SONY®

OLED

What is it and how it works

Introduction

For years OLED has been talked about as the next thing in display technology. At first look, it can be. However there are still many obstacles to overcome. While the theory is simple, there are many factors involved in manufacturing. So much so, that the majority of panels shown to the public have been expensive prototypes. Some panels have made it to market, but these have been rather small and only useful in limited applications. This paper attempts to describe the elementary operation of OLED and the current level of performance.

What is OLED?

OLED is an acronym for Organic Light Emitting Diode. This is an emissive technology that generates light from each pixel. This is not a transmissive light valve technology such as LCD nor does it use any gases to excite a phosphor and there is no gun design similar to CRT. Instead it creates light by the combination or more accurately, the recombination of an electron and a hole within certain organic materials. These materials are sandwiched together to build a mechanism that brings about this reaction. The process is extremely efficient when compared to the current technologies used for display.

Electroluminescence

Electroluminescence is the process that is the basis of OLED. It is an electrical/optical process wherein illumination is produced by electrical current passing through a material. This is not to be mistaken as an incandescent or a bioluminescent process. Electroluminescence is the process of recombining electrons and the absence of electrons (or holes) in a material. When this happens in specific materials, the molecule will move from an excited state to a ground state. To do this, the material must drop the charge. If done correctly, the process will result in a photon emission.

Silicon vs. organic materials

The illumination process is performed on the molecular level. Therefore the chemical and physical properties of the materials are the largest variable in building an OLED. Typically semiconductors are all silicon based. Within silicon based or inorganic materials, electron excitation follows the principles defined by Gregory Wannier. The Wannier function defines the binding energy and field size of electrons in crystalline materials. In a nutshell, it can be assumed that the binding energy within a silicon semiconductor has a strength of -10meV with a binding area of around 100Å. This is a rather large area and encompasses a large lattice of molecules. However with organic materials, theories devised by Yakov Frenkel show that these energies are within one molecule and that it is possible to move electrons within a pair of molecules. Strengths within certain organic compounds can be as low as -1meV with a field radius of about 10Å.

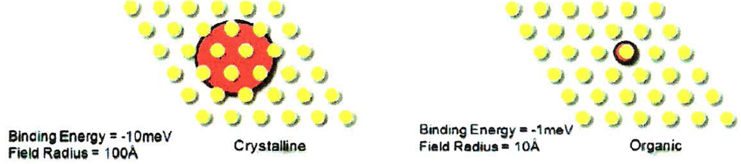

Figure 1. Binding energy within crystalline materials vs. organic materials

Advantages of organic materials

There are other advantages of using organic materials. In order for the device to work, electrons have to be transported through different materials. If these materials can allow free movement, then there can be control of the point within the materials where hole/electron injection can be placed. Organic materials have their electrons residing on P orbitals, meaning they are on the same plane and can move molecule to molecule with little required force. Molecules within organic materials have binding forces. This results in higher electron carrier mobilities allowing easier transfer of the electrons through the material. Organic materials have higher fluorescence efficiencies allowing more illumination with less power. In addition, semiconductors use a monocrystalline deposition method which is not necessary when fabricating organic materials.

Where does the light come from?

Simple Synoptic

Below is a simple diagram showing the operational layers of a generic OLED design. As with many electronic components, an anode and cathode are used to deliver the necessary charges to the device. Typically these are around 2 to 3 volt potentials.

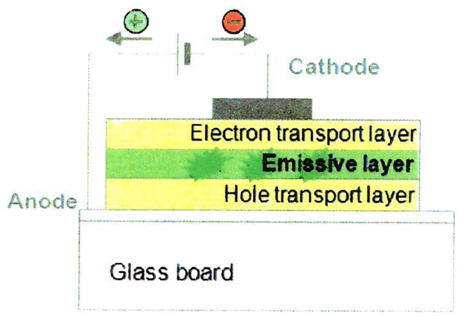

Figure 2. Basic layers of an OLED

Injection

Electrons are brought to the emissive layer through the Electron Transport layer (ETL) and holes are brought to this same emissive layer by the Hole Transport Layer (HTL). The molecular content includes both host and guest molecules from each layer. The characteristics of these materials used in either spread each electric field evenly throughout the layer.

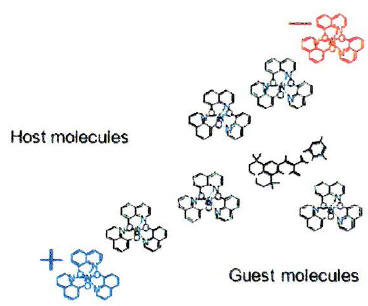

Figure 3. Injection

Electron Pairing

The holes and electrons jump across molecular bands into the emission layer where they pair, one side as a hole (Lower Unoccupied Molecular Orbital or LUMO), the other as an electron (Higher Occupied Molecular Orbital or HOMO).

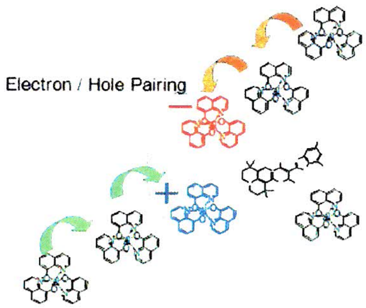

Figure 4. Pairing

Recombination

As the electrons and holes recombine, they transfer this extra energy over to the guest molecule.

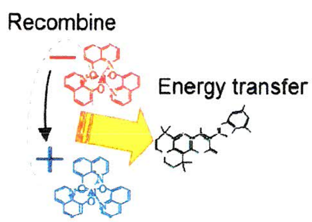

Figure 5. Recombination

Excitation

The elevation in the energy state of the guest molecule causes a highly excited state. This excitation cannot be maintained and the guest molecule must release some energy. It does this by emitting a photon.

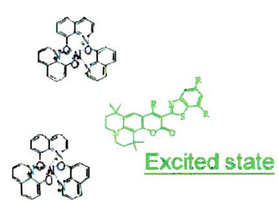

Figure 6. Excitation