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AN INNOVATIVE TECHNIQUE OF LIGHT EMISSION USING ORGANIC COMPOUNDS

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Abstract

OLED is a solid state device composed of thin films of organic molecules that create light with the application of electricity. OLEDs can provide brighter, crisper displays on electronic devices and use less power than conventional light emitting diodes(LEDs) used today. Like an LED, an OLED is a solid state semiconductor device that is 100 to 500 nanometres thick or about 200 times smaller than a human hair. OLEDs can have either two layers or three layers of organic material. OLED display devices use organic carbon-based films, sandwiched together between two charged electrodes. One is a metallic cathode and the other a transparent anode, which is usually glass. OLED displays can use either passive-matrix (PMOLED) or active-matrix (AMOLED) addressing schemes. Active-matrix OLEDs (AMOLED) require a thin-film transistor backplane to switch each individual pixel on or off, but allow for higher resolution and larger display sizes. An OLED display works without a backlight; thus, it can display deep black levels and can be thinner and lighter than a liquid crystal display (LCD). In low ambient light conditions (such as a dark room), an OLED screen can achieve a higher contrast ratio than an LCD, regardless of whether the LCD uses cold cathode fluorescent lamps or an LED backlight.

Index Terms: *AMOLED, LED, OLED, PMOLED*

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1. INTRODUCTION

An organic light-emitting diode (OLED) is a light-emitting diode (LED), in which the emissive electroluminescent layer is a film of organic compound that emits light in response to an electric current. OLED’s are used to create digital displays in devices such as television screens, computer, portable systems such as mobile phones, handheld game consoles and PDAs. A major area of research is the development of white OLED devices for use in solid-state lighting applications.

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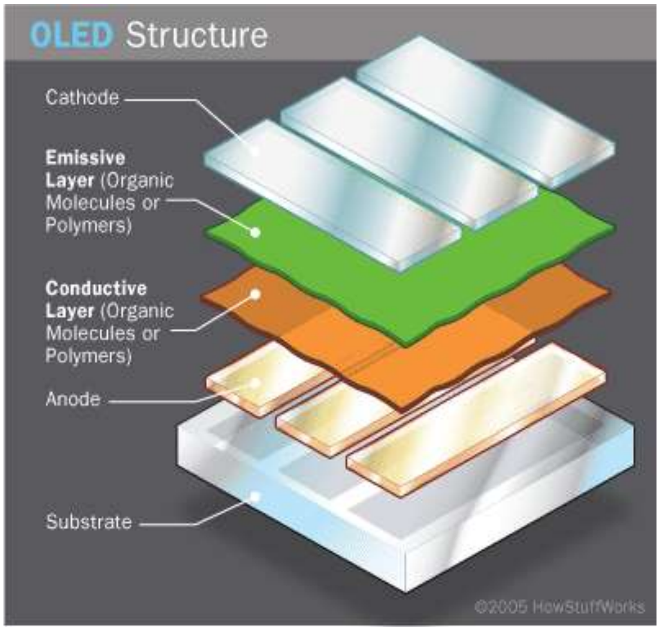

Fig 1 Basic OLED structure

2. CONSTRUCTION

A typical OLED is composed of a layer of organic materials situated between two electrodes, the anode and cathode, all deposited on a substrate. The organic molecules are electrically conductive as a result of delocalization of pi electrons caused by conjugation over part or the entire molecule. These materials have conductivity levels ranging from insulators to conductors, and are therefore considered organic semiconductors. The highest occupied and lowest unoccupied molecular orbital's (HOMO and LUMO) of organic semiconductors are analogous to the valence and conduction bands of inorganic semiconductors.

Originally, the most basic polymer OLEDs consisted of a single organic layer. One example was the first light-emitting device synthesized by J. H. Burroughes et al., which involved a single layer of poly(p-phenylene vinylene). However multilayer OLEDs can be fabricated with two or more layers in order to improve device efficiency.

As well as conductive properties, different materials may be chosen to aid charge injection at electrodes by providing a more gradual electronic profile, or block a charge from reaching the opposite electrode and being wasted. Many modern OLEDs incorporate a simple bilayer structure, consisting of a conductive layer and an emissive layer.

During operation, a voltage is applied across the OLED such that the anode is positive with respect to the cathode. Anodes are picked based upon the quality of their optical transparency, electrical conductivity, and chemical stability. A current of electrons flows through the device from cathode to anode, as electrons are injected into the LUMO of the organic layer at the cathode and withdrawn from the HOMO at the anode. This latter process may also be described as the injection of electron holes into the HOMO. Electrostatic forces bring the electrons and the holes towards each other and they recombine forming an exciton, a bound state of the electron and hole. This happens closer to the emissive layer, because in organic semiconductors holes are generally more mobile than electrons. The decay of this 7 excited state results in a relaxation of the energy levels of the electron, accompanied by emission of radiation whose frequency is in the visible region. The frequency of this radiation depends on the band gap of the material, in this case the difference in energy between the HOMO and LUMO.

When a DC bias is applied to the electrodes, the injected electrons and holes can recombine in the organic layers and emit light of a certain color depending on the properties of the organic material. Since charge carrier transport in organic semiconductors relies on individual hopping processes between more or less isolated molecules or along polymer chains, the conductivity of organic semiconductors is several orders of magnitude lower than that of their inorganic counterparts. Before actually decaying radiatively, an electron-hole pair will form an exciton in an intermediate step, which will eventually emit light when it decays. Depending on its chemical structure, a dye molecule can be either a fluorescent or a phosphorescent emitter. Only in the latter, all excitons – singlets and triplets – are allowed to decay radiatively. In the former, however, three quarters of all excitons – the triplet excitons – do not emit any light. Fluorescent emitters therefore have a maximum intrinsic efficiency of only 25 % and their application is avoided if possible. However, up to now, the lifetimes of phosphorescent emitters, especially at a short wavelength (blue), are inferior to those of fluorescent ones

As electrons and holes are fermions with half integer spin, an exciton may either be in a singlet state or a triplet state depending on how the spins of the electron and hole have been combined. Statistically three triplet excitons will be formed for each singlet exciton. Decay from triplet states (phosphorescence) is spin forbidden, increasing the timescale of the transition and limiting the internal efficiency of fluorescent devices. Phosphorescent organic light-emitting diodes make use of spin–orbit interactions to facilitate intersystem crossing between singlet and triplet states, thus obtaining emission from both singlet and triplet states and improving the internal efficiency.

Indium tin oxide (ITO) is commonly used as the anode material. It is transparent to visible light and has a high work function which promotes injection of holes into the HOMO level of the organic layer. A typical conductive layer may consist of PEDOT:PSS as the HOMO level of this material generally lies between the work function of ITO and the HOMO of other commonly used polymers, reducing the energy barriers for hole injection. Metals such as barium and calcium are often used for the cathode as they have low work functions which promote injection of electrons into the LUMO of the organic layer. Such metals are reactive, so they require a capping layer of aluminum to avoid degradation.

Experimental research has proven that the properties of the anode, specifically the anode/hole transport layer (HTL) interface topography plays a major role in the efficiency, performance, and lifetime of organic light emitting diodes. Imperfections in the surface of the anode decrease anode-organic film interface adhesion, increase electrical resistance, and allow for more frequent formation of non-emissive dark spots in the

OLED material adversely affecting lifetime. Mechanisms to decrease anode roughness for ITO/glass substrates include the use of thin films and self-assembled monolayers. Also, alternative substrates and anode materials are being considered to increase OLED performance and lifetime. Possible examples include single crystal sapphire substrates treated with gold (Au) film anodes yielding lower work functions, operating voltages, electrical resistance values, and increasing lifetime of OLEDs.

Single carrier devices are typically used to study the kinetics and charge transport mechanisms of an organic material and can be useful when trying to study energy transfer processes. As current through the device is composed of only one type of charge carrier, either electrons or holes, recombination does not occur and no light is emitted. For example, electron only devices can be obtained by replacing ITO with a lower work function metal which increases the energy barrier of hole injection. Similarly, hole only devices can be made by using a cathode made solely of aluminum, resulting in an energy barrier too large for efficient electron injection.

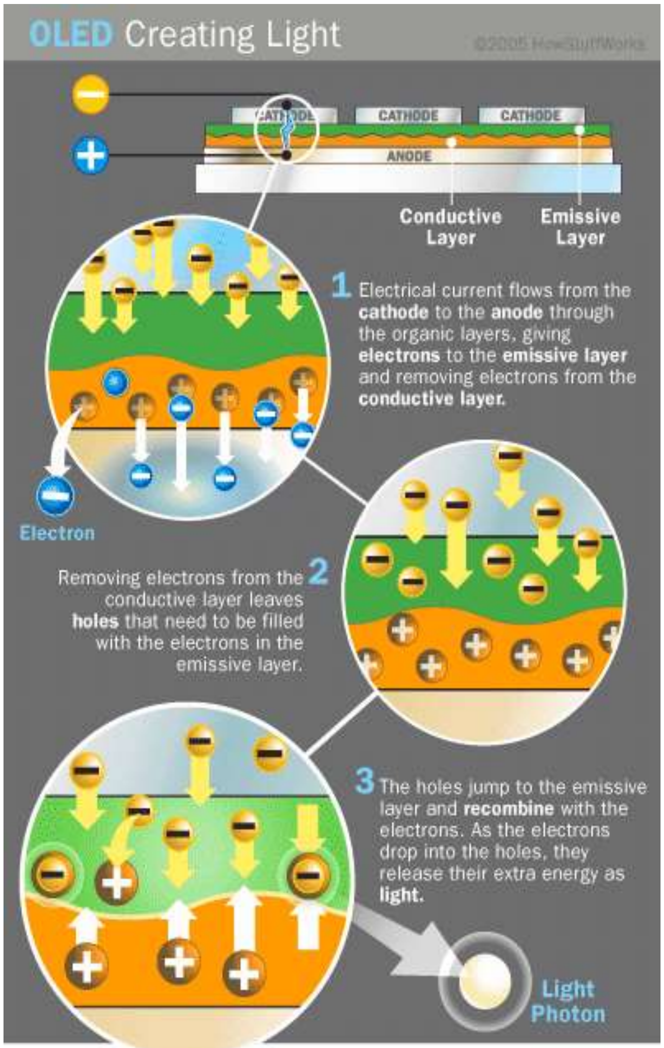

Fig 2 Basic OLED working

3. WORKING

OLEDs emit light in a similar manner to LEDs, through a process called electrophosphorescence. An electrical current flows from the cathode to the anode through the organic layers. When a voltage is applied to OLED, the holes and the electrons are generated from each of the two electrodes, which have a positive and negative electric charge respectively. When they recombine in the emissive layer, organic materials make the emissive layer to turn into a high energy state termed “excitation”. The light is emitted when the layer returns to its original stability. The molecular structure of organic materials has limitless combinations, each of which varies in its colour and durability. Within these limitless combinations, identifying organic materials that provide high efficiency and long life will determine its practical application. A semi-conducting material such as silicon has an energy gap between its lower, filled electrons state called as valence band and its upper, unfilled electrons state called as conduction band. As electrons drop to the lower state and occupy holes, photons of visible light are emitted. The colour of the light depends on the type of organic molecule in the emissive layer and the intensity or brightness of the light depends on the amount of electrical current applied.

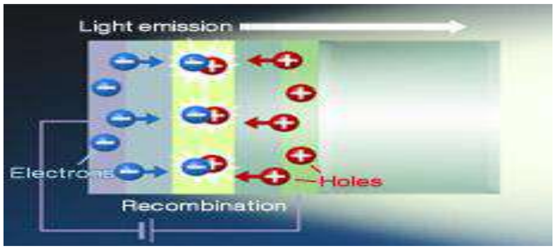

Fig 3: Oled working

The device does not work when the anode is put at a negative potential with respect to the cathode. In this condition, holes move to the anode and electrons to the cathode, so they are moving away from each other and do not recombine. Indium tin oxide is commonly used as the anode material. It is transparent to visible light and has a high work function which promotes injection of holes into the polymer layer.

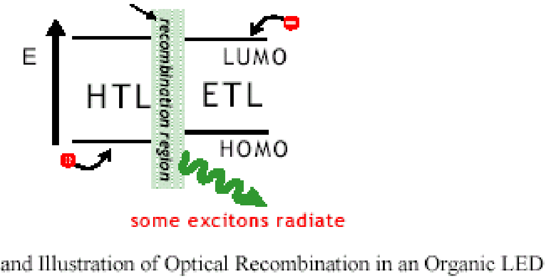

Fig 4: Energy Band diagram

Metals such as aluminum and calcium are often used for the cathode as they have low work functions which promote injection of electrons into the polymer layer.

OLED has more control over colour expression because it only expresses pure colours when electric current stimulates the relevant pixels. The primary colour matrix is arranged in red, green and blue pixels which are mounted directly to a printed circuited board. Each individual OLED element is housed in a special micro cavity structure designed to greatly reduce ambient light interference that also improves overall colour contrast. The thickness of the organic layer is adjusted to produce the strongest light to give a colour picture. Further, the colours are refined with a filter and purified without using a polarizer to give outstanding colour purity.

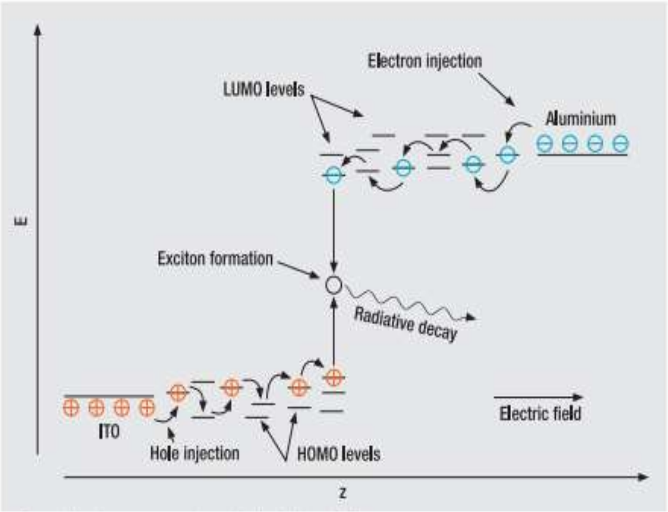

Fig 5: Energy Level diagram

4. TYPES OF OLED

4.1 PASSIVE-MATRIX OLED :

PMOLEDs have strips of cathode, organic layers and strips of anode. The anode strips are arranged perpendicular to the cathode strips. The intersections of the cathode and anode make up the pixels where light is emitted. External circuitry applies current to selected strips of anode and cathode, determining which pixels get turned on and which pixels get turned off. The brightness of each pixel is proportional to the amount of applied current. PMOLEDs are easy to make, but they consume more power than other types of OLED, mainly due to the power needed for the external circuitry. They are most efficient and are used in cell phones, PDAs and MP3 players.

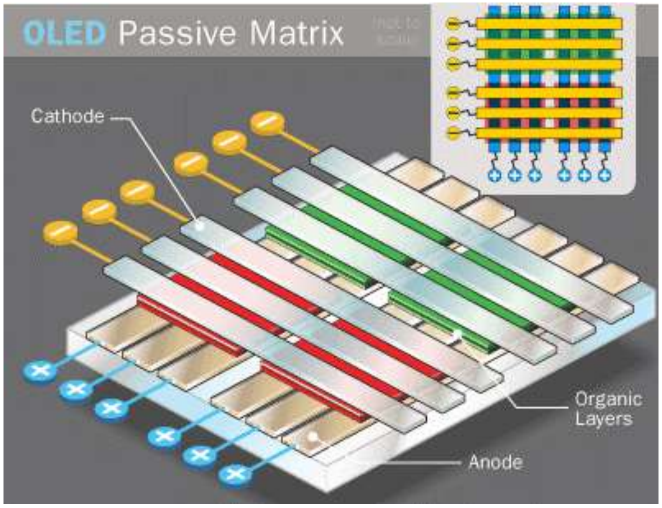

Fig 6: PMOLED structure

4.2 ACTIVE-MATRIX OLED (AMOLED):

AMOLEDs have full layers of cathode, organic molecules and anode, but the anode layer overlays a thin film transistor (TFT) array that forms a matrix. The TFT array itself is the circuitry that determines which pixels get turned on to form an image. AMOLEDs consume less power than PMOLEDs because the TFT array requires less power than external circuitry, so they are efficient for large displays. They are used in computer monitors, large-screen TVs and electronic signs or billboards. The life expectancy of it is 3 0,000 hours.

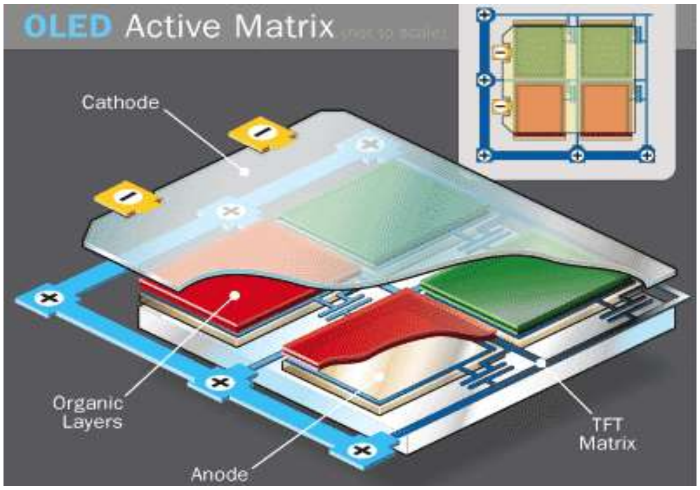

Figure 7: AMOLED structure

4.3 TRANSPARENT OLED:

Transparent OLEDs have only transparent components that are substrate, cathode and anode. When turned off, they are 85% as transparent as their substrate. When a transparent OLED display is turned on, it allows light to pass in both directions.

This can be either active or passive matrix. This technology can be used for heads-up displays.

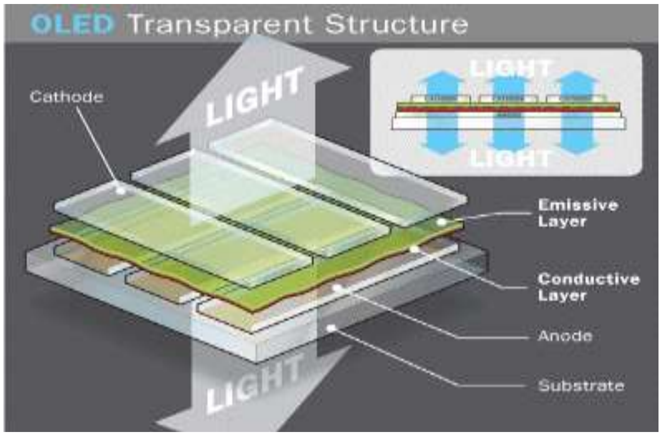

Fig 8: Transparent OLED structure

4.4 TOP-EMITTING OLED:

Top-emitting OLEDs have a substrate that is either opaque or reflective. The top-emitting OLED display includes providing a handling substrate. A composite layer is formed on the handling substrate. An organic light emitting unit is formed on the composite layer. A top electrode is formed on the organic light emitting unit. A reflective type display and fabrication method thereof is provided. The reflective type display includes providing a handling substrate. A composite layer is formed on the handling substrate; a thin film transistor array is formed on the composite layer. They are best suited to active-matrix design. These displays are used in smart cards. The efficiency is 500 cd/m2 and the life span is 17,000 hours.

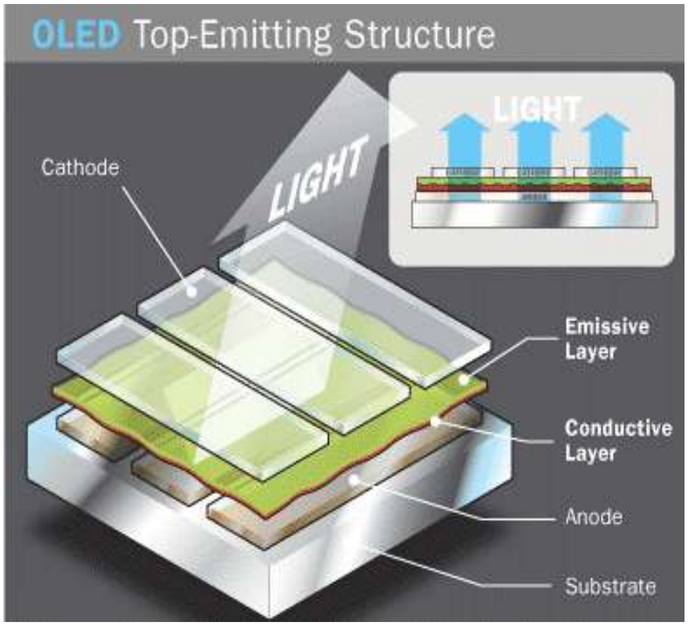

Fig. 8: Top-Emitting OLED structure

4.5 OLDABLE OLED:

Foldable OLEDs have substrates made of very flexible metallic foils or plastics. They are very light-weight and durable. Their use in devices such as cell phones and PDAs can reduce breakage, a major cause for return or repair. Potentially, these displays can be attached to fabrics to create smart clothing, such as outdoor survival clothing with an integrated computer chip, cell phone, GPS receiver and OLED display sewn into it. They are less breakable and more impact resistant – than other displays. With glass breakage a major cause of display-containing product returns, this is a highly desirable commercial alternative. They are very flexible i.e., they may be manufactured on a variety of substrates. Such displays may be made to bend, flex and conform to many surfaces. The luminance is 200 cd/m2.

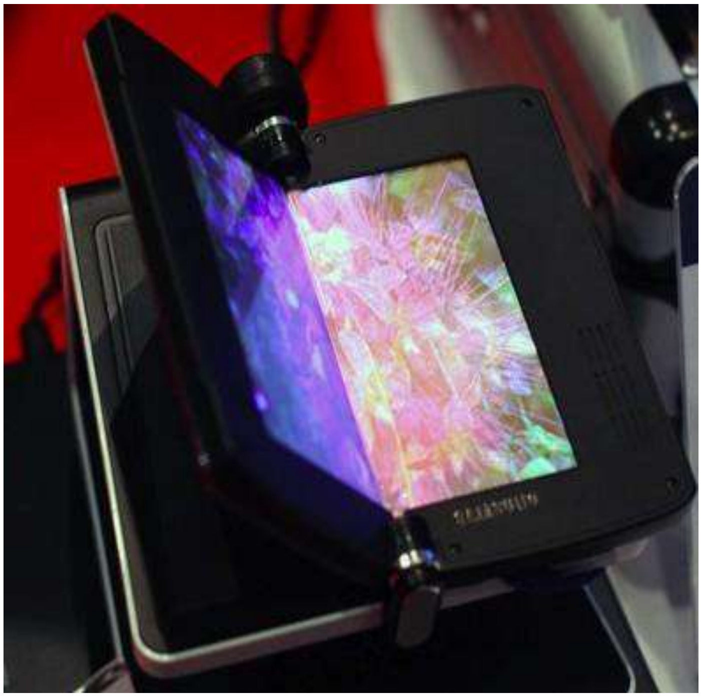

Fig 9: Foldable OLED

4.6 WHITE OLED:

White OLEDs emit white light that is brighter, more uniform and more energy efficient than that emitted by fluorescent lights. They also have the true-colour qualities of incandescent lighting. They can replace fluorescent lights that are currently used in homes and buildings because they can be made in large sheets. Their use could potentially reduce energy costs for lighting. Its efficiency is 90 lm/W at a brightness of 1000 cd/m2 .

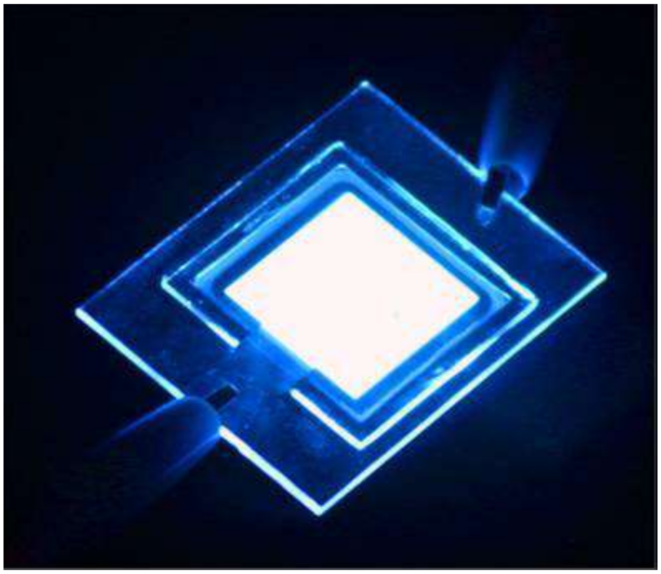

Fig 10: White OLED diagram

5. CONCLUSION:

OLED is emerging as the new technology for thin panel displays. It can be used for mp3players, cell phones, digital cameras or hand-held gaming devices. The field of applications forOLED displays has a wide scale.

According to a report of Maxim Group revenues will rise from 600 million dollars in 2005 to more than five billion dollars by 2009. Other reports have shown that the total number ofsold OLED units grew up to over fifty percent in the past year. It is expected that this numberwill rise up to 80 or 90 percent in the following year.

One of the future visions is to roll out OLEDs or to stick them up like post-it notes.Another vision is the transparent windows which would function like a regular window by day.At night it could be switched on and become a light source. This could be possible because OLED allows transparent displays and light sources.

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