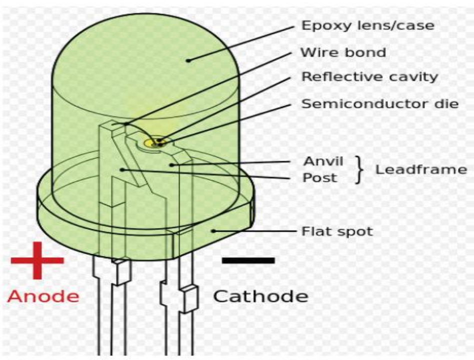
What is LED (Light Emitting Diode)?

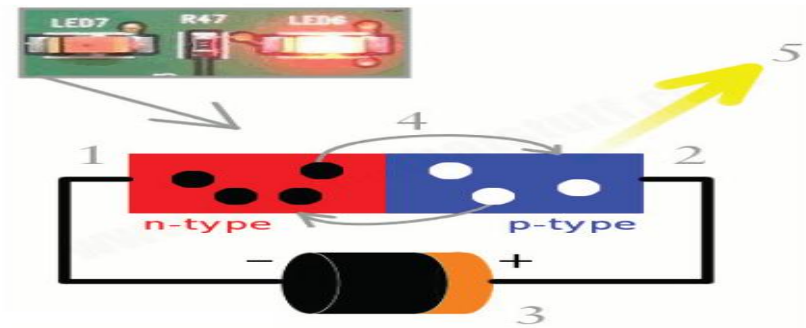
* The Light emitting diode is a two-lead semiconductor light source.
* In 1962, Nick Holonyak has come up with an idea of light emitting diode, and he was working for the general electric company.
* The LED is a special type of diode and they have similar electrical characteristics of a PN junction diode. Hence the LED allows the flow of current in the forward direction and blocks the current in the reverse direction.
* The LED occupies the small area which is less than the 1 mm^2. The applications of LEDs used to make various electrical and electronic projects.
* The light 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.



Light Emitting Diode

How does the LED work?

* The light emitting diode simply, we know as a 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, and 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.



Working of Light Emitting Diode

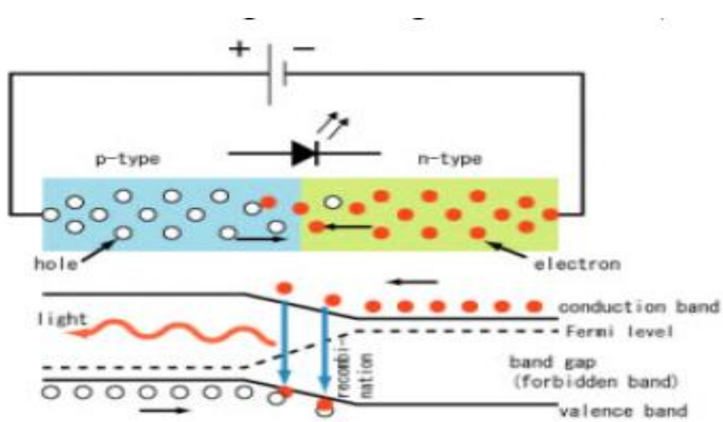
- From the diagram, we can observe that the N-type silicon is in red color and it contains the electrons, they are indicated by the black circles.
- The P- type silicon is in the blue color and it contains holes, they are indicated by the white circles.
- The power supply across the p-n junction makes 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.

Types of LED

- 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

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.



Working Principle of LED

* The flow of current in the semiconductors is caused by the both flow of free electrons 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.
* For an example, let us consider the quantum theory, the energy of the photon is the product of both Planck constant and frequency of electromagnetic radiation. The mathematical equation is shown

$$\mathbf{Eq = hf}$$

Where h is known as a Planck constant, and the velocity of electromagnetic radiation is equal to the speed of light i.e c. The frequency radiation is related to the velocity of light as a $f= c / \lambda$. λ is denoted as a wavelength of an electromagnetic radiation and the above equation will become as a

$$\mathbf{Eq = he / \lambda}$$

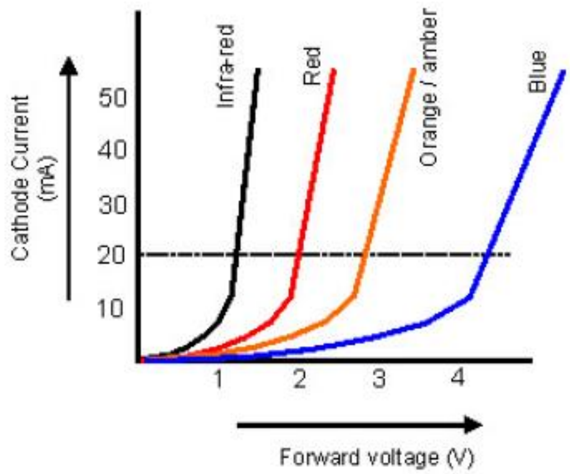
From the above equation, we can say that the wavelength of electromagnetic radiation is inversely proportional to the forbidden gap.
In general silicon, germanium semiconductors this forbidden energy gap is between the conduction and valence bands are such that the total radiation of electromagnetic wave during recombination is in the form of the infrared radiation. We can’t see the wavelength of infrared because they are out of our visible range.

The infrared radiation is said to be as a heat because the silicon and the germanium semiconductors are not direct gap semiconductors rather these are indirect gap semiconductors. But in the direct gap semiconductors, the maximum energy level of the valence band and minimum energy level of conduction band does not occur at the same moment of electrons. Therefore, during the recombination of electrons and holes are a migration of electrons from the conduction band to valence band the momentum of electron band will be changed.

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.
In the starting use of LED, there is the only red color.

As the use of LED is increased with the help of the semiconductor process and doing the research on the new metals for LED, the different colors were formed.



I-V Characteristics of LED

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.

Quantum-Dot Based Light-Emitting Diodes

Quantum dot-based light-emitting diodes (QD-LEDs) represent a form of light-emitting technology and are regarded like a next generation of display technology after the organic light-emitting diodes (OLEDs) display.

QD-LEDs are different from liquid crystal displays (LCDs), OLEDs, and plasma displays due to the fact that QD-LEDs present an ideal blend of high brightness, efficiency with long lifetime, flexibility, and low-processing cost of organic LEDs.

So, QD-LEDs show theoretical performance limits which surpass all other display technologies.

The goal of this chapter is, firstly, to provide a historical prospective study of QD-LEDs applications in display and lighting technologies, secondly, to present the most recent improvements in this field, and finally, to discuss about some current directions in QD-LEDs research that concentrate on the realization of the next-generation displays and high-quality lighting **with superior color gamut (The entire range of colors available on a particular device such as a monitor or printer. A monitor, which displays RGB signals, typically has a greater color gamut than a printer, which uses CMYK inks. When a color is "out of gamut," it cannot be properly converted to the target device; for example, to a different type of printer.), higher efficiency, and high color rendering index.**

QDs obey the quantum mechanical principle of three-dimensional confinement of the charge carriers (electrons, holes) that determine novel quantum phenomena and tunable optical properties, which are sensitive to the size, shape, and material composition of the QDs.

QDs have an intrinsic energy bandgap that decides required wavelength of radiation absorption and emission spectra.

The bandgap energy increases with the decrease in the dimension of the QD. The color of the light which a QD emits is directly connected to its size; the bigger dots cause longer wavelengths, lower frequencies, and redder light while the smallest dots produce shorter wavelengths, higher frequencies, and bluer light.

This dimension dependence permits the modulating of the bandgap energy by varying the size of the QD.

QD technology is used to filter light from light-emitting diodes (LEDs) to backlit liquid crystal displays (LCDs).

With the recent enhancements introduced by the usage of the QDs to backlighting technology, LED/LCD TVs are much better today than they were just few years ago.

Structure of quantum dot-based light-emitting diodes

Due to the multiple advantages of using QDs and their applications in optoelectronic instruments like LEDs, the scientists have created quantum dot-based light-emitting diode (QD-LED) with the improved efficiency and flexibility.

QD-LED represents the following generation's display technology after OLED displays.

QD-LEDs are a form of light emitting technology for creating large-area displays that could have applications for TVs, cell phones, and digital cameras.

A classical QD-LED is composed of three layers: one inner layer of QDs as an emissive layer, one outer layer that transports electrons, and one outer layer that transports holes

(The researchers addressed these requirements by using a layer of 6-nm cadmium-selenide quantum dots and an electron transport layer made of ZnO nanocrystals. The researchers fabricated four different versions of the QLED, each having a different quantum dot film thickness (15, 30, 45, or 60 nm).

After applying an electric field on the outside layers, electrons and holes shift in the layer of QD, where they are captured by QD and recombine, emitting photons.

Due to the multiple advantages of using the colloidal QDs, the colloidal QDs are a promising way for making QD-LEDs.

A great effect of an increased recombination efficiency is obtained by constructing an emissive layer in a single layer of QDs, so that the electrons and holes may be moved directly from the surfaces of electron-transport layer and hole-transport layer.

For the definition of the performance of a QD-LED is used the external quantum efficiency (EQE), which is the term that designates the number of photons emitted from the device per electron.

QD-LEDs not only reduce the consumption of energy but also show high color purity. Studies reported that QD-LEDs exhibit the ability to be more than twice as power efficient than OLEDs at the same color purity. QD-LEDs have the advantages of foldability and their wide application for next-generation electronic displays and optical communication technology.
QD-LEDs exhibit pure and saturated emission colors with narrow bandwidth. In QD-LEDs, the emission color is powerfully directed by the dimension of the used QD due to the confinement effects. It has been proven that QD-LEDs present a 30–40% luminance efficiency advantage above OLEDs for the same color point.

The Color Rendering Index (CRI) is a scale from 0 to 100 percent indicating how accurate a "given" light source is at rendering color when compared to a "reference" light source. The higher the CRI, the better the color rendering ability. Light sources with a CRI of 85 to 90 are considered good at color rendering.

A color rendering index (CRI) is a quantitative measure of the ability of a light source to reveal the colors of various objects faithfully in comparison with an ideal or natural light source. Light sources with a high CRI are desirable in color-critical applications such as neonatal care and art restoration. It is defined by the International Commission on Illumination (CIE) as follows:[1]

Color rendering: Effect of an illuminant on the color appearance of objects by conscious or subconscious comparison with their color appearance under a reference illuminant