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A REVIEW ON OLED AND EMISSION CHARACTERISTICS OF OLED

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ABSTRACT

Organic light emitting diode is a solid device containing thin films of organic molecules that create light with the application of electricity. Organic LED's can provide brighter ,crisper displays on electronic devices and it uses less power than conventional light emitting diodes use today. An organic LED is a solid state semiconductor device and it is 100 to 500 nanometers thick or 200 times smaller than a human hair. In this paper, we review the emission characteristics from organic light-emitting diodes (OLEDs) and organic molecular thin films with planar and corrugated structures. In a planar thin film structure, light emission from OLEDs was strongly influenced by the interference effect. With suitable design of microcavity structure and layer thicknesses adjustment, optical characteristics can be engineered to achieve high optical intensity, suitable emission wavelength, and broad viewing angles. To increase the extraction efficiency from OLEDs and organic thin-films, corrugated structure with micro- and nanoscale were applied.

1. INTRODUCTION

An organic light emitting diode is simply a light emitting diode which has electro luminescent layer is composed of a film of organic compounds. This layer of organic semiconductor is situated between two electrodes; typically, at least one of these electrodes is transparent.Oled are used to create digital displays in devices such as TV screens, computer monitors, portable system such as mobile phones and PDAs. The layers are made up of small organic molecules or macro polymers that conduct electricity. They have conductivity levels ranging from insulators to conductors, so OLEDs are considered as organic semiconductors. The layer of organic semiconductor material is formed between two electrodes, where at least one of the layers is transparent. Material with self- luminous property that eliminates the need o f a back light. These result in a thin and compact display. The organic light-emitting diode (OLED) is one of the most promising technologies for display and lighting applications . Compared with existing liquid crystal display (LCD) technology, OLED exhibits the advantages of self-emission, wide viewing angle, fast response time, simple structure, and low driving voltage. OLED is a self-emissive display, and no extra backlight unit is needed, which makes the process flow easier, compared to LCD technology. OLED fabrication is typically a low temperature process, which is suitable for flexible optoelectronics applications. There are two main families of OLED those based on small moleculars and those employing polymers.

OLED displays may be operated in two basic architectures: passive matrix (PM) and active matrix (AM) displays. The AM architecture is expected to be the main technology on which advanced OLED displays will be based. An OLED displays works without a backlight; thus, it can displays deep black levels and can be thinner and lighter than a liquid crystal display (LCD). Conventionally, an OLED is fabricated on a glass substrate. Organic thin-films are sandwiched by a transparent indium tin oxide (ITO) anode and a reflective metal cathode, which is also called bottomemission OLED By applying a voltage (typically <10 V) to such a device, carriers are injected into the device and recombine to give light. Photons generated from the organic layers propagate through the glass substrate and radiate out to the air for light emission. Emission wavelength of OLED is determined by the organic material, as well as the device configuration. Because the conductivity of organic material is quite low, layer thickness of total organic thin films was limited to 100 to 200 nm for driving an OLED with reasonably low voltage.

2. HISTORY

The first observations of electroluminescence in organic materials were in the early 1950 by André Bernanos and coworkers at the Nancy-University in France. They applied high alternating voltages in air to materials such as acridine orange. In 1960, Martin Pope and some of his co-workers at New York University developed ohmic dark-injecting electrode contacts to organic crystals .They further described the necessary energetic requirements for hole and electron injecting electrode contacts. These contacts are the basis of charge injection in all modern OLED devices. Pope's group also first observed direct current (DC) electroluminescence under vacuum on a single pure crystal of anthracene and on anthracene crystals doped with tetracene in 1963 using a small area silver electrode at 400 volts. The proposed mechanism was field-accelerated electron excitation of molecular fluorescence. Pope's group reported in 1965 that in the absence of an external electric field, the electroluminescence in anthracene crystals is caused by the recombination of a thermalized electron and hole, and that the conducting level of anthracene is higher in energy than the exciton energy level. Also in 1965, W. Helfrich and W. G. Schneider of the National Research Council in Canada produced double injection recombination electroluminescence for the first time in an anthracene single crystal using hole and electron injecting electrodes, the forerunner of modern double injection driven (100–3000 Hz) electrically insulated one millimetre thin layers of a melted phosphor consisting of ground anthracene powder, tetracene, and graphitepowder .Their proposed mechanism involved electronic excitation at the contacts between the graphite particles and the anthracene molecules. Electroluminescence from polymer films was first observed by Roger Partridge at the National Physical Laboratory in the United Kingdom. The device consisted of a film of poly(n-vinyl carbazole) up to 2.2 micrometres thick located between two charge injecting electrodes. The results of the project were patented in 1975 and published in 1983.The first diode device was reported at Eastman Kodak by Ching W. Tang and Steven Van Slyke in 1987. This device used a novel two-layer structure with separate hole transporting and electron transporting layers such that recombination and light emission occurred in the middle of the organic layer; this resulted in a reduction in operating voltage and improvements in efficiency that led to the current era of OLED research and device production. Research into polymer electroluminescence culminated in 1990 with J. H. Burroughes et al. at the Cavendish Laboratory in Cambridge reporting a high efficiency green light-emitting polymer based device using 100 nm thick films of poly(pphenylene vinylene).Universal Display Corporation holds the majority of patents concerning the commercialization of OLEDs.

3. MATERIAL

Materials are a critical factor for both efficiency and lifetime, the utilization of new materials has allowed revolutionary improvements in OLED efficiency. From the first generation fluorescent materials to the novel transport and emission layer host materials the efficiency of OLEDs have grown more than tenfold and can now challenge and defeat LEDs in terms of efficiency at wavelengths close to 550 nm . Moreover, continued development of OLED materials have allowed for devices with hundreds of thousands of hours of operating lifetime. The components 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 the device 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. Any type of OLED consists of the following components.

***3.1. Substrate**:*The substrate is used to support the OLED. The substrate most commonly used may be a plastic, foil or even glass. OLED devices are classified as bottom emission devices if light emitted passes through the transparent substrate on which the panel was manufactured.

3.2. Anode: The anode component usually used is indium tin oxide ITO. This material is transparent to visible light and is sufficiently conductor and has a high work function which promotes injection of holes into the HOMO level of the organic layer. A typical conductive layer behaving as a transparent electrode that replace the traditionally used ITOconsist of PEDOT:PSS polymer or poly(3,4-ethylenedioxythiophene) poly(styrenesulfonate) 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. Another anode based on grapheme yields to performance comparable to ITO transparent anodes.

3.3. Cathode:The cathode component depends on the type of OLED required. Noteworthy, even a transparent cathode can be used. Usually metals like barium, calcium and aluminum are used as a cathode because they have lesser work functions than anodes which help in injecting electrons into the LUMO level of the different layers.

3.4. Electrons transport layer:The commonly used components are: PBD, Alq3, TPBI and BCP

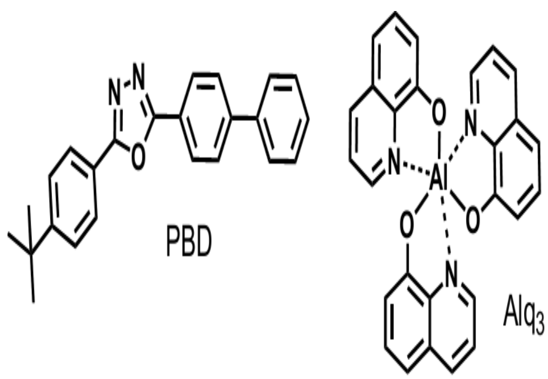

Figure 1 : *Commonly used components in electrons transport layer.*

3.5. Emissive layer: The emissive layer component is made up of organic plastic molecules, out of which the most commonly used is polyfluorene. Such emitters are fluorescent dye and phosphorescent dye. In organic semiconductors holes are generally more mobile than electrons. The decay of the 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 the LUMO. The color of the light produced can be varied according to the type of organic molecule used for its process. To obtain color displays, a number of organic layers are used. Another factor of the light produced is its intensity. If more current is applied to the OLED, the brighter the light appears.

4. WORKING PRINCIPLE

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 all of the molecule. These materials have conductivity levels ranging from insulators to conductors, and are therefore considered organic semiconductors. The highest occupied and lowest unoccupied molecular orbitals (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 (pphenylene vinylene).

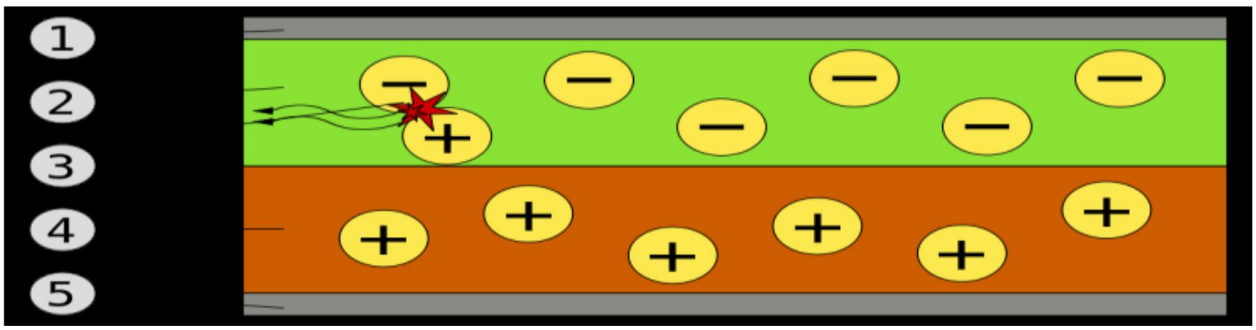

Figure2: Schematic of a bilayer OLED: 1. Cathode (−), 2. Emissive Layer, 3. Emission of radiation, 4. Conductive Layer, 5. Anode (+)

However multilayer OLEDs can be fabricated with two or more layers in order to improve device efficiency. As well as conductive properties, different materials devices. In the same year, Dow Chemical researchers patented a method of preparing electroluminescent cells using high voltage (500–1500 V) AC- 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. More recent developments in OLED architecture improves quantum efficiency (up to 19%) by using a graded heterojunction. In the graded heterojunction architecture, the composition of hole and electron-transport materials varies continuously within the emissive layer with a dopant emitter. The graded heterojunction architecture combines the benefits of both conventional architectures by improving charge injection while simultaneously balancing charge transport within the emissive region. 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 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. 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 theefficiency, 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 none missive 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 monolayer. 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.

5. ADVANTAGES

OLED have many advantages over flat panel displays or LED.

5.1 Lower cost in the future:OLEDs can be printed onto any suitable substrate by an inkjet printer or even by screen printing, it will make OLED cheaper than LCD or plasma displays. However, fabrication of the OLED substrate is more costly than that of a TFT LCD, until mass production methods lower cost through scalability. Roll-to-roll vapourdeposition methods for organic devices do allow mass production of thousands of devices per minute for minimal cost, although this technique also induces problems in that devices with multiple layers can be challenging to make because of registration, lining up the different printed layers to the required degree of accuracy.

5.2 Lightweight and flexible plastic substrates:We can fabricate OLED on flexible plastic substrates which will reveal new application, such as roll-up displays embedded in fabrics or clothing. As the substrate used can be flexible such as polyethylene terephthalate (PET), the displays may be produced inexpensively.

5.3 Wider viewing angles and improved brightness:OLEDs can enable a greater artificial contrast ratio (both dynamic range and static, measured in purely dark conditions) and a wider viewing angle compared to LCDs because OLED pixels emit light directly. OLED pixel colors appear correct and unshifted, even as the viewing angle approaches 90° from normal.

5.4 Response time:OLEDs also have a much faster response time than an LCD. Using response time compensation technologies, the fastest modern LCDs can reach as low as 1ms response times for their fastest color transition and are capable of refresh frequencies as high as 144 Hz (frame interpolation on modern "240Hz" and "480Hz" LCD TVs is not a true increase in refresh frequency). OLED response times are up to 1,000 times faster than LCD according to LG, putting conservative estimates at under 10µs (0.01ms), which in theory could accommodate refresh frequencies approaching 100 kHz (100,000 Hz). Due to their extremely fast response time, OLED displays can also be easily designed to interpolate black frames, creating an effect similar to CRT flicker in order to avoid the sample-and-hold behaviour used on both LCDs and some OLED displays that creates the perception of motion blur.

6. OLEDS APPLICATION

OLEDs are used to create digital displays in devices such as television screens, computer monitors, portable systems such as mobile phones, digital media players, car radios, digital cameras, car lighting, handheld games consoles and PDAs. Such portable applications favor the high light output of OLEDs for readability in sunlight and their low power drain. Intense research has yielded OLEDs with remarkable color fidelity, device efficiencies and operational stability. According to the type of manufacture and the nature of their use, OLED’s are mainly classified into several types:

6.1. Passive-matrix OLED (PMOLED): 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 pixel is 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 (mainly due to the power needed for the external circuitry) but still less power consuming than an LCD and LED. PMOLED displays are also restricted in resolution and size (the more lines you have, the more voltage you have to use). PMOLED displays are usually small (up to 3" typically) and are used to display character data or small icons: they are being used in MP3 players, mobile phone sub displays, etc.

6.2. Active-matrix OLED (AMOLED): *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. This is the least power consuming type among others and also has quicker refresh rates which makes them suitable for video as well. The best uses for AMOLEDs are computer monitors, large-screen TVs (Figure 8a) and electronic signs or billboards.

6.3. 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 inboth 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. This device has a good contrast even in bright sunlight so it is applicable in head-up displays, laptops , mobile phones and smart windows.

CONCLUSION

In summary, we have reviewed the optical design of planar and non-planar OLEDs. An OLED consists of a stacked thin film, with effective optical length comparable to the visible wavelength. Today, OLED technology is widely seen as a next generation component for flat panel displays and is expected to become a key technology in the development of flexible displays. OLEDs offer many advantages over both LEDs and LCDs. They are thinner, lighter and more flexible than the crystalline layers in an LED or LCD. They have large fields of view as they produce their own light.

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