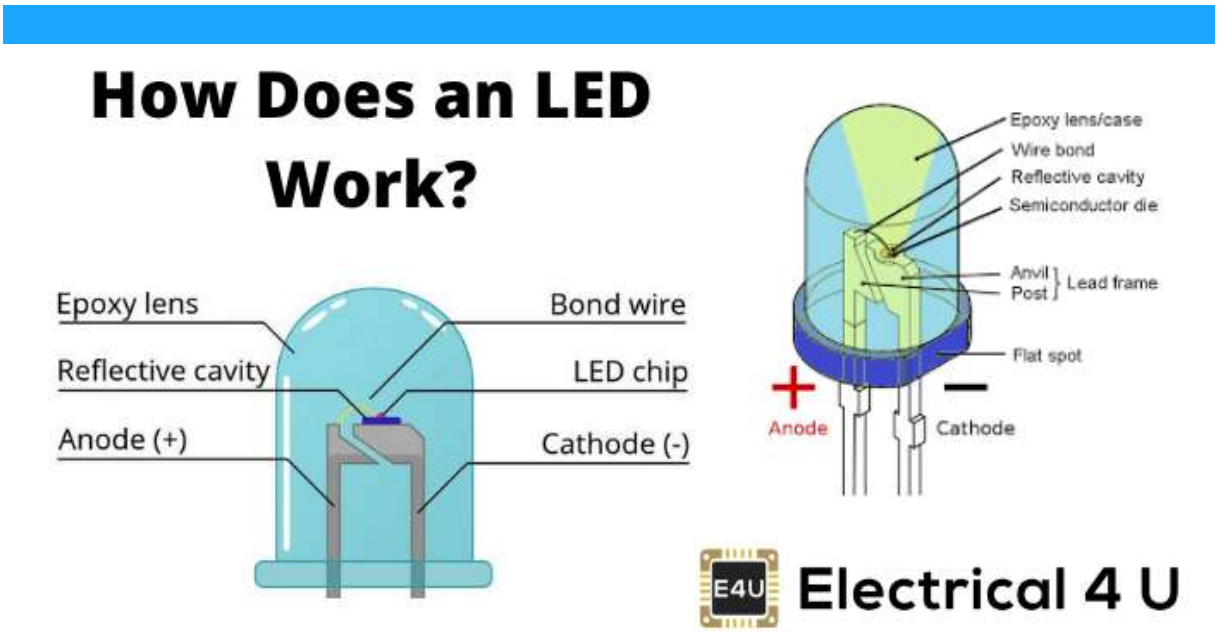
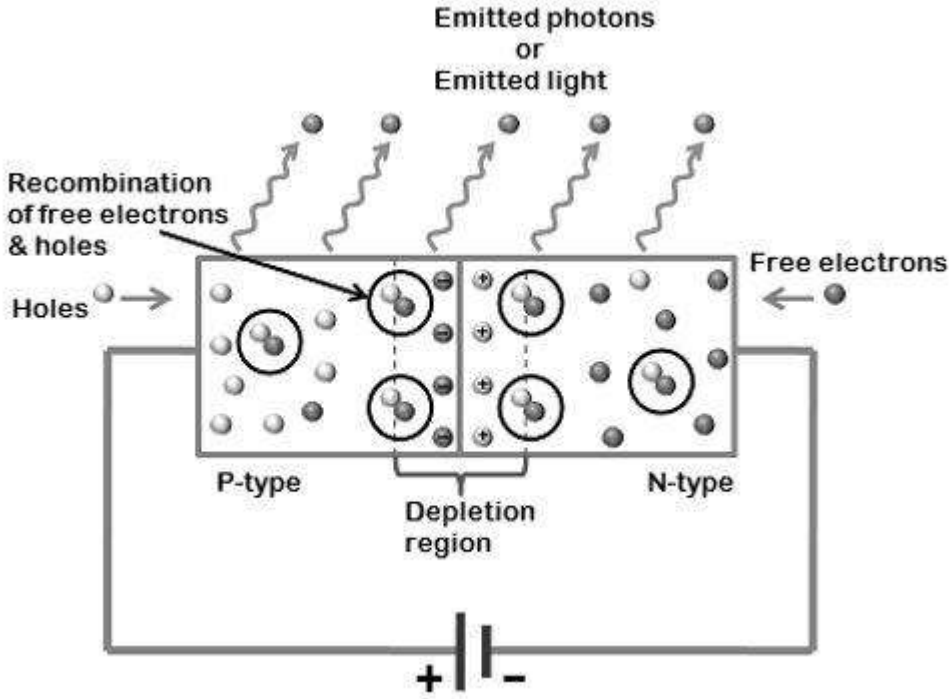
Working Principle of Light Emitting Diode



An LED is just like a normal p n junction diode, but with light-emitting properties. Its construction and working can be explained as follows.

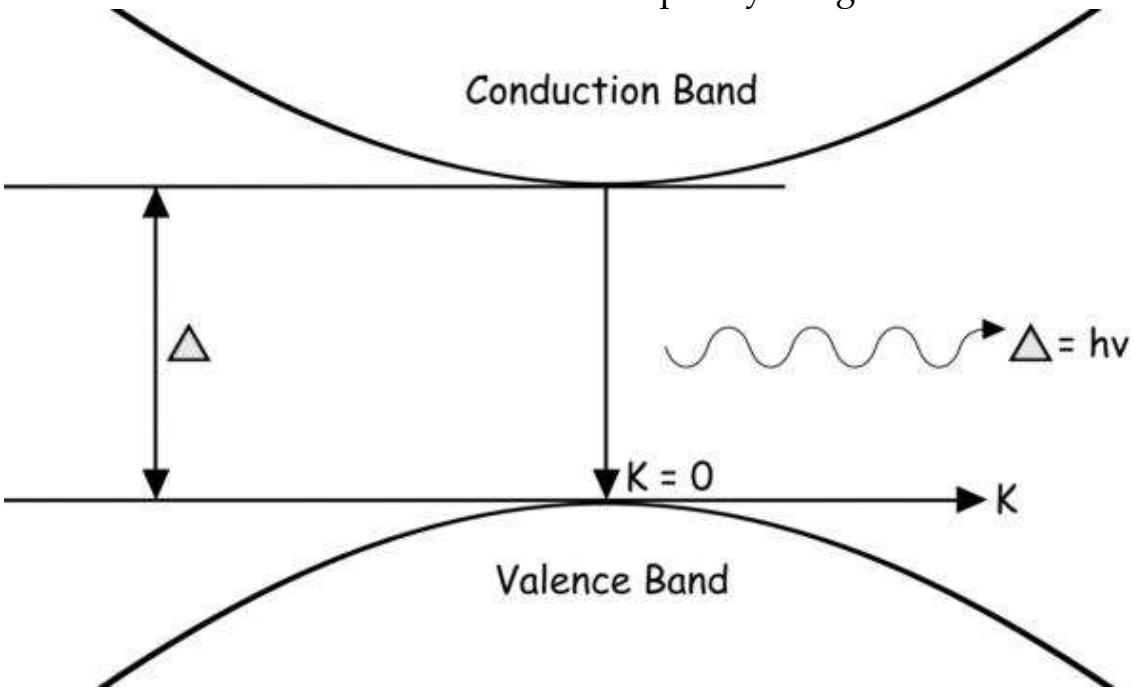
Working of LED

Like an ordinary diode, the LED diode works when it is forward biased. In this case, the n-type semiconductor is heavily doped than the p-type forming the p-n junction. When it is forward biased, the potential barrier gets reduced and the electrons and holes combine at the depletion layer (or active layer), light or photons are emitted or radiated in all directions. A typical figure blow showing light emission due electron-hole pair combining on forward biasing.



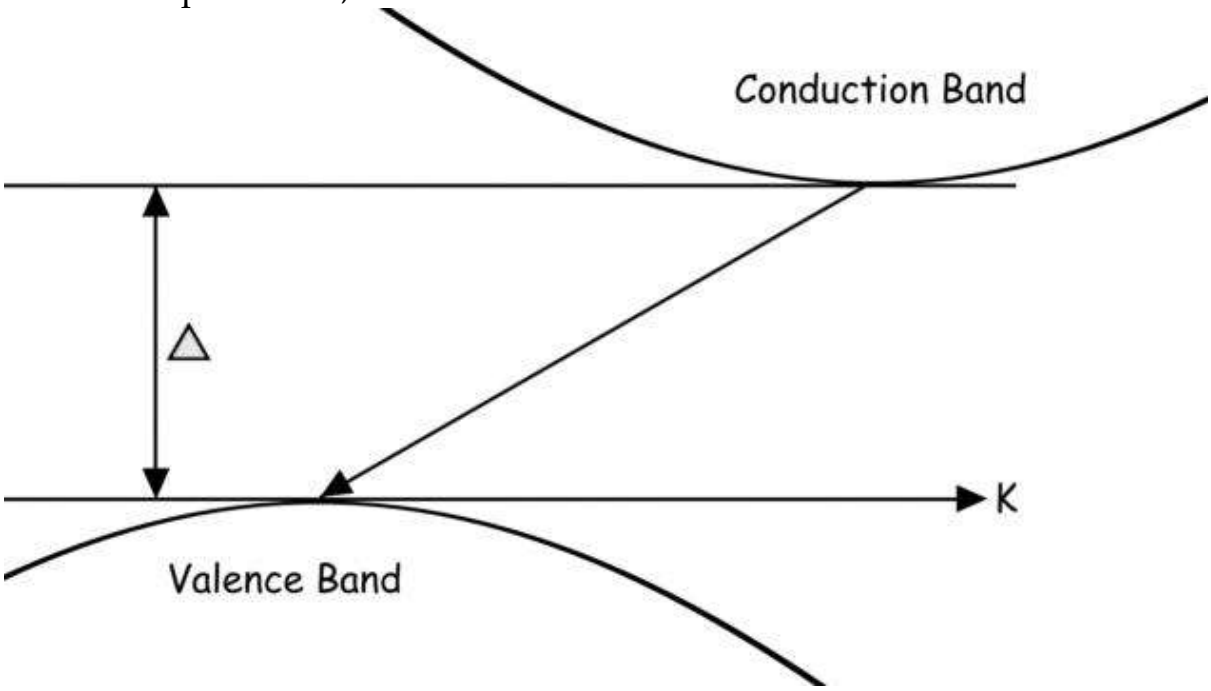
The explanation behind the emission of photons in an LED diode lies in the energy band theory of solids. According to this theory, whether the electron-hole combining will give out photons or not depends on whether the material has a direct band gap or indirect band gap. Those semiconductor materials which have a direct band gap are the ones that emit photons. In a direct bandgap material, the bottom of the energy level of conduction band lies directly above the topmost energy level of the valence band on the Energy vs Momentum (wave vector 'k') diagram. When electrons and hole recombine, energy $E = h\nu$ corresponding to the energy gap $\triangle$ (eV) is escaped in the form of light energy or photons where

h is the Planck's constant and ν is the frequency of light.



Direct Band Gap

While the indirect band gap is non-radiative in nature as the bottom of the conduction band does not coincide with the top of the valence band and the energy corresponding to the energy gap is mostly given in the form of heat. Examples are Si, Ge etc.



Indirect Band Gap

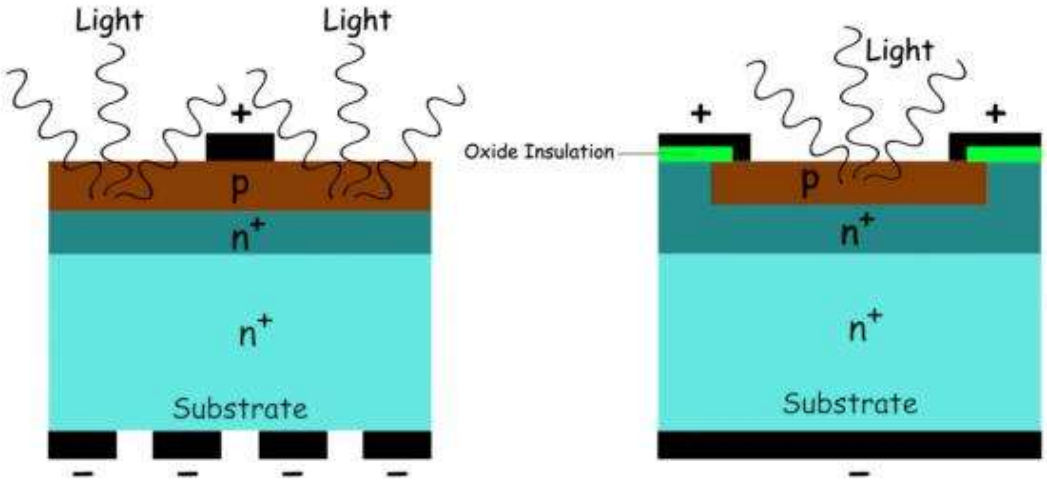
Example of material which has direct band gap is Gallium Arsenide(GaAs),

a compound semiconductor which is the material used in LEDs. Dopant atoms are added to GaAs to give out a wide range of colors. Some of the materials used in LEDs are:

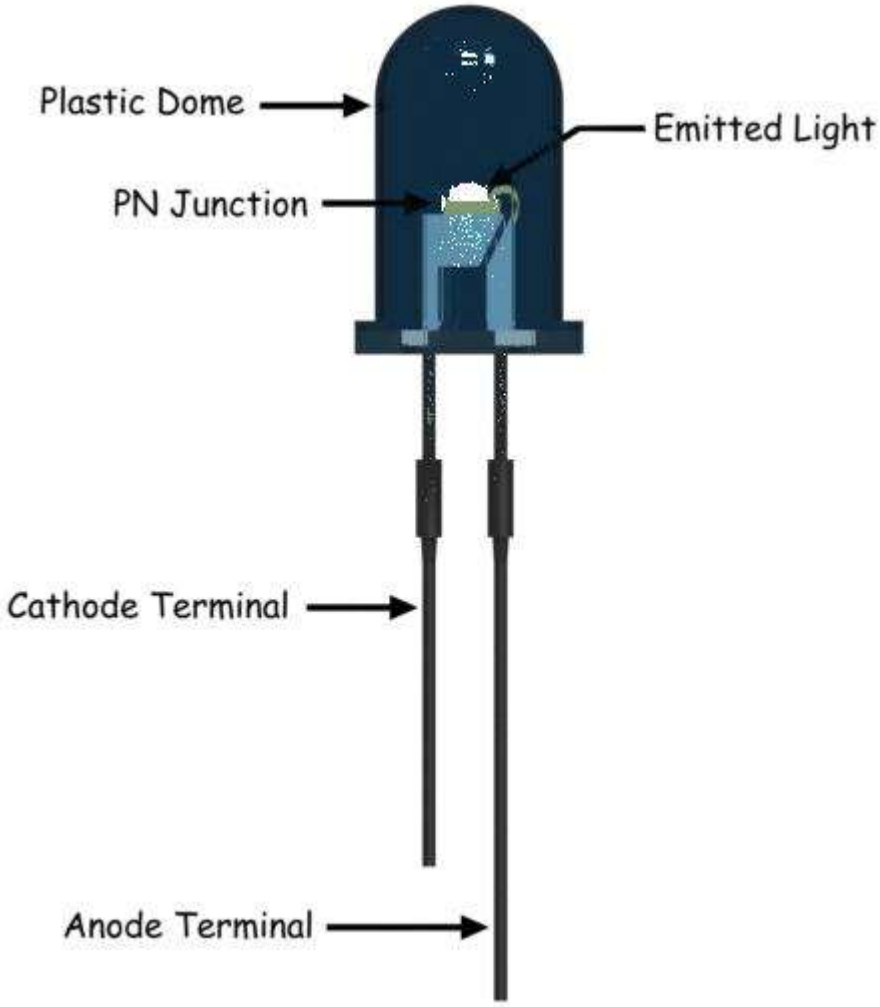
- Aluminium Gallium Arsenide(AlGaAs) – infrared.
- Gallium Arsenic Phosphide(GaAsP) – red, orange, yellow.
- Aluminium Gallium Phosphide(AlGaP) – green.
- Indium gallium nitride (InGaN) – blue, blue-green, near UV.
- Zinc Selenide(ZnSe) – blue.

Physical Structure of LED

LED is structured in such a way so that light emitted does not get reabsorbed into the material. So it is ensured that the electron-hole recombination takes place on the surface.



The above figure shows the two different ways of structuring LED p-n junction. The p-type layer is made thin and is grown on the n-type substrate. Metal electrodes attached on either side of the p-n junction serve as nodes for external electrical connection. The Light emitting diode p-n junction is encased in a dome-shaped transparent case so that light is emitted uniformly in all directions and minimum internal reflection to take place.



The larger leg of LED represents the positive electrode or anode.

LEDs with more than 2 legs are also available such as 3, 4 and 6 pin configurations to obtain multi-colors in the same LED package. Surface mounted LED displays are available that can be mounted on the PCBs.

The current rating of LED is of few tens milli-amps. Hence it is necessary to connect a high resistance in series to it. The forward voltage drop of an LED is much larger than an ordinary diode and is around 1.5 to 3.5 volts.

White Light LEDs or White LED Lamps

LED lamps, bulbs, street lighting are becoming very popular these days because of the very high efficiency of LEDs in terms of light output per unit input power(in milliWatts), as compared to the incandescent bulbs. So for

general purpose lightings, white light is preferred. To produce white light with the help of LEDs, two methods are used :

1. Mixing of three primary colors RGB to produce white light. This method has high quantum efficiency.
2. The other method is coating an LED of one color with phosphor of a different color in order to produce white light. This method is commercially popular to manufacture LED bulbs and lightings.

Applications of LEDs

- Electronic displays such as OLEDs, micro-LEDs, quantum dots etc.
- As an LED indicator.
- In remote controls.
- Lightings.
- Opto-isolators.