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PHYSICS
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LIGHT EMITTING DIODE

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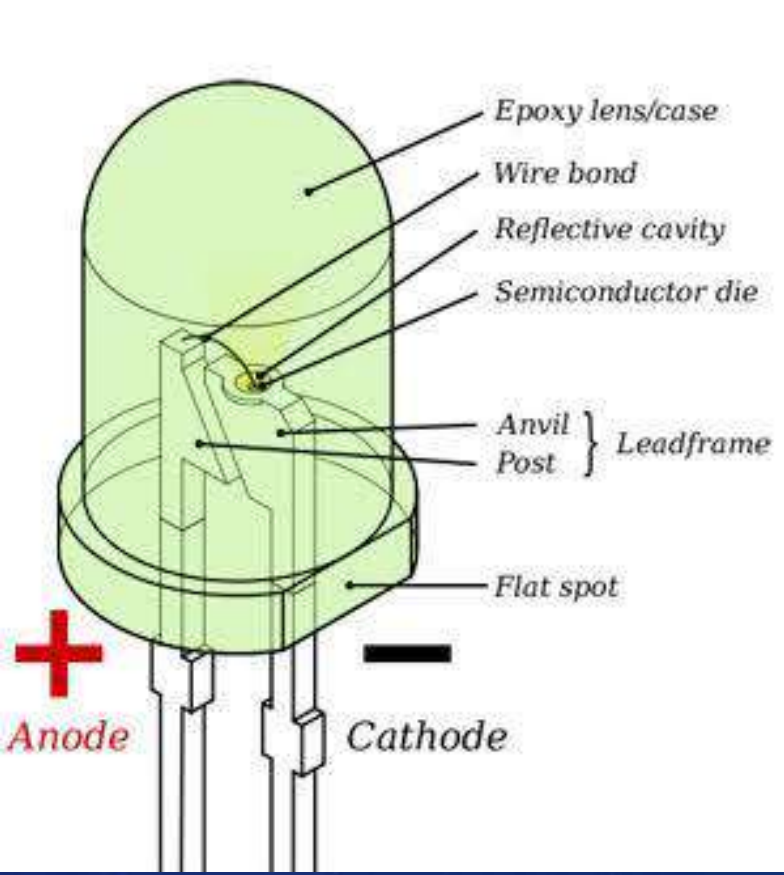
WHAT IS LED?

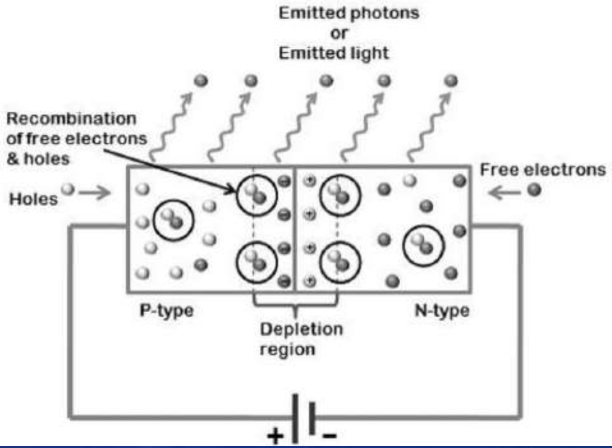
Definition: The LED is a PN-junction diode which emits light when an electric current passes through it in the forward direction. In the LED, the recombination of charge carrier takes place. The electron from the N-side and the hole from the P-side are combined and gives the energy in the form of heat and light. The LED is made of semiconductor material which is colourless, and the light is radiated through the junction of the diode.



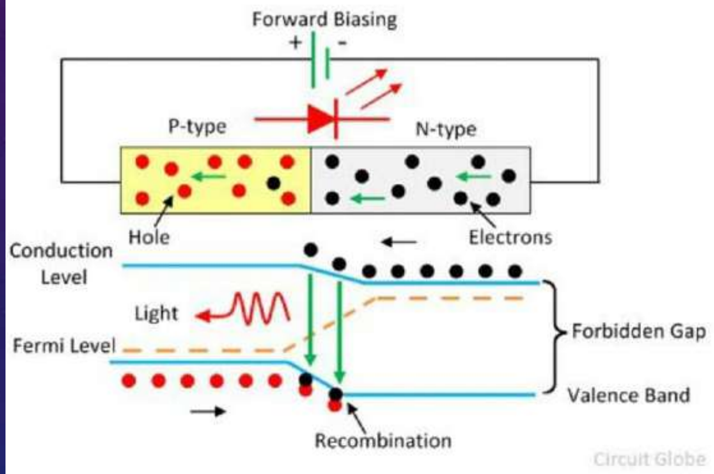
https://youtu.be/Yo6JI_bzUzo

CONSTRUCTION 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 working of the LED depends on the quantum theory. The quantum theory states that when the energy of electrons decreases from the higher level to lower level, it emits energy in the form of photons. The energy of the photons is equal to the gap between the higher and lower level.



The LED is connected in the forward biased, which allows the current to flows in the forward direction. The flow of current is because of the movement of electrons in the opposite direction. The recombination shows that the electrons move from the conduction band to valence band and they emits electromagnetic energy in the form of photons. The energy of photons is equal to the gap between the valence and the conduction band.

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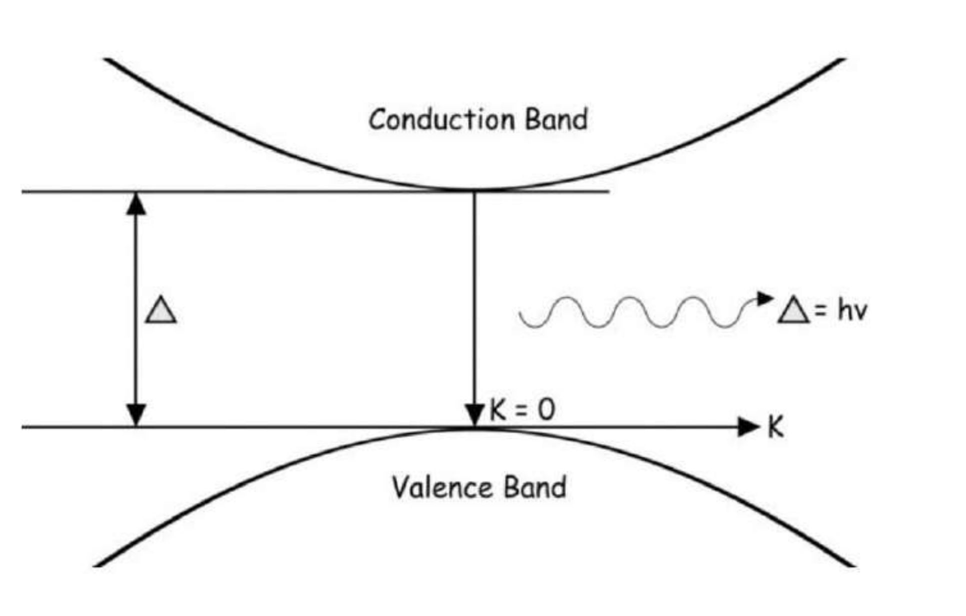
EXPLANATION



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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 △ (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.

WHY SIMPLE DIODE CAN NOT BE A LED?

The explanation is here: Direct and indirect band gaps
Standard diodes are made of silicon, an indirect band gap material, thus no photon emission is possible. LEDs are made of direct band gap semiconductors like GaAs.

. Silicon is what is known as an *indirect band gap* material. In a direct-band gap material, the electron goes from conduction band to valence band and gives off the difference in energy. In an indirect-band gap material, the electron loses some energy into the material itself (particularly photons, which a sort of vibration of the crystal lattice). I think for silicon and its low-energy band gaps involved, the extra energy is just heavily-favoured to be absorbed by the lattice.

LED COLOUR

Typical LED Characteristics			
Semiconductor Material	Wavelength	Colour	V_F @ 20mA
GaAs	850-940nm	Infra-Red	1.2v
GaAsP	630-660nm	Red	1.8v
GaAsP	605-620nm	Amber	2.0v
GaAsP:N	585-595nm	Yellow	2.2v
AlGaP	550-570nm	Green	3.5v
SiC	430-505nm	Blue	3.6v
GaInN	450nm	White	4.0v

Unlike normal signal diodes which are made for detection or power rectification, and which are made from either Germanium or Silicon semiconductor materials, **Light Emitting Diodes** are made from exotic semiconductor compounds such as Gallium Arsenide (GaAs), Gallium Phosphide (GaP), Gallium Arsenide Phosphide (GaAsP), Silicon Carbide (SiC) or Gallium Indium Nitride (GaInN) all mixed together at different ratios to produce a distinct wavelength of colour.

Different LED compounds emit light in specific regions of the visible light spectrum and therefore produce different intensity levels. The exact choice of the semiconductor material used will determine the overall wavelength of the photon light emissions and therefore the resulting colour of the light emitted.

KEY WORDS

Thus, the actual colour of a light emitting diode is determined by the wavelength of the light emitted, which in turn is determined by the actual semiconductor compound used in forming the PN junction during manufacture.

NEW VERSION OF LED

Recently developed blue and white coloured LEDs are also available but these tend to be much more expensive than the normal standard colours due to the production costs of mixing together two or more complementary colours at an exact ratio within the semiconductor compound and also by injecting nitrogen atoms into the crystal structure during the doping process.

2019 REPORTS

What's more, **the new LED technique** — doping the gallium nitride with a rare earth element called europium — is compatible with current GaN-based LED technologies. We commonly see GaN-based LEDs at work in commercial solid-state lighting, which means this advancement will have significant implications in the commercial sector going forward.

Reversed LED Cooling

Another exciting new development in LED physics is that we're seeing researchers **run LEDs in reverse to create a cooling effect**. In February 2019, a research team demonstrated that if you run LEDs backward — rather than doing nothing, as one would expect from a diode — you achieve a very short-range cooling effect to the tune of $6W/m^2$.