Metal-Semiconductor ohmic Contacts :- Contacts must be made b/w any s.c device or integrated circuits and the outer world. These contacts are made via ohmic contacts. ohmic contacts are metal to semiconductor contacts but in this case they are not rectifying contacts. An ohmic contact is a low resistance Junction providing conduction in both direction b/w the metal and semiconductor.

Ideally, the current through the ohmic contacts is a linear function of applied voltage, and the applied voltage should be very small. Two general types of ohmic contacts are possible.

(i) Ideal non rectifying barrier
(ii) tunneling barrier.

Ideal non rectifying barrier :- In this type of contacts, after thermal equillibrium, which occurs when electrons flows from metal to the semiconductor lower energy levels. These electrons flow back into the metal part if a possitive bias in the metal part was applied, and they feel no barrier.

Tunneling barrier :- Tunneling Junction is a barrier, such as a thin insulating layer or electrical potential, b/w two electrically conducting materials. Classically e⁻ has zero probability of passing through the barrier, but a/c to quantum mechanics there in non-zero probability of passing the barrier.

Semi-Conductor materials of interest for optoelectronic devices:-

All semiconductors have some electronic response to an optical signal provided that the wave-length of the photons is properly chosen, there is a wide section of materials to chose from.
Here we will discuss some broader driving forces in the choice of S.C detector materials.

Substrate availability:- S.C properties uses only in few materials (Si, GaAS, Ge, InP). So the choice is limited to those which have good lattice matching with the substrate. S.C alloys are widely used for detectors.

Long distance communication applications:-

For long distance communications, the photons with wave-length of 1.55 μm or 1.3 μm are used. Transmission losses in a optical fibre is very low at these wave-lengths. A detector is thus needed to respond to these energies.
The most widely used detector material is $In_{0.53}Ga_{0.47}$
Ge is also used for long Communication.

Local area network:-

The LANS (Local area network) where the optical signal has to propagate about a Kilometer, GaAs based emitters can be used for long distance communication.
Si forms a good detector materials. Silicon available photo diodes are used widely for LAN applications.

Long wavelength detection:- Among narrow band gap materials important choices are HgCdTe alloys, PbTe, PbSe, InSb extrinsic detectors based on Si and Ge implanted with impurities can also be used.

High speed detector:- An important advance in high speed detectors response has been the recent discovery of low temp. where a large no. of the defects are incorporated into the materials. These defects decrease the e-h recombination time to ~1Ps in contrast to about 1ns for high quality GaAs. The very short response time leads to high speed optical detection system.

Photonic Materials – Light Emitting diodes :-

LED is a semiconductor pn junction diode which convert electrical energy to light energy under forward biasing.

Principle:-

The diode is forward biased. Due to forward bias, the majority charge carriers from 'n' & 'p' regions cross the junction and become minority charge carrier in other region. Electron from n side cross the junction and becomes minority charge carrier, similarly, holes from p side cross the junction and becomes minority carriers in n side. This phenomenon is called minority carrier injection.

Now if voltage is further increased, these excess minority carriers diffuse away from the junction and they directly recombine with the majority carriers and emit light.

Total current flowing through the device as given by

$$I = I_o \left[\exp\left(\frac{eV}{\beta KT}\right) - 1\right]$$

Where $I_o \rightarrow$ saturation current

$K \rightarrow$ Boltzman constant.

$\beta \rightarrow$ Varies from 1 to 2 depending on s.c and temp.

Energy of optical photon $E_g = \frac{hc}{\lambda}$

LED Construction :- An LED must be constructed such that the light emitted by the recombination event can escape the structure.

LED can be designed as either surface or edge emitting LED 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 a 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.

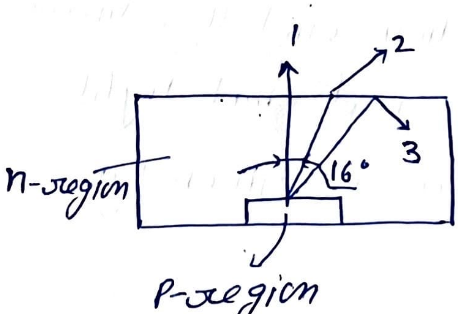
The internal critical angle at the semi-conductor - air boundary is given by $\sin\theta_c = \frac{n_2}{n_1}$.

$n_2 \rightarrow$ refractive index of air $\simeq 1.0$

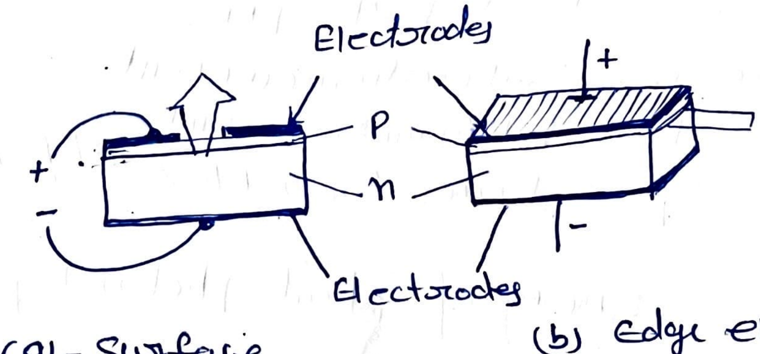
$n_1 \rightarrow$ refractive index of semiconductor

for group III semiconductor $n_1 = 3.5$

Therefore $\theta_c = 16^\circ$



At 16° all rays suffer total internal reflection and reflect back inside the semiconductor.



(a) - Surface emitting LED

(b) Edge emitting LED

So we have to increase the surface transmission to improve the external efficiency losses.
one method to achieve this, is to give the semiconductor a dome structure as shown in fig.

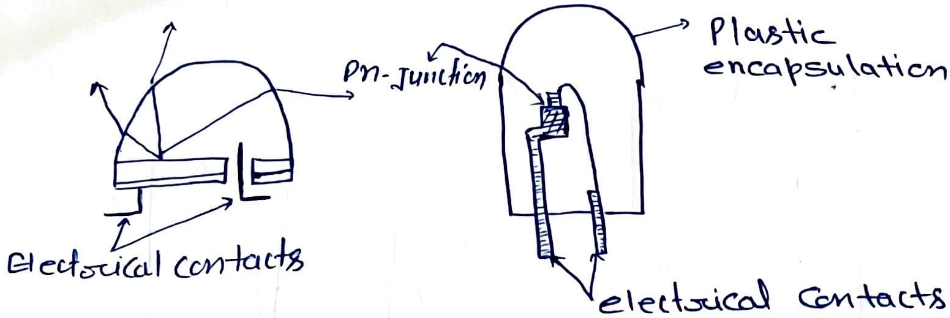


Fig:- Two methods used to reduce reflection losses in LEDs

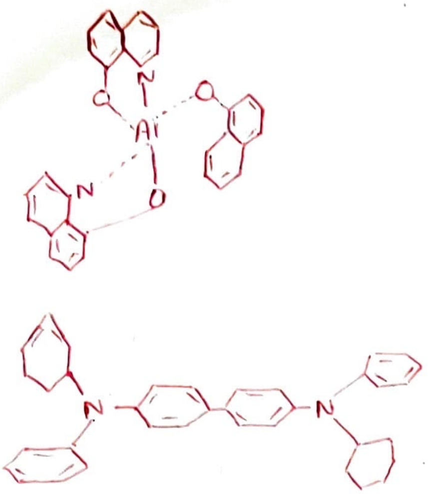
Hemi spherical domes made from plastics are effective in increasing the external efficiency by a factor 2 or 3.

Materials

- Most commonly used material for LEDs are GaP, GaAs and their related ternary Compound Ga As_xP_{1-x}
- The band gap radiation of GaP, GaAs gives peak at 560 nm is very close to the wavelength of maximum eye response.

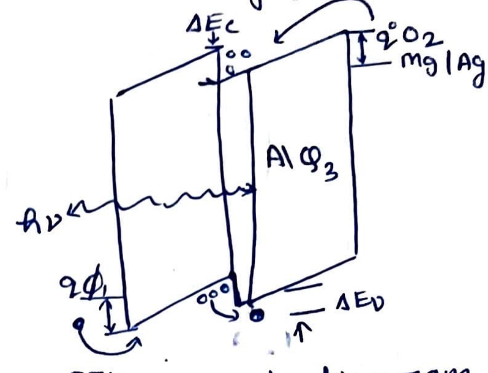
Material	Dopant	BandGap	Wavelength (Nm)	Quantum efficiency (%)
GaP	N	2.88	430	0.6
GaP	ZnO	1.80	690	0.2
GaP	N	2.25	550	0.1
GaAs	P	1.88	660	0.2
AlGa	As	1.84	675	0.2

Organic LEDs :- The organic LED (OLED) is Particularly used for multicolour, large area flat panel display because of its attributes of low-power consuption and excellent emissive quality with a wide view angle.



(a)

(OLED)
(b)



ITO
(c)

Band diagram OLED

fig (a) shows the molecular structures of two representative organic semi conductors. They are tris (8-hydroxy-quinolinato) aluminium. (AlQ_3) whic contain 6 benzene rings connected to a central aluminium atom and the aromatic diamine, which also contain six benzene rings but with different molecular arrangement.

A basic OLED has a no. of layers on a transpart substrate (glass). onto the substrate we deposite in sequence a tranparent conductive anode [e.g. ITO (indium tin oxide)]. the diamine as a hole transport layer, and the cathod contact (e.g Mg alloy with 10% Ag) fig b.

fig c shows the band diagram of OLED. It is basically a hetrojunction formed b/w AlQ_3 and diamine. Under proper biasing condition, electrons are injected from the cathod and move towards the hetrojunction interface. whereas holes are injected from the anode and move toward the interface. Because of the energy barriers ΔE_c and ΔE_v, these carriers will accumulate at the interface to enhance the chance of radiative recombination.

for AlQ_3, the emitted light is green. By choosing different organic semi-conductor with different band gabs, various colours including red, yellow, and blue can be obtained.