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Advancement in the Technology of Organic Light Emitting Diodes

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Abstract: *Organic light-emitting diodes (OLEDs) have been seen as one of the most promising technologies for future displays. A number of materials have been developed and improved in order to fulfil the requirements of this application. The materials differ from one another by their structure but also by the mechanism involved in the electroluminescence produced (fluorescence versus phosphorescence). When properly stacked, these materials result in a device that can achieve the required high efficiency and long lifetime. Opto-electronic devices using organic materials are becoming widely desirable for manifold reasons. In fact, organic devices have the potential for cost advantages over inorganic devices. In addition, inherent properties of organic materials, such as their flexibility make them well suited for particular applications such as fabrication on a flexible substrate In this paper, we will study the newer technological advancements that has improved the manufacturing process and application of organic LED's*

Keyword: *Active OLEDs, Passive OLEDs, Organic Polymer, Emitting Layer, Conductive Layer,*

I. Introduction

During the last two decades, organic light-emitting diodes (OLEDs) have attracted considerable interest owing to their promising applications in flat-panel displays by replacing cathode ray tubes (CRTs) or liquid crystal displays (LCDs). Electroluminescent is the emission of light from materials in an electric field, and in the 1960s this phenomenon was observed from single crystals of anthracene. Despite the high quantum efficiency obtained with such organic crystals, no application has emerged owing to the high working voltage required as a result of the large crystal thickness and poor electrical contact quality. Nevertheless, these studies have led to a good understanding of the basic physical processes involved in organic electroluminescent, i.e. charge jection, charge transportation, exciting formation and light emission. There are two main classes of OLED devices: those made with small organic molecules and those made with organic polymers. OLEDs have the unique properties of lightweight, flexible, transparent and color tune ability, which makes them an ideal modern light source. Interest in OLEDs is explained by the manifold benefits presented by this technology: operation in emissive mode (not require back lighting), a wide viewing angle, a low operating voltage (less than 5V), light emission throughout the visible (by modifying the chemical structure of material), flexible displays and reduced production costs. OLED displays are based on component devices containing organic electroluminescent material (made by small molecules or polymers) that emits light when stimulated by electricity.

II. Market Trends In Oled Technology

Recent trends in the market showcases a drastic development of screen technology which is directed towards improving the factors of energy conservation, eco-friendliness, and flexible materials. Flexible displays are prime targets in the markets due to its enormous possibilities to provide products that are light, thin, and foldable. E-paperbased displays have the potential to meet the need for displays that are focused on the target to conserve energy and can operate for long periods without recharging. Whereas, R2R technology, mostly coined as a core technology in the future market for environmentally friendly, reasonably priced printed electronics.

Fig.1-AMOLED Products [3]

Active matrix organic light-emitting diode displays (AMOLEDs) using glass substrates, is presently getting widespread focus in gadget industry. These products are already being seen in applications in smart handheld devices such as smart phones and tablets, and AMOLED production technology using plastic substrates is under development among display manufacturers. Different types of OLEDs available in market are as given below [5]:

a) Passive-matrix OLED: - PMOLEDs have organic layers and strips of anode arranged perpendicular to the cathode strips. The intersections of the cathode and anode make up the pixels where light is emitted. The Brightness of each pixels proportional to the amount of applied current. External circuitry applies current to selected strips of anode and cathode, determining which pixels get turned on and which pixels remain off. PMOLEDs are easy and cheap to fabricate, but they consume more power than other types of OLED

b) Active-matrix OLED:- AMOLEDs have full layers of cathode, organic molecules and anode. The anode layers have a thin film transistor (TFT) plane in parallel to it so as to form a matrix. This helps in switching each pixel to it's on or off state as desired, thus forming an image. Hence, the pixels switch off whenever they are not required or there is a black image on the display, this helps in increasing the battery life of the device.

c) Transparent OLED: - Transparent OLEDs (TOLEDs) have only transparent components: substrate, cathode and anode. When a TOLED display is turned on, it allows light to pass in both directions. This type of OLED can be included in both the active and passive matrix categories. As they have transparent parameters on both the sides, they can create displays that are top as well as bottom emitting.

d) White OLED: - White OLEDs have the truecolour qualities of incandescent lighting and emit white light that is brighter, more uniform and more energy efficient than that emitted by fluorescent lights and incandescent bulbs. Because white OLEDs can be manufactured in large sheets, are cost-effective and also consumes less power they can replace fluorescent lamps and could potentially reduce energy costs for lighting. White OLED is perfectly suited for car lighting because it can display very deep black as well as light so that the displays can be crisp and easy to use while also showing a higher contrast than LCD and LED backlights.

e) Foldable OLED:- Foldable OLEDs (FOLEDs) have substrates made of very flexible metallic foils or plastics. FOLEDs are flexible, very lightweight and durable. This type is mainly used in devices which have more chance of breaking. As this material is strong it reduces breakage and therefore is used in GPS devices, cell phones and large curved screen TVs. FOLEDs are offering crisper picture resolution, a faster response time and high contrast images for curved televisions, which manufacturers say offer a more immersive TV experience. Potentially, foldable OLED displays can be attached to fabrics to create "smart" clothing, such as outdoor survival clothing with an integrated computer chip, cell phone.

III. Structure Of Oled

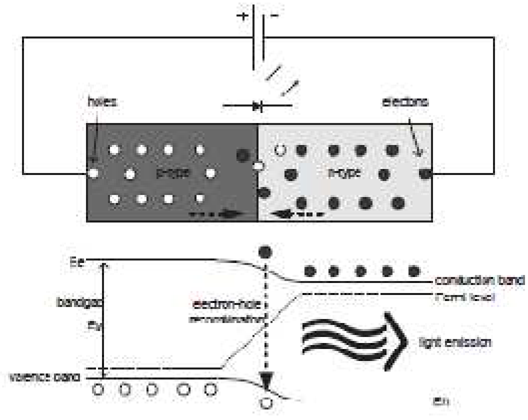

Fig.2-Structure of OLED [3]

The basic components of an OLED are [5]: _ Substrate-This is support for the OLED. _ Anode-The anode removes electrons when a current flows through the device. _ Organic layers-These layers are made of organic molecules or polymers. _ Conducting layer. This layer is made of organic plastic molecules that send electrons out from the anode._ Emissive layer. This layer is made of organic plastic molecules (different ones from the conducting layer) that transport electrons from the cathode; this is where light is made._ Cathode-The cathode injects electrons when a current flows through the device

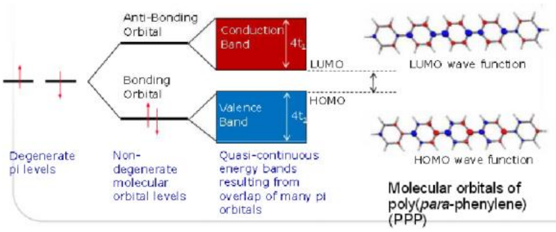

Fig 3 Bondings in OLED structure

In the three layers based OLED; the conductive layer is replaced by two more effective layers: electron transport layer (ETL) and hole-transport layer (HTL). When the anode is at a more positive electrical potential with respect to the cathode, injection of holes occurs from the anode into the HOMO (Highest occupied molecular orbital) of HTL, while electrons are injected from the cathode into the LUMO (Lowest unoccupied molecular orbital) of ETL. Under the influence of an applied electric field, the injected holes and electrons each migrate toward the oppositely charged electrode following a hopping transport regime which consists in a series of "jumps" of the charge from molecule to molecule. In the organic emissive layer (EML), when an electron and hole localize on the same molecule and are spatially close, a fraction of them recombine to form an *exciton* (a bound state of the electron and hole); which is a localized electron-hole pair having an excited energy state. Then some of these exactions relaxes via a photo emissive mechanism and decay radioactively to the ground state by spontaneous emission. In some cases, the *exciton* may be localized on an exciter (excited dimer) or an*exciplex* (excited complex). Non-radioactive mechanisms, such as thermal relaxation, may also occur, but are generally considered undesirable. Upon recombination, energy is released as light and at least one electrode must be semi-transparent to enable a light emission perpendicular to the substrate. The result is a very bright and crispy display with power consumption lesser than the usual LCD and LED. In fig.3 various molecular levels are represented. The top most layer is known as emissive layer the light which is been emitted gets illuminated by this layer thus it is called as emissive layer. The second layer consists of the conduction material present in the OLED, it is the organic polymer layer of OLED. The third layer from the top of the side is the anode of the OLED. The anode terminal of the LED is located in this layer. The final layer of OLED consists of cathode terminal

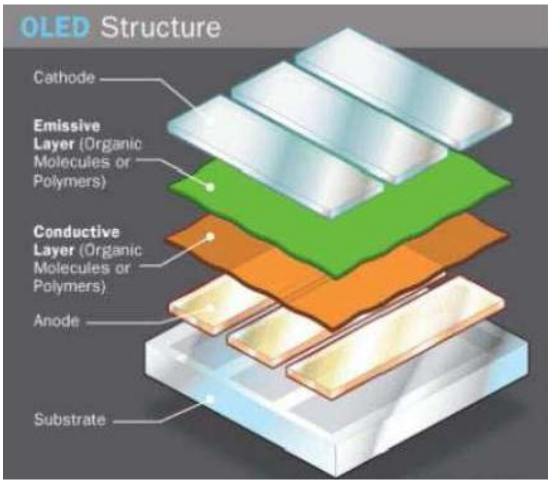

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Fig.4- Layers of OLED [5]

OLED materials have allowed for devices with hundreds of thousands of hours of operating lifetime. The omponents in an OLED differ according to the number of layers of the organic material. There is a basic single layer OLED, two layers and also three layers OLED's. As the number of layers increase the efficiency of thedevice also increases. The increase in layers also helps in injecting charges at the electrodes and thus helps in blocking a charge from being dumped after reaching the opposite electrode.

IV. Working Of Oled

OLED (organic light emitting diode) is a monolithic, thin-film, semi conductive device that emits light when a voltage is applied to it. Various ways of light are generated by applying an electricintermediate energy forms - the phenomenon known as organic OLEDs, and operation OLEDs**.**Organic Light Emitting Diodes operation and application in displays electroluminescence (EL). EL is the result of the electric field imposedformation of emissive states without recourse of any intermediate energy forms, such as heat. In its most basic form, an OLED consists of a series of vacuum-deposited, small-molecule organic thin films that are sandwiched between two thin-film conductors. The following figures show most often met constructions of this device. The output of the EL light can go through the anode, cathode or through the both electrodes as well. The ETL has the function of assisting the injection of electrons from a metal cathode and their transport throughout the bulk. Recombination of holes and electrons occurs at the boundary regions between two organic layers.

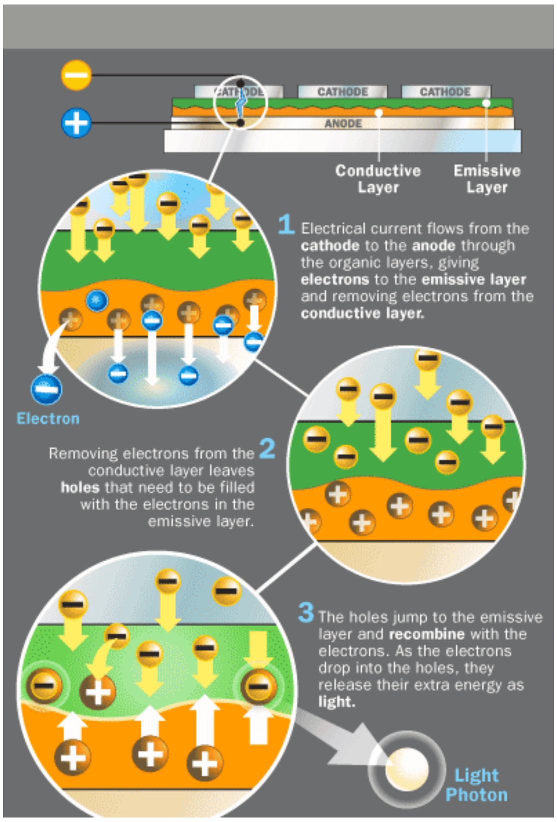

Fig.6- Working Layout of OLED [5]

When the recombination region is located within an ETL, the ETL behaves as an emissive layer EML). When the recombination occurs within the HTL, on the other hand, the HTL can behave as an EML. Thus these sevices are classifed into two types: ITO/HTL/ETL (EML)/ Metal and ITO/HTL (EML)/ETL/Metal. In three-layer structure shown in Fig. 2, an independent thin EML is sandwiched between HTL and ETL ITO/HTL/EML /ETL /Metal), in case bipolar materials (which have ability to transport both electrons and holes) are available. Figure depicts this typical device structure. In its most basic form, an OLED is amonolithic, solid-state electronic device consisting of a series of vacuum-deposited organic thin films sandwiched between two transparent thin film conductors. When voltage is applied across the device, these organic thin films emit light. This light emission is based upon a luminescence phenomenon wherein electrons nd holes are injected and migrate from the contacts toward the organic heterojunction.

V. Oled Manufacturing Technology

Applying the organic layers to the substrate can be accomplished in three ways [5]: a) Vacuum Deposition or Vacuum Thermal Evaporation (VTE) - In a vacuum chamber, the organic molecules are evaporated through a slow heat process and then allowed to condense as thin films onto a cooled substrate. This is a veryinefficient and expensive process. b) Organic Vapor Phase Deposition (OVPD) – This process employs an inert carrier gas (such as nitrogen) to precisely transfer films of organic material onto a cooled substrate in a hot-walled, low-pressure chamber. The precise transfer and ability to better control film thickness translates tolower material cost and higher production throughput. c) Inkjet Printing- OLEDs are sprayed onto the substrate the same way our desktop inkjet printer sprays ink onto paper. This greatly reduces the cost of manufacturing OLEDs and allows for printing on very large films. This allows for a much lower cost and larger home displays and PIPD products. To fulfill the requirements of advanced displays, such as thinness and a light and robust design, researchers have long aspired to develop a flexible AMOLED, because a flexible AMOLED can be bent, folded, or rolled, it is foreseeable that smart phones and tablet PCs can be converged in futuredesigns. To render the active matrix displays flexible, the Flexible Universal Plane (FlexUP) [7] technology inserts a thin layer of release material between a polyimide (PI) layer and a glass carrier to be processed in the existing TFT processing line. The TFT array used for the flexible display is composed on a high-temperature stable PI film that is subsequently removed from the glass carrier without damaging the transistors on the PI film. AMLCDs have two major issues: 1) the cell gap is difficult to control when the panel is bent, which could result in poorer image quality; and 2) a flexible backlight is required for AMLCDs, making the structure far more complex. [7]

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