ORGANIC LIGHT EMITTING DIODES:

An OLED is a device which emits light under application of an external voltage. These are made with organic electroluminescent material (emit light when stimulated by applying an electric field) . These materials are small organic molecules or organic polymers.

Advantages of OLEDS over inorganic semiconductor based LEDs:

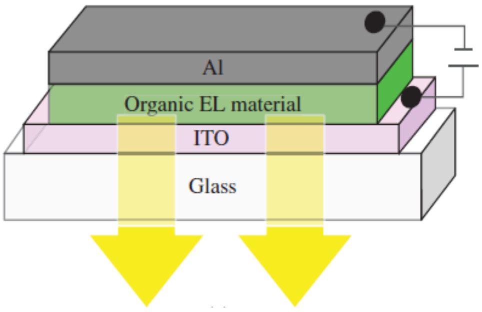
- Light weight
- flexiblility
- color tenability by varying substituents
- Ease of processability

Advantages of OLED based flat panel displays over Liquid crystal displays (LCDs):

- Ease of fabrication of large area flat panel displays
- Fast switching speed
- Light weight and flexibility
- Low operating voltage
- No backlight is required
- Wider viewing angle

COMPONENTS OF AN OLED:

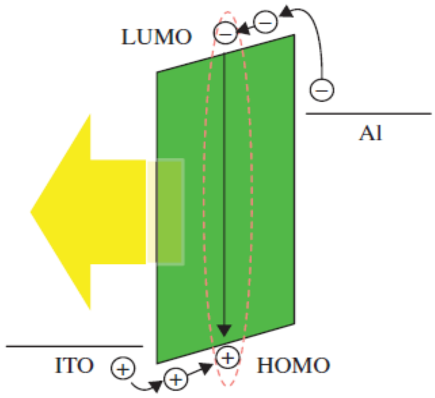
The components of a basic single layer OLED consists of a thin layer (~10-100 nm) of an organic electroluminescent material sandwiched between two electrodes.



Working Mechanism:

- When an electric bias is applied across the electrodes electrons are injected from cathode to the LUMO (Lowest Occupied Molecular Orbital) of the organic material and holes are injected from anode into the HOMO (Highest Occupied Molecular Orbital) states of the organic material.
- The electrons and holes then drift under the effect of the applied electric across the organic layer towards each other.
- They then recombine producing singlet and triplet excited states called excitons. Excitons are essentially electrostatically bound electron-hole (e-h) pairs that comprise an electron in a LUMO state and a hole in a HOMO state of the same molecule.
- The electron then relaxes from the higher energy state(LUMO) and fills the hole in the lower energy state(HOMO), emitting the energy radiatively as a photon.

- In the first approximation, the energy or wavelength of the emitted photon corresponds to the HOMO‑LUMO energy difference, which is the band-gap *E*g of the organic electroluminescent material.



Energy band diagram of the OLED. The arrows illustrate the different steps of the electroluminescence process.

Quantum Efficiency of the light emission:

Generally, the efficiency of an OLED is determined by charge balance, radiative decay of excitons, and light extraction.

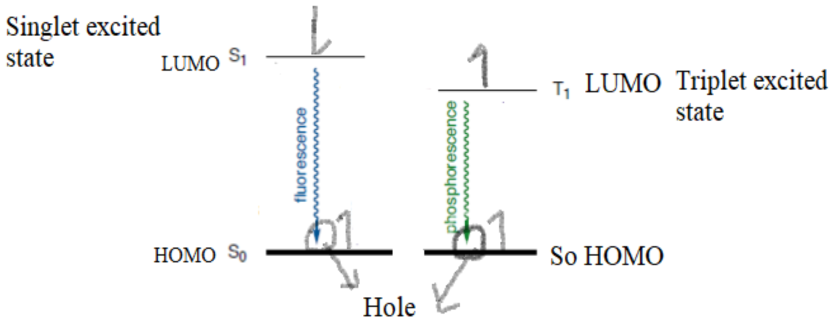
External Quantum Efficiency $\eta_{ex} = \dfrac{photons\ emitted}{electrons\ injected}$

Internal quantum efficiency $\eta_{in} = \dfrac{photons\ emitted}{Excitons\ produced}$

Efficiency is less compared to inorganic semiconductors

Reasons for decreased internal efficiency:

- In emissive layer of the OLED, two types of excitons—singlets and triplets—are generated at a ratio of 1:3 i.e., more number of triplet excitons.



- Fluorescence is the radiative recombination of e-h from singlet excited state and is highly favoured.
- Phosphorescence is the radiative recombination of e-h from triplet excited states which is forbidden.
- In addition, the excitons can relax through non-radiative processes like thermal relaxations.

- Thus the quantum efficiency of fluorescent light emitting materials is only 25%, and the remaining 75% of the electrically-generated energy is dissipated via non-radiational methods.
- Hence materials that can harvest both singlet and triplet excitons to provide nearly 100% of the internal conversion of charge into light are employed.

Reasons for decreased external efficiency in single layer LEDs:

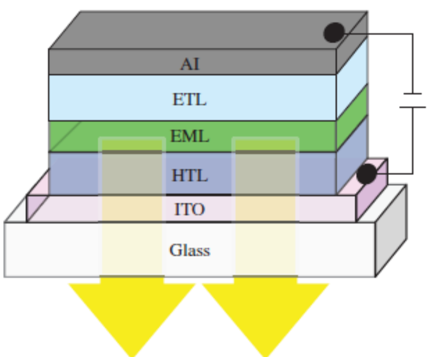
- Hole and electron injection in to the active materials occurs at the anode and cathode respectively. There will be energy barriers for the injection of charge carriers into the emissive material. Thus, for effective injection of charge carriers, higher operating voltages are required to overcome the barriers, leading to decreased external efficiency.
- Organic semiconductors (conjugated polymers) have higher hole mobility and lower electron mobility. In order to increase electron movement, higher voltages are required. This also decreases efficiency.
- When electric field is applied holes that are injected into the organic material near the anode migrate across the layer towards the cathode and the electrons injected in the material migrate towards the anode. During their migration, electrons and holes coming close to each other form excitons. Other holes and electrons migrate to the opposite electrodes and get discharged. Thus the probability of formation of excitons is reduced.

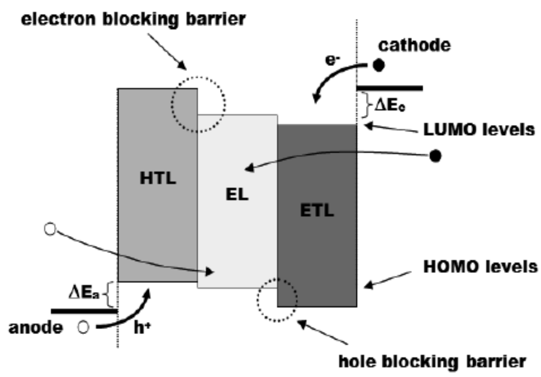
STRATEGIES USED TO IMPROVE EFFICIENCY:

1. **Multilayer Device Architectures:**

The components in an OLED differ according to the number of layers of the organic material. Basic single layer OLED, two, three and five layer OLED's. As the number of layers increase the efficiency of the device also increases.

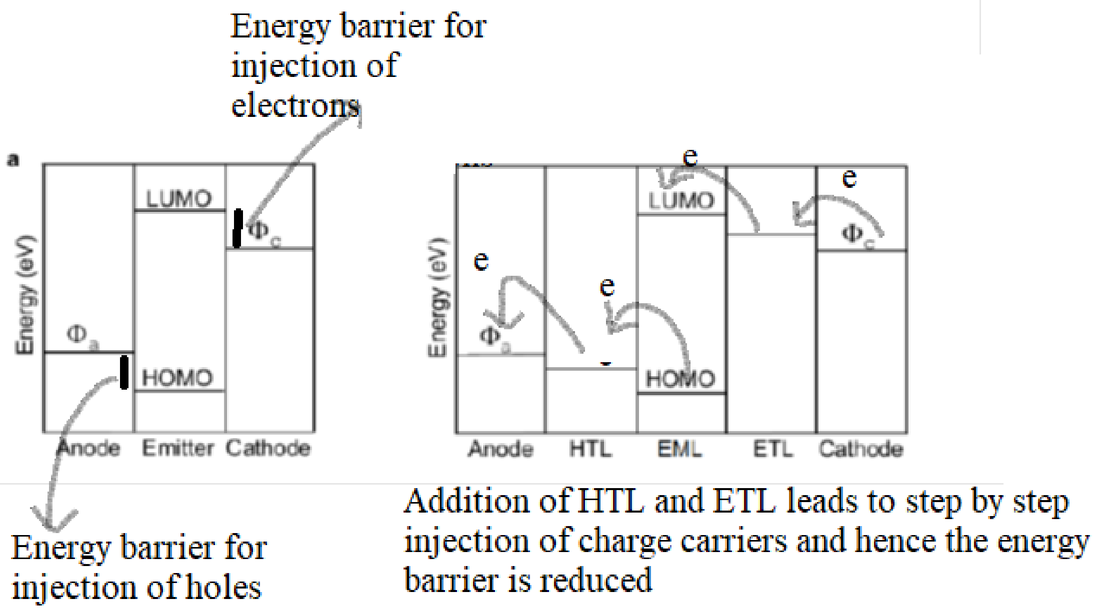
Generally, in addition to the organic electroluminescent material layer, OLEDs normally include at least two additional organic semiconductor layers, interposed between it and the electrodes, called the Electron Transport Layer(ETL) and Hole TransportLayer(HTL).





Roles of ETL and HTL:

- These layers help facilitate charge carrier (holes or electrons) injection from the electrodes.



(a) Single layer device (b) Multilayer device

Φ_C and Φ_A are the work functions of cathode and anode, respectively.

- The interfaces at HTL/EL and EL/ETL act as electron and hole barriers, respectively and reduce the leakage of carriers to the counter electrodes. Thus, the electrons and holes are confined to the emissive layer, thereby increasing e–h recombination probability. Hence the device electroluminescent efficiency is increased.
- To further improve efficiencies, the HTL and ETL are doped to improve the carrier mobilities.

2. **Phosphorescent OLEDs:**
Using phosphorescent materials that utilise triplet excitons for light emission. Phosphorescent OLEDs generate light from both triplet and singlet excitons in a highly efficient manner, with the internal quantum efficiencies of such devices approaching 100%. Example heavy metal organometallic complexes like iridium complexes doped in a conjugated polymer matrix are used.

CHALLENGES IN OLED TECHNOLOGY:

- Lifetime is only 40,000 hours (when it loses 50% of its initial luminance). This is the the biggest technical problem for OLEDs. In particular, blue OLEDs have a lifetime of around 14,000 hours when used for flat-panel displays.
- High brightness levels in OLED displays require the high voltages which also reduces expected lifetime.
- High sensitivity to to O2 and moisture. Over time, moisture and O2 can react with the organic layers and cause oxidative degradation and defects in an OLED display. The materials are also prone to photodegradation.
- Since multilevel architectures are used, the thermal expansion coefficients will be different for different layers which may also influence the lifetime of the devices.•