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A Comparison of Efficient Biomedical Applications for Enhancement of Illumination Characteristics

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ABSTRACT
This paper describes the device operation and various biomedical applications of OLEDs, such as OLEDs used in skin wound healing, wearable photomedicine for the treatment of neonatal jaundice using blue OLEDs, revolutionary pulse oximetry using OLEDs, OLEDs used in optogenetics, etc. in which the research is similar to effective light extraction techniques, improving efficiency and lifetime and reducing energy consumption. By comparing different research papers, it has been observed that current density of neonatal jaundice treatment is best with the value of 10^8mA/cm^2 at 8V, 10^3 mA/cm^2 at 7V is for application of Optogenetics and 10 mA/cm^2 at 4.7V is for application of wound healing which is least. The peak value of luminance obtained for application of wound healing for green emission is at 550nm and for red emission is at 620nm, for neonatal jaundice treatment is at 470nm for both ITO and Ag anode, for optogenetics it is at 450nm and for revolutionizing pulse oximetry it is at 500nm for green and 630nm for red emission.

KEYWORDS
Organic Light Emitting Diode (OLED); Hole Transport layer (HTL); Electron Transport layer (ETL); Liquid Crystal Displays (LCD); Thin Film Transistor (TFT); Current density; Fluorescence.

1. INTRODUCTION

OLED i.e. organic Light Emitting Diode is a thin electronic device of solid state consisting of a conductive layer and a light emitting layer which are placed between two electrodes on a substrate. OLEDs require a continuous supply of electrons and holes to produce electroluminescence [2-3]. Two-layer OLEDs inject holes and electrons from the anode and cathode, respectively, while three-layer OLEDs replace the conductive layer with an electron-transporting layer and a hole-transporting layer, resulting in a bright display [9]. OLEDs are used in creating digital displays in devices such as TV screens, computer monitors, and portable systems like smartphones and handheld game consoles. OLED have also become attractive light sources for compact and "indiscernible" biomedical devices that uses the light to probe, manipulate or treat biological cases. The inherent mechanical flexibility of OLEDs and their compatibility with a widely available substrates and geometries are particularly beneficial in such context. The recent progress and the development for the applications of OLEDs in biomedical field is reviewed here. The promising benefits of OLEDs over the broadly used Liquid Crystal presentations (LCDs) is that they are inexpensive, brighter, have broader viewing angles, devour lesser energy and have higher contrast. Due to the fact that they are self-radiant, have broader viewing angles, consume little power and have good contrast.

These OLEDs have thinner displays because backlight is not required for them [12]. OLEDs are thin-film electronic devices that emit light in response to an electric current. It works in solid state and is based on bioluminescence. In the last 20 years, OLEDs have been replaced by CRTs and LCDs. It is a type of LED where the bioluminescence layer is an organic layer. We can classify the OLEDs in two types, one is based on small molecules and the other is based on polymers. OLED displays are either PMOLED (Passive Matrix Organic Light Emitting Diode) or AMOLED (Active-Matrix Organic Light Emitting Diode). Unlike LCD, OLED does not require a backlight to function. OLED has many recompences over liquid crystal displays as well. The idea of hole or electron restricted bioluminescence in OLEDs reduces the working voltage while concurrently increasing the output of light and performance. OLEDs additionally include organic resonant tunneling diodes, organic photo transistors, natural photo detectors, and organic sun cells [9]. Figure 1 below shows general structure of an OLED.

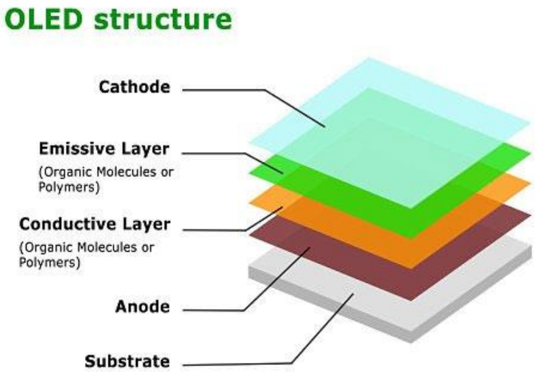

Fig. 1. Basic Structure of OLED [21]

2. MATERIALS AND STRUCTURE

OLED is a digital device which comprise of thin-layer, monolithic semi-conductor tool that generates light when voltage is applied to it. When electric field is carried out to organic materials, various ways of light are generated. This is known as bioluminescence. OLEDs have a series of vacuum thin organic layers deposited between two film conductors. OLEDs consist of a hole transport layer and an electron transport layer packed between two electrodes. They differ from inorganic LEDs in two ways. First, the films utilized in OLEDs are huge energy hole semiconductors manufactured from small molecules. Secondly, singlet and triplet exciton, which can be neutral molecules in an excited state, are produced by means of charge recombination and light emission by radiative transfer. There are two kinds of bioluminescence substances utilized in OLEDs: small molecules OLEDs (SM-OLED) and polymer LED (PLED). Figure 2 explains the mechanism that is involved in light emission from an OLED.

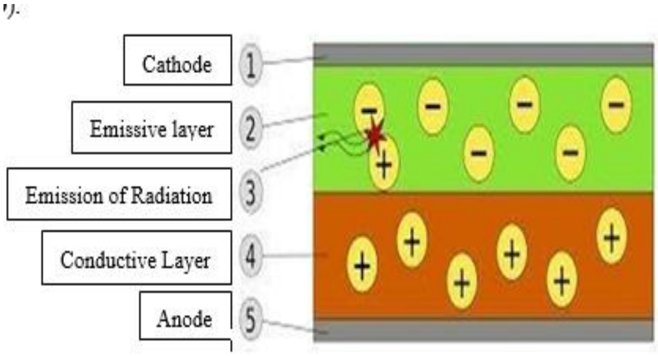

Fig. 2. Bilayer OLED [3][9]

OLED consist of the following configuration: substrate used in an OLED can be of material plastic or it can be glass. When generated light enters through a substrate, such OLED devices are called back-emission devices. The cathode is the negative electrode of the OLED and is responsible for injecting electrons into the organic layers, it can be of aluminum or calcium or barium. Anode part is a sufficient conductor having high work function characteristic sending injection of holes into the HOMO stages. Hole-transport layer (HTL) is the p-type substances for OLED are TPD and NPB. ETL allows it to transport the electrons from cathode into the emitting layer of the OLED, this is the best part of the jump mechanism which involves the instantaneous burst of molecular anion radicals. Emissive layer of an OLED consists of natural plastic molecules. For elaboration we will consider an example of poly- fluorine holes which have greater mobility than electrons in natural semiconductors. The coloration of the light generated varies to sort of natural molecule used. Top Protective Layer, often made of glass or a durable plastic, is added on top of the OLED structure to protect it from physical damage, scratches, and environmental factors. In recent years, the competition between OLED displays and liquid crystal displays (LCDs) has been fierce. The main advantage of LCD and OLED displays over cathode ray tubes (CRTs) is their active area layout, which consists of pixels that can be turned on or off as needed to display an image. Specifically, OLED pixels emit light and can be turned off to produce true black. On the other hand, because LCD pixels are transmissive, they cannot completely block the backlight, affecting their ability to display true blacks.

PASSIVE MATRIX DISPLAYS and ACTIVE-MATRIX DISPLAYS A pixel is largely an overlapping place of linear electrodes located on both aspect of an OLED liquid crystal or light emitting material. In this situation, each line is chosen for the duration of the T/N length, where T is the frame time and N is the quantity of displayed traces [1][3]. Then the next row is selected. Slow response converters like LCDs have variable display contrast, making them suitable for 100–200-line displays. OLEDs work with 240-line displays, but this uses more power and can damage pixels.

Passive matrix OLEDs (PMOLEDs) are an attractive option due to their simple device structure. This technology uses TFT circuits and capacitors to drive each pixel, which is identified by its own electrode [10]. LCD, or OLED acts as the active material and is placed on top of active-matrix circuit [11]. It is not the opposite of the pattern. This method is used in FPDs to create large, high-resolution devices. The thin film transistors (TFTs) act as converting device to keep the pixel state while considering the other pixels. There are two common TFT technologies generally used. They are the non-crystalline thin-film silicon and the polycrystalline silicon. Mentioned technologies aid in the fabrication of active- matrix backplanes for flexible plastic substrates. These Flexible plastic substrates are significant in producing flexible AMOLED displays [10]. Figure 3 shows the configuration of AMOLED and PMOLED.

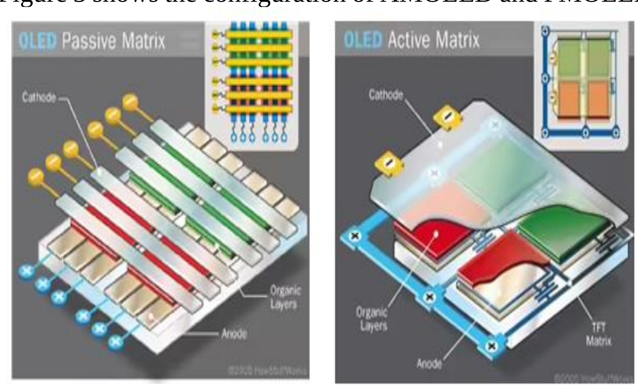

Fig. 3 (a). OLED passive matrix (b) OLED active matrix [11]

3. APPLICATIONS IN BIOMEDICALS

In this section, applications of OLEDs have been elaborated. OLEDs have extensive kind of applications which we encounter in each and everyday existence. To mention enormous applications of OLEDs: OLEDs used for Skin Wound Healing, Wearable photo medicine for Neonatal jaundice treatment using Blue OLED's, Revolutionizing pulse oximetry using OLED, OLED Used in Optogenetics [6], Near-infrared spectroscopy (NIRS), Photo- and photodynamic therapy, therapeutic devices, Integration with microfluidics. In this paper we are focusing mainly on the following four applications. These are discussed in the detail in the following sub-sections.

3.1 OLED used for skin wound healing

Maximum photo scientific studies have been performed by using rigid LED, rigid OLED and rigid QLED light bases. Advanced photon related research has been done using solid LED, solid OLED and solid QLED light sources. However, recently the wound healing field has learned to utilize high-quality OLEDs, and clinical studies have also been conducted using high-quality QLEDs [5]. Due to the fact that conformable OLEDs have a surface light source, they may be connected to the human body, which offers numerous benefits, which includes low warmth generation, light uniformity, and being extremely-skinny and light weight. But, to gain advanced picture clinical effects and extra handy programs, research needs to be carried out to increase optoelectronic gadgets with a greater diversity of shapes and substances [8]. The STOLED become fabricated with the aid of sandwiching an OLED inside transferable limitations [13]. The transferable obstacles encompass a 2.3-µm thick PET film on a 1.8-µm-thick acrylic adhesive and a 0.7-µm-thick encapsulation layer. The encapsulation layer includes 2 dyads of ZnO, Al_2O3, MgO (ZAM) layer and a Si-based polymer. The combination of OLED of ~0.4 µm which is sandwiched between transferable barriers of 4.8 µm ends in a complete STOLED device thickness of simplest 10 µm [5][8]. Figure 4 shows the structure used for different applications.

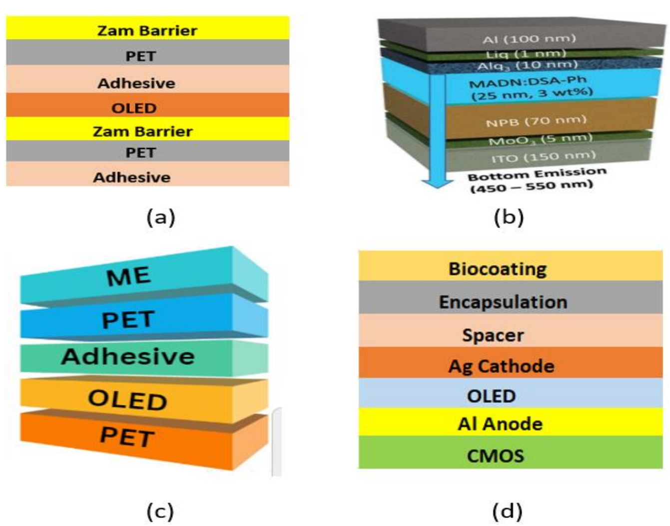

Fig 4. Structure of devices with different applications (a) structure for OLED used in skin wound healing (b) structure for OLED used in jaundice treatment [14] (c) structure for OLED used in pulse oximeter (d) structure for OLED used in optogenetics

3.2 Wearable photomedicine for Neonatal jaundice remedy using Blue OLEDs

If left untreated, jaundice can be fatal. This article explores the use of OLED technology as a solution to treat jaundice. This paper explores the use of wearable OLED technology as a potential solution for treating jaundice in newborns. Learn how this textile-based platform emits blue light to effectively treat jaundice while providing comfort and flexibility for the baby. Planarizing the textile substrate is a crucial step in creating a wearable OLED. We have discovered that how a robust process is developed using buffer strain and SU-8 planarization. This planarization substrate guarantees flexibility at the same time as supplying a flat base for OLED fabrication.

OLEDs are susceptible to moisture and oxygen, making encapsulation necessary for long-term reliability. Explore the 2.5-dyad structure used to protect the OLED [14]. The adhesive PET transfer process employed to enhance washing reliability and ensure only textile and virgin PET are in contact with the skin. With the implemented textile planarization and encapsulation processes, the wearable OLED can be safely used on the human body. Share in the excitement as we discuss the potential impact of this technology in neonatal care and the possibilities for further advancements in wearable photomedicine [14].

3.3 Revolutionizing pulse oximetry using OLED

A pulse oximeter measures blood oxygen saturation by sending two pulses of light to the patient's tissues. The quantity of light absorbed by using the oxygenated and deoxygenated hemoglobin is then used to calculate oxygen saturation tiers [4]. Device structure is as follows: The base layer of the OLED is usually a glass or plastic substrate, which provides mechanical support and stability to the OLED panel. The anode is a transparent conducting layer that is deposited on the substrate. It acts as the positive electrode and allows current to flow into the OLED layers. The heart of the OLED display is the organic layers**.** The organic process is at the heart of the OLED display. This layer consists of organic molecules and the HTL, emissive layer and electron transport layer (ETL) emit light when electric current is applied [16-17]. The cathode is the negative electrode of the OLED and is responsible for injecting electrons into the organic layers it can be of aluminum or calcium or barium. To protect the organic layers from oxygen and moisture, an encapsulation layer is often added. A protective layer, often made of glass or a durable plastic, is added on top of the OLED structure to protect it from physical damage, scratches, and environmental factors [15-17].

3.4 OLED Used in Optogenetics

To simulate optogenetic stimulation of sensory neurons, OLEDs were attached to the plantar skin and induced voltages were measured in the somatosensory cortex. The glass plate changed into once more located between the OLED and the pores and skin for thermal and electric powered insulation. The Organic Light Emitting Diode was determined with pulse periods of five and 10 ms at the pulse amplitude of 15 V [5]. The two responses inside the somatosensory cortex generated by optical stimulation as well as electrical stimulation displayed a couple of consecutive terrible and superb peaks; the expectancy of the first negative height became ~25 ms. the height amplitude becomes ~25 μV. A continuous duration of 10 ms results in a more efficient response in the potential [19].

4. RESULT DISCUSSION AND COMPARISON

In this section we will discuss the comparison of output response and characteristics like current density, irradiation, luminance and electroluminescent intensity. Figure 5 will help in analyzing the different aspects of the various curves.

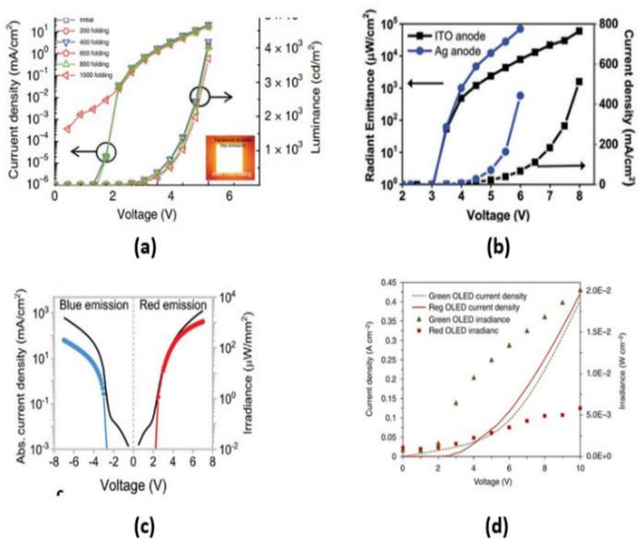

Fig 5. Current Density vs Voltage Characteristics of different application of OLEDs
(a)in skin wound healing (b) in jaundice treatment
(c) in optogenetics (d) in pulse oximeter

In the four graphs, here is a comparison of the current density and voltage for each graph: In figure 5 (a), for ITO Anode, the current density is highest at around 8 x 10^{-5} A/cm² at 10 V. The current density decreases as the voltage increases to 10 V. In figure 5 (b), for Ag Anode the current density is highest at around 4 x 10^{-4} A/cm² at 8 V. The current density cannot be determined at lower voltages because the scale starts at 2 V. For figure 5 (c): Blue Emission, the current density is highest at around 5 x 10^{-7} A/cm² at 10 V. The current density decreases as the voltage increases to 10 V. Fig 5 (d): Gas OLED, the current density is highest at around 1 x 10^{-5} A/cm² at 4 V. The current density cannot be determined at higher voltages because the scale ends at 4 V.

In conclusion, the current density is highest in figure (b) for Ag Anode at 8 V. The current density is lowest in figure (c) for Blue Emission at 10 V. It is important to note that the scales of the graphs are different, so it is difficult to make a direct comparison of the current density between the graphs. Additionally, the graphs for (b) and (d) do not show data at lower and higher voltages, respectively, so it is difficult to say definitively what the current density is at those voltages.

Comparing the four graphs based on the numerical values of radiance and wavelength reveals the following aspects: Fig 6(a): Absorption Radiance ranges from 0 to 1. Highest radiance (around 1) is observed at a wavelength of around 425 nm. Radiance decreases as the wavelength goes from 425 nm to 700 nm. Fig 6(b): Fluorescence Radiance ranges from 0 to 0.8. Highest radiance (around 0.8) is observed at a wavelength of around 530 nm. Radiance is generally lower than in graph (a) and shows two peaks, one at 530 nm and another around 470 nm. Fig 6 (c): Fluorescence Intensity Radiance (labeled as "Normalized radiance" on the y-axis) ranges from 0 to 1.2. Highest radiance (around 1.2) is observed at a wavelength of around 530 nm.

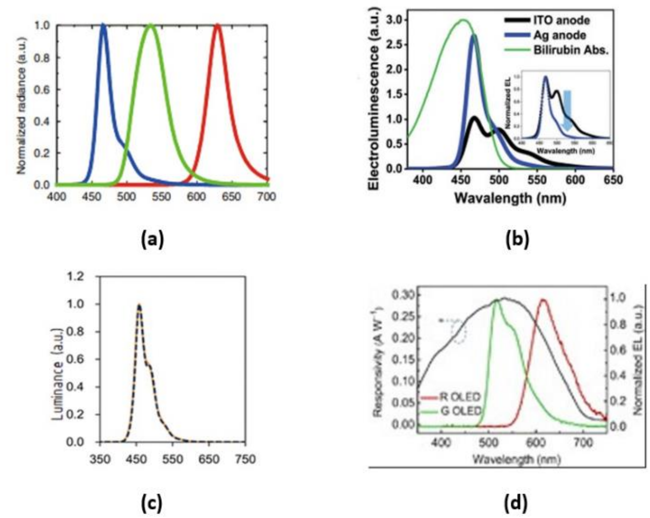

Fig 6. Luminance vs Wavelength Characteristics of different application of OLEDs
(a) in skin wound healing (b) in jaundice treatment
(c) in optogenetics (d) in pulse oximeter

The graph in figure 6 (a) shows a similar trend to graph 6 (b) with a peak at 530 nm but with a higher overall radiance. Fig 6 (d): Absorption Radiance (labeled as "Responsivity" on the y-axis) ranges from 0 to 0.3. The peak radiance cannot be determined precisely from the graph due to the scale, but it appears to be around 0.25 at a wavelength around 440 nm. Similar to graph (a), radiance decreases as the wavelength increases from 440 nm to 700 nm. Overall Comparison says that figures (a) and (d) likely depict absorption spectra, with a higher radiance signifying higher absorption. Both the figures show a decreasing trend in radiance with increasing wavelength, indicating greater absorption at lower wavelengths. Graphs (b) and (c) likely represent fluorescence spectra, where the peak radiance corresponds to the emission wavelength. Both graphs show a peak around 530 nm, suggesting fluorescence emission at this wavelength. In summary, graphs (a) and (d) deal with absorption, while graphs (b) and (c) deal with fluorescence. The highest radiance is observed in graph (c) at a wavelength of 530 nm. It is important to note that the y-axes of these graphs have different scales, so a direct comparison of radiance magnitudes might be misleading.

5. ADVANTAGES

Natural materials such as OLEDs have important applications in electronic devices due to their many advantages. These advantages include thin state materials, light weight structure, high luminous efficiency and fast response time due to weak OLED elements that do not emit light or use energy. They have got high luminous power performance, for the reason that an inactive element of OLED does not generate light or consume power, bearing in mind genuine blacks. They have got fast reaction instances, making them best for stimulating animations. LCDs can reach as low as 1ms reaction time for the quickest color change in them [3]. They have got a wide viewing angle, that is wider than that of LCDs due to the fact pixels in OLEDs emit light directly, resulting in colors appearing efficaciously. They are self-emitting, disposing of the requirement for a backlight supply. They can tune colors for full-color displays. They are supple and can be fabricated on flexible plastic substrates which in return therefore produce organic LEDs with flexibility [9]. They offer cost effectiveness when compared with inorganic devices. OLEDs are less-priced than LCDs. They have low power consumption. They do not require a backlight, so they consume less energy than LCD displays. In addition, OLED displays are easy to manufacture, and their plastic composition allows them to be made into large, thin panels. OLED displays refresh faster than LCD displays and provide a more realistic and up-to-date video image [20].

6. CONCLUSION

In conclusion, the intersection of OLED era and biomedical applications holds good promise for re-modeling healthcare through enhancing diagnostics, monitoring, and customized remedy. As era continues to conform, OLEDs are poised to play a pivotal position in shaping the destiny of biomedical devices, contributing to greater powerful and patient-centric healthcare answers [3]. Instead of numerous developments and probable benefits, contests such as long-term stability and scalability need to be considered to ensure extensive implementation in the biomedical field. Continued research and innovation in OLED technology are crucial for overcoming these challenges and unlocking the full potential of OLEDs in healthcare. In this paper, we conclude that OLED used in biomedical application of neonatal jaundice treatment is best in context to current density with the value 108 mA/cm^2 at 8V and least for biomedical application of wound healing with the value 10 mA/cm^2 at 4.7V.

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