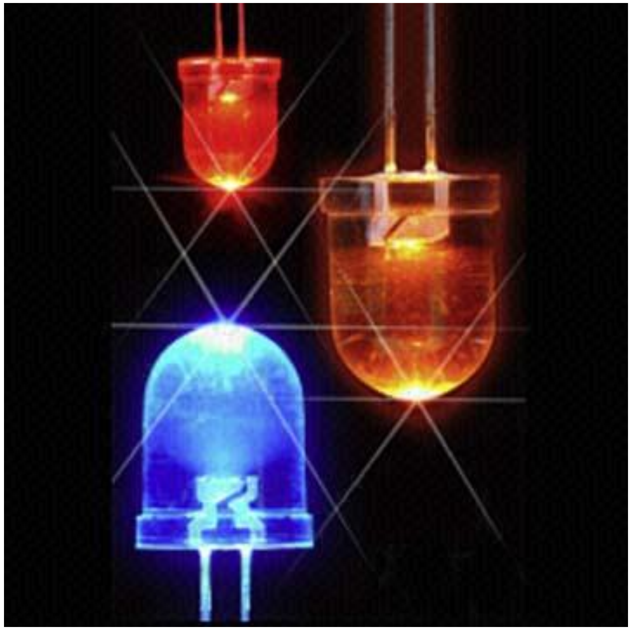
DEPARTMENT OF PHYSICS AND NANOTECHNOLOGY
SRM INSTITUTE OF SCIENCE AND TECHNOLOGY

18PYB103J –Semiconductor Physics

Module 2 Lecture 14

1. ***Light emitting diode – Construction & Working***
2. ***Classification of Light emitting diode (edge and surface)***

What is LED?



- Semiconductors bring quality to light!

LED are semiconductor p-n junctions that under forward bias conditions can emit radiation by electroluminescence in the UV, visible or infrared regions of the electromagnetic spectrum. The quanta of light energy released is approximately proportional to the band gap of the semiconductor..


12:16


Inside a
Light Emitting
Diode
Emitted Light
Beams
Diode
Transparent
Plastic Case
Terminal Pins

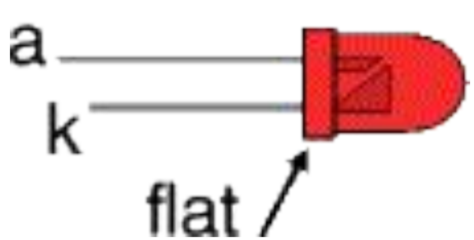

0.9999

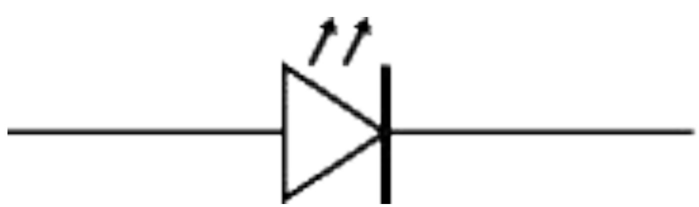

LED SIGN

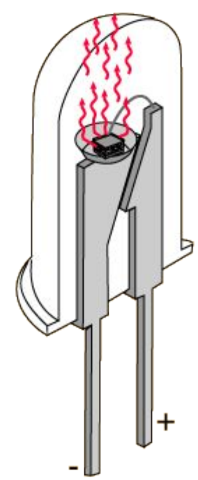

9:58

•A light emitting diode (LED) is essentially a PN junction opto-semiconductor that emits a monochromatic (single color) light when operated in a forward biased direction.

•LEDs convert electrical energy into light energy. They are frequently used as "pilot" lights in electronic appliances to indicate whether the circuit is closed or not.





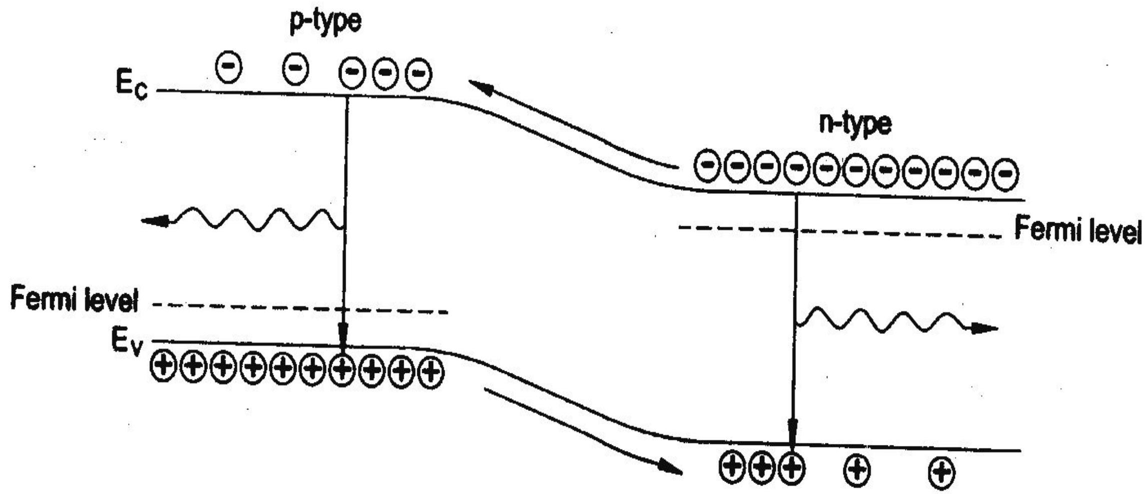


Light Emitting Diodes

Principle

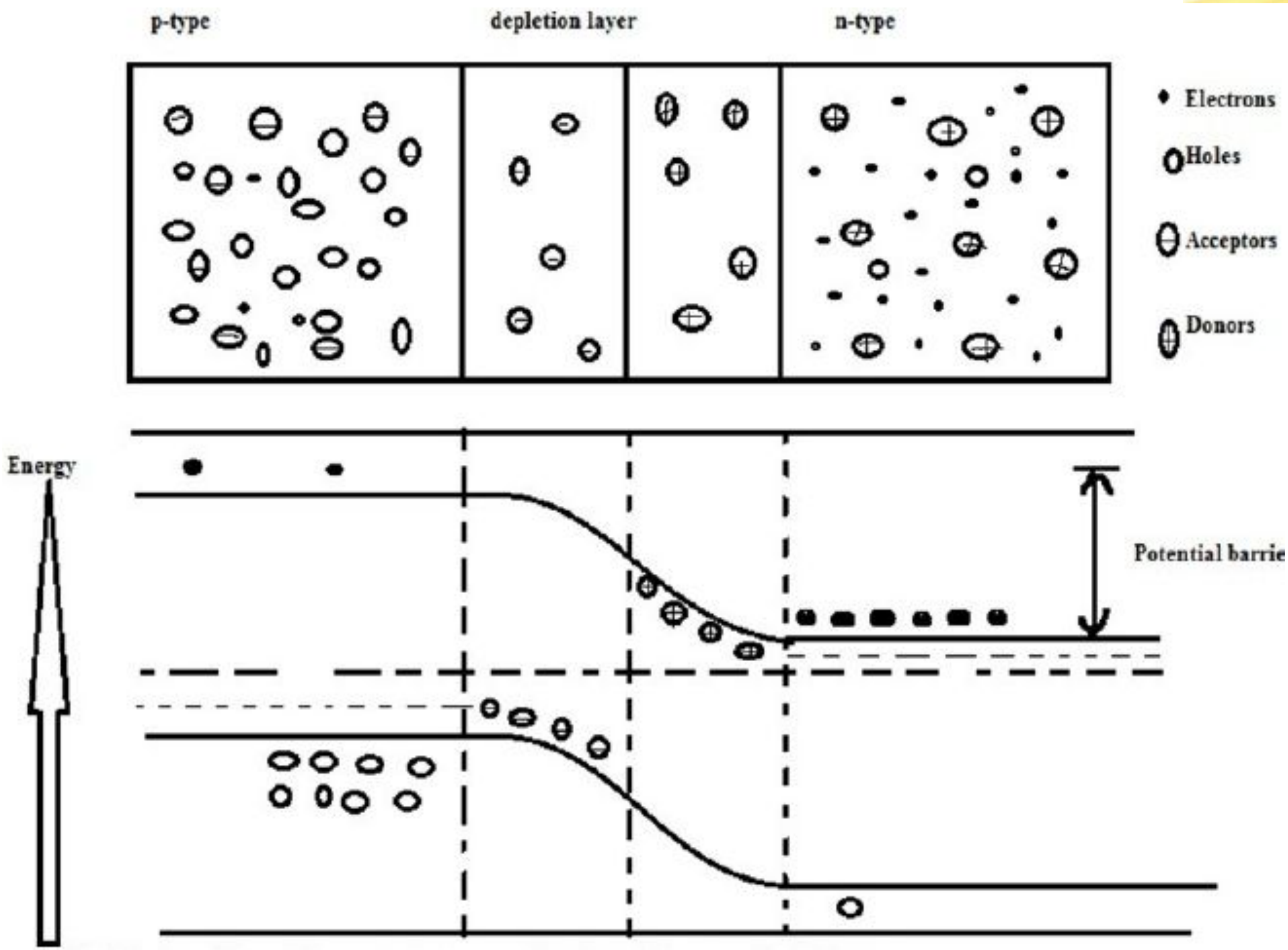
- The p-n junction diode is forward biased. Due to forward bias, the majority carriers from ‘n’ and ‘p’ regions cross the junction and become minority carriers in the other junction (i.e.) Electrons, which are majority carriers in ‘n’ region cross the junction and go to ‘p’ region and become minority carriers in p-region.
- Similarly, holes which are majority carries in ‘p’ region cross the junction and go to ‘n’ region and become minority carriers in ‘n’ region and this phenomenon is called ***minority carrier injection.***

Radiative Recombination



Now if the biasing voltage is further increased, these excess minority carriers diffuse away from the junction and they directly recombine with the majority carriers. (i.e.) the electrons, which are excess minority carriers in p-region recombine with the holes which are the majority carriers in 'p' region and emit light. Similarly, the holes which are excess minority carriers in 'n' region recombine with the electrons which are majority carriers in 'n' region and emit light.

Radiative Recombination



Radiative Recombination

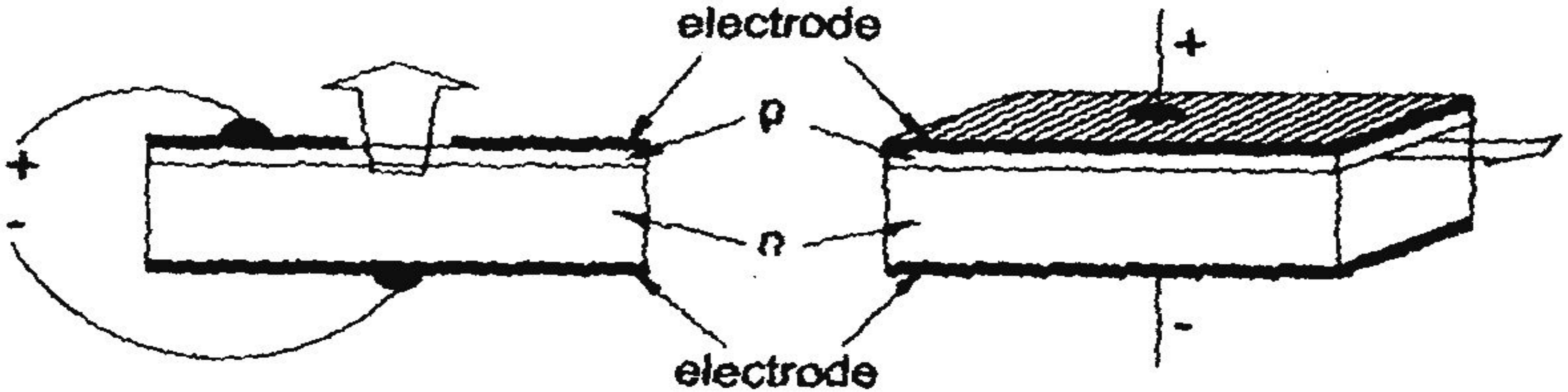
Thus radiative recombination events lead to photon emission. The number of radiative recombination is proportional to the carrier injection rate and hence to the total current flowing through the device as given by $I = I_0\left[\exp\left(\frac{eV}{\beta kT}\right) - 1\right]$

where I_0 - the saturation current ; V- the forward bias voltage; k - the Boltzmann constant ; β -varies from 1 and 2 depending on the semiconductor and temperature.

The optical photon emitted due to radiative recombination has the energy very close to the bandgap energy E_g and frequency of the emitted photon is given by $\frac{hc}{\lambda} = E_g$ where λ - the photon wavelength; h – Planck's constant; c - the velocity of light in vacuum.

LED Construction

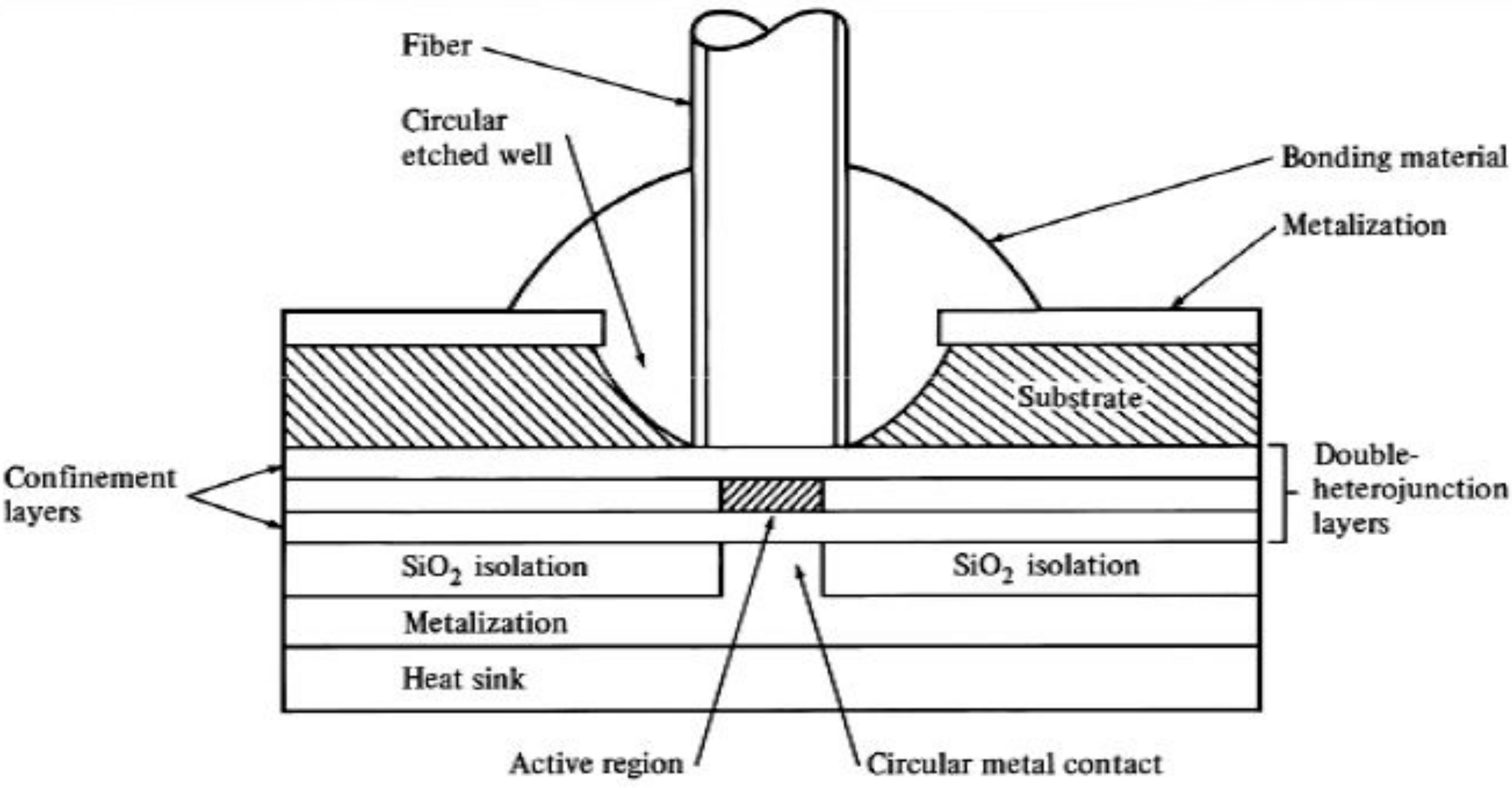
An LED must be constructed such that the light emitted by the radiative recombination events can escape the structure.



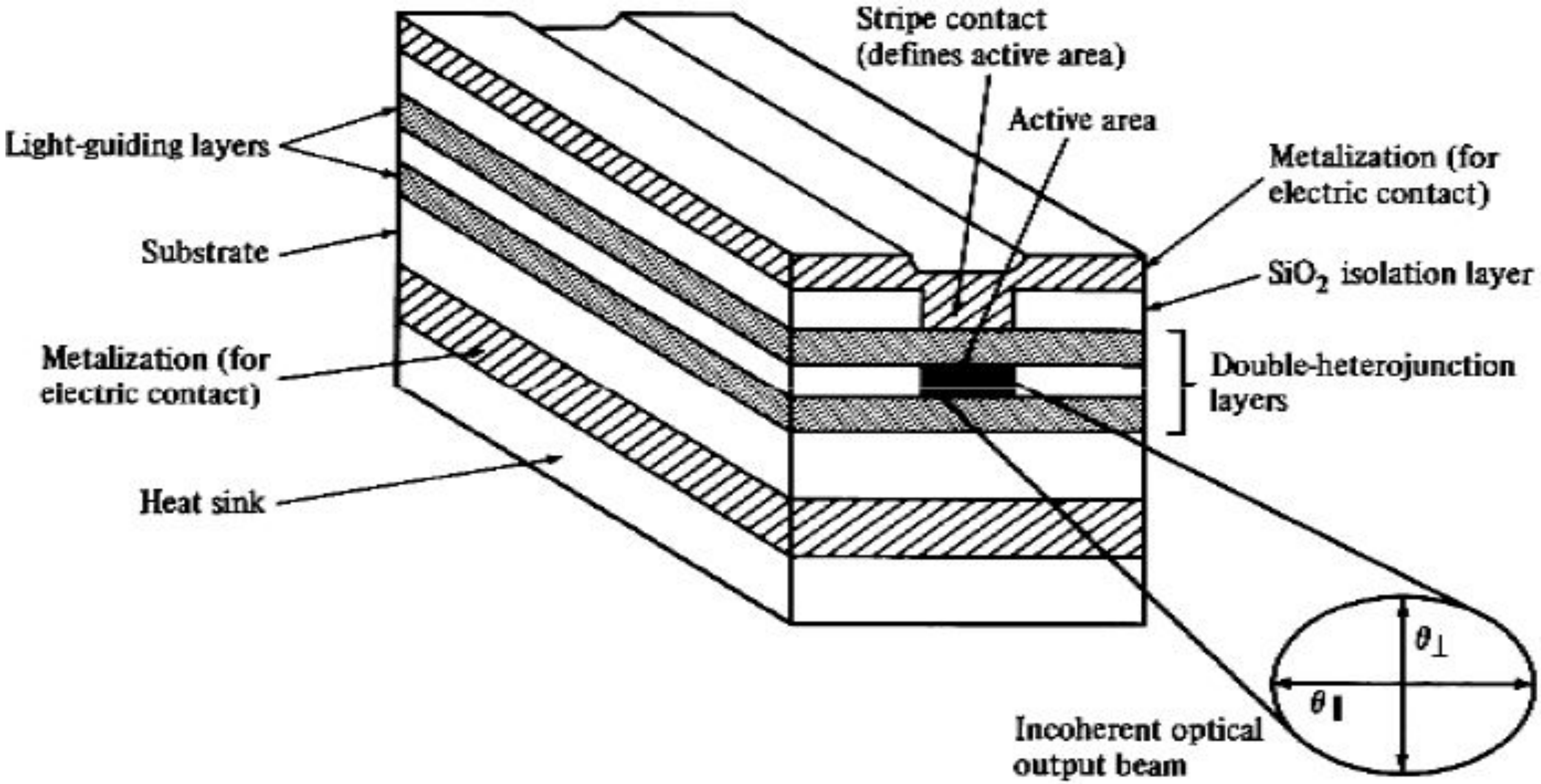
(a) Surface emitting LED

(b) Edge emitting LED

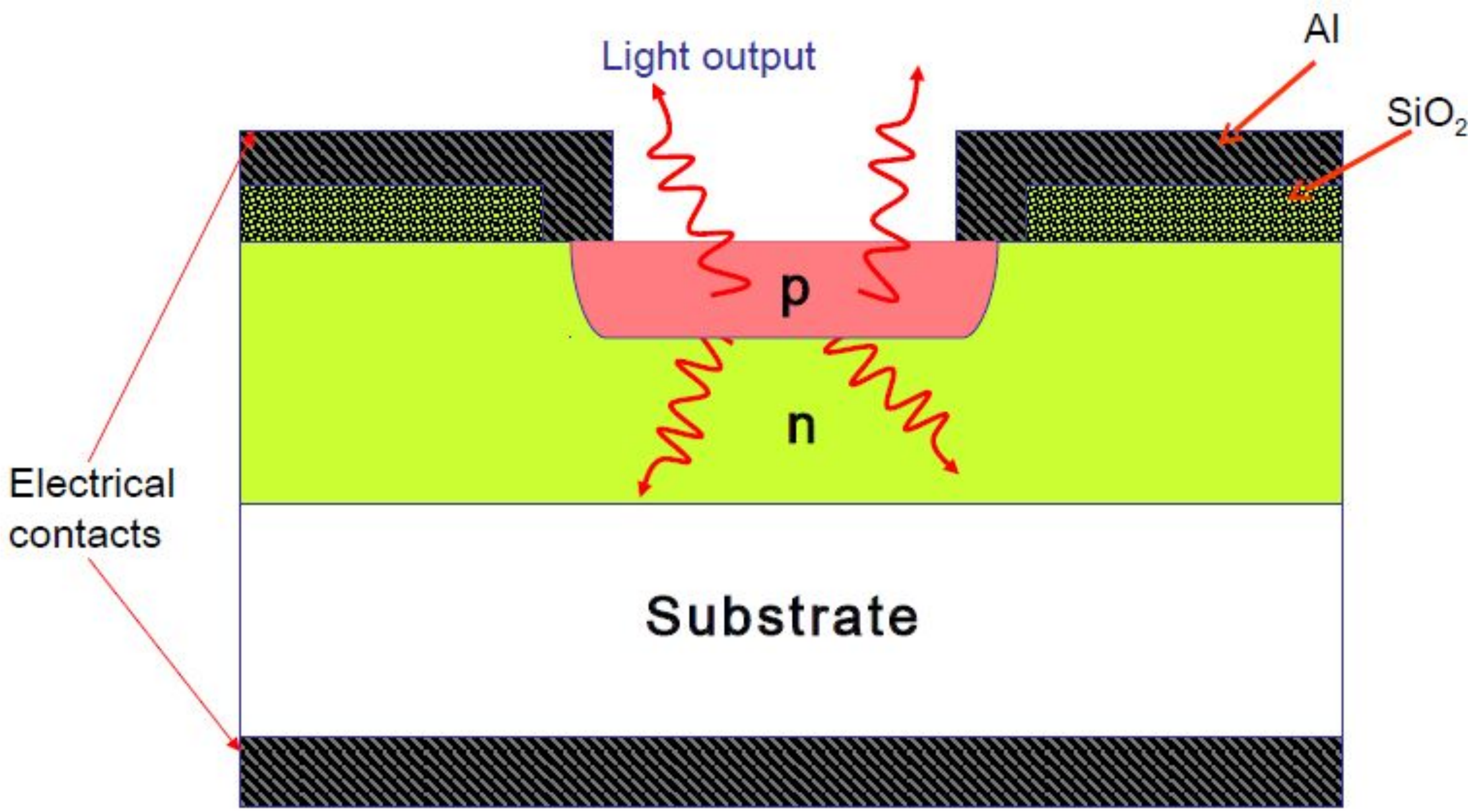
Surface Emitting LED



Edge Emitting LED



Construction of Typical LED



LED Construction

- LEDs can be designed as either surface or edge emitters. Surface emitting LEDs can be made such that the bottom edge reflects light back towards the top surface to enhance the output intensity. The main advantage of edge emitter LEDs is the emitted radiation is relatively direct. Hence edge emitter LEDs have a higher efficiency in coupling to an optical fibre.
- Although the internal quantum efficiency of LEDs is 100%, the external efficiencies are much lower. The main reason is that most of the emitted light radiation strikes the material interface at greater than critical angle and hence trapped with in the device. The internal critical angle at the semiconductor – air boundary is given by $\sin\theta_c = \frac{n_2}{n_1}$

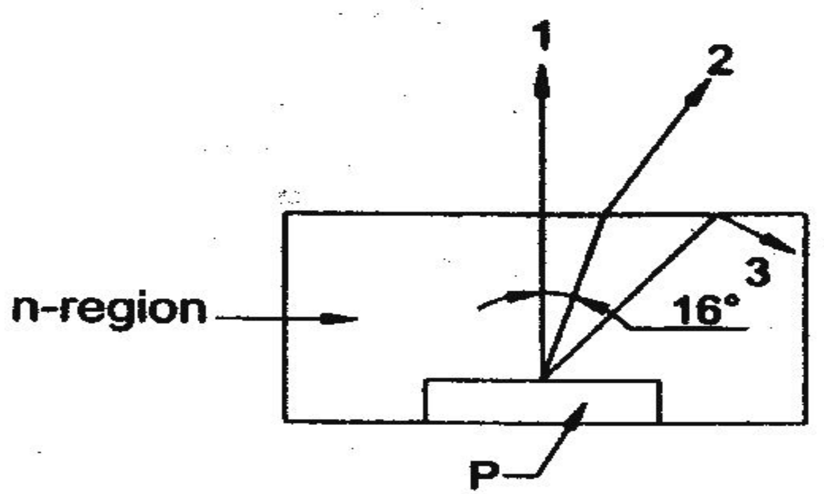
Critical angle

Where n_1- is the refractive index of air = 1.0

n_2 is the refractive index of the semiconductor

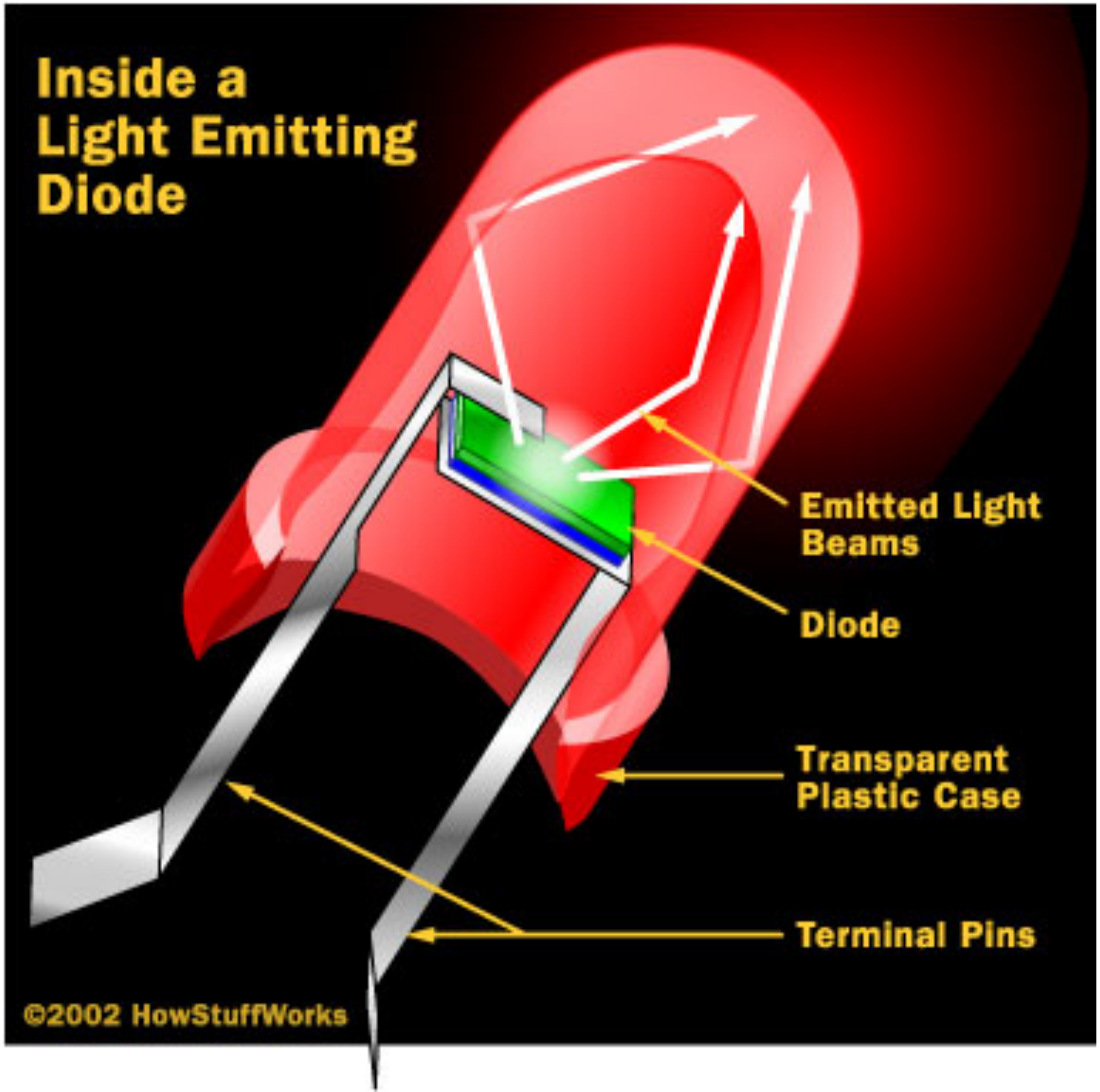
For group III semiconductor $n_2 = 3.5$

Therefore $\theta c = 16°$



Therefore all rays of light striking the surface at an angle exceeding 16° suffer total internal reflection and as a result most of the emitted light is reflected back inside the semiconductor crystal.

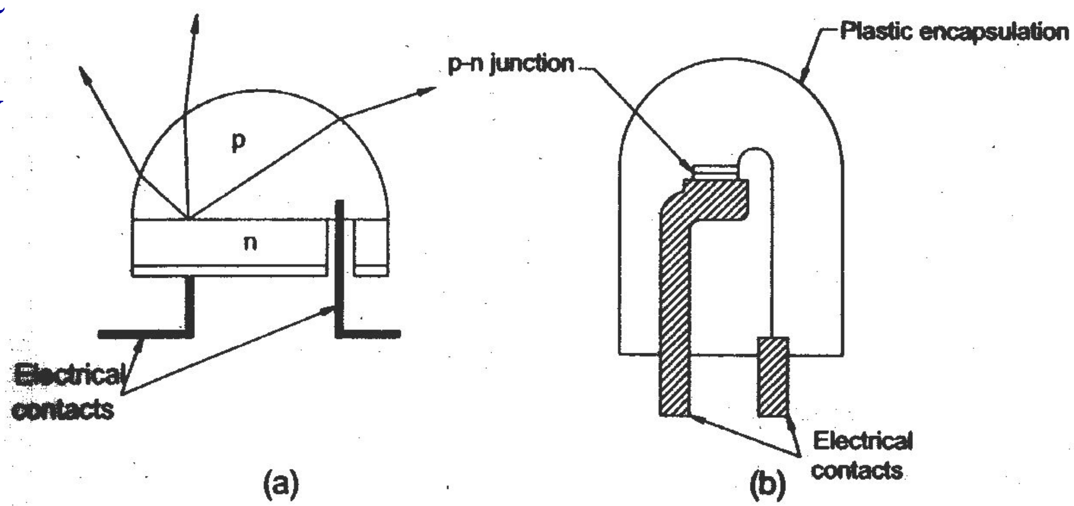
Inside a Light Emitting Diode



1. Transparent Plastic Case
2. Terminal Pins
3. Diode

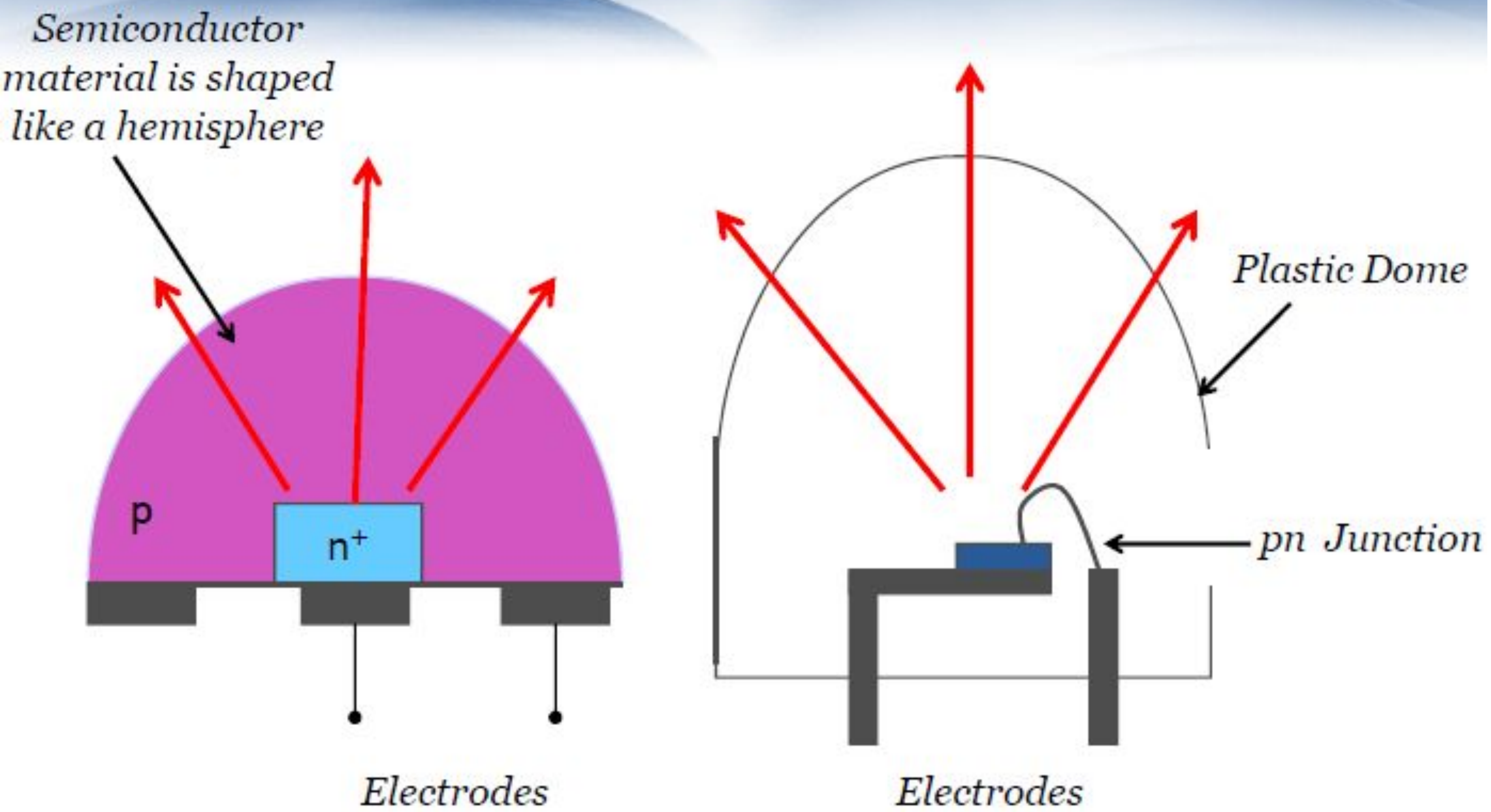
Hemispherical Dome shape

- Hence to improve the external efficiency losses caused bulk absorption has to be minimized and the surface transmission has to be increased. One method to achieve this is to give the semiconductor a dome structure.
- Hemi spherical domes made from plastics are effective in increasing the external efficiency by a factor 2 or 3. There will be some losses at the plastic/ air interface but these are easily minimized by molding the plastic into an approximately hemispherical shape.



Hemispherical Dome shape

Why do we need the DOME ?



To reduce TIR ...

LED Materials

- The choice of the materials for an LED is decided by the spectral requirements for a particular application. The most commonly used materials for LEDs are GaP, GaAs and their related ternary compound $Ga\,As_x\,P_{1-x}$
- The bandgap radiation of GaP, GaAs and GaAsP. GaP which gives a peak at 560 nm is very close to the wavelength of maximum eye response.

LED Materials

•This makes GaP one of the most useful of all visible semiconductor light sources since in addition to green light both red and other colours can be produced by appropriate dopants.

Wavelength response of LED materials

Materia l	Dopant	Band gap (eV)	Wavelength (Nm)	Quantum efficiency (%)
GaP	N	2.88	430	0.6
GaP	Zn0	1.80	690	0.2
GaP	N	2.25	550	0.1
GaAs	P	1.88	660	0.2
AlGa	As	1.84	675	0.2