Industrial Engineering Journal
ISSN: 0970-2555
Volume : 52, Issue 8, No. 5, August : 2023

WHITE ORGANIC LIGHT-EMITTING DIODES IS GENERATED WITH MIXING COMPLEMENTARY COLOURS WITH MULTILAYER DEVICE & ITS ARCHITECTURE

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Abstract:

W-OLEDs are gaining recognition as a possible light radiate / emitting technology as they have a wide range of uses, including solid-state lighting and the backlight for liquid translucent displays. Here, researchers demonstrate methods one produces organic light-emitting diodes which process
alabaster / white light using a layered colour scheme. Early WOLEDs used components generating two complimentary colours, reddish-orange and greenish-blue, to create white. The total quantity of light generated through each layer was predetermined to such an extent that when the two types of light merged together, they made white light. By determining the best thickness for apiece layer and adding a thin layer of BCP that closes holes in between emissive layers, the quantity of light emitted from each layer was kept under control. We employed the phosphorescent dopant Fir Pic for greenish-blue light and the phosphorescent dopant $Ir(btp)_2$ (acac) for reddish-orange light; both of these dopants were doped in the host 4,4′-Bis(N-carbazolyl)-1,1′-biphenyl (CBP). We investigated how the operating voltage of these WOLEDs affected the colour of the light they produce, and we discovered that this relationship was practically complete. The Commission International de I' Eclairage (CIE) coordinates for the WOLEDs were 0.25, 0.32, and they produced 1600 cd/m2 at 15 V. We also investigated the properties of these devices' current density vs. voltage (J-V) and voltage vs. luminescence (V-L) and estimated their efficiency, which was determined to be 0.35 cd/A. Additionally, we set up various WOLEDs-based numerical displays just for demonstration purposes.

Keywords: Organic light-emitting diodes, WOLEDs, electroluminescence, exciton recombination, charge transfer layers, thin films, thermal evaporation, and exciton recombination.

1.0 Introduction

Organic light emitting diodes (OLEDs) were made by Tang and Van Slyke [1], and they became known around the world as an alternative to other ways of making light. OLEDs are very lightweight and emit little light. As opposed to liquid crystal graphs, they are devoid of a backlight. They additionally appear to have been very cheap and flexible because they may be made on flexible materials that include plastic or thin metal foils [2–6]. In comparison to other technologies for displaying such as liquid crystal displays, artificial light emitting diodes, plasma displays, cathode ray tubes, etc., OLEDs are very energy efficient and cost-effective. They also have a wide viewing range, high brightness, and a fast reaction time. Since OLEDs were invented, a lot of work has gone into making them commercially practical. Thanks to the research and development done around the world and the great qualities of OLEDs, they are now ready for sale [7–12]. OLEDs have altered the way technological devices work and are currently utilized in almost everything with a screen, like TVs, smart phones, computers, digital cameras, audio players, watch watches, video games, and so on. OLEDs can be made at low temperatures, and there are a lot of ways to change their colors. You can easily change the way an OLED works to make it light up in any color you want [12]. Now, everyone is trying to make white OLEDs (WOLEDs), which would be a great choice for full-color screens and solid-state lights because they would be cheap, flexible, big, have high clarity, and use little energy. Since it is hard to make a single material that can give off pure

white light alongside a wide spectrum, white light typically arises by mixing three main hues (red, green, and blue) or two opposite colors (red and bluish green, blue and orange, green and magenta) to encompass the entire visible spectrum from 380 to 780 nm. WOLEDs might have been made by putting different emitters together in different ways, like using the multilayer approach, the single layer approach, or the down conversion approach [11]. The way each part gives off light is carefully controlled so that when all the colors mix, the result is a clean white color. Kido et al. made the first WOLED in 1995. They used three biological layers to make red, green, and blue light in a single device [13]. Those WOLEDs had a power efficiency of less than 1 lm/W, but now WOLEDs have a power efficiency of over 100 lm/W [14, 15]. Universal Display Corporation says its WOLEDs could have a light power of more than 150 lm/W [14]. Japan's Research Institute of Organic Electronics made a 14 x 14 cm2 WOLED prototype with a power efficiency of 10 lm/W at 5000 cd/m2 [16,17]. In 2010, Panasonic said that their LEDs had >30 lm/W and >40000 h @1000 cd/m2. In 2018, the OLED Works Company made a thin glass base with a 10 cm-bendable WOLED lighting panel. People have said that WOLEDs can convert power more efficiently than 100 lm/W, but the theoretical limit is 248 lm/W [17], and we are still a long way from that number. Because of this, we need to work harder to find out what's wrong with WOLEDs and fix them. Singlet and triplet excitons are made when charge carriers are added to organic semiconductors. Based on data about how electrons spin, 25% of excitons are singlet excitons and 75% are triplet excitons. From bright materials, only singlet excitons give off light. Since triplet excitons don't release light when they die, bright materials only have a 25% internal quantum efficiency. The phosphorescent materials can turn both singlet and triplet excitons into light, and their internal quantum efficiency can be 100%. So, phosphorescent materials [18–20] are used to make OLEDs work well as light sources. Phosphorescent sources are put into a host material with a wide band gap so that triplet excitons can be collected more efficiently. This makes it easy for electrons and holes introduced into the host material to move to the phosphorescent dopant (also called guest material) and rejoin there, which makes the dopant give off light. The choice of the host material's highest filled molecular orbital (HOMO) and lowest empty molecular orbital (LUMO) is very important for capturing both singlet and triplet excitons efficiently. To get high efficiency, the host must have a bigger gap between its energy bands than the dopant. This lets energy move quickly from the host to the dopant's triplet energy, which can only happen when the triplet energy of the dopant is lower than that of the host. Iridium and platinum metals give off strong phosphorescent light and are very useful for OLEDs [18, 21–23]. Depending on how OLEDs are made to get close to white emission, these phosphorescent complexes can be put in a single layer or spread out over several layers. There have also been attempts [21, 24] to get the triplet excitons from fluorescent materials using thermally driven delayed fluorescence and other ways. In this article, we talk about how WOLEDs were made using a very simple design for the gadget. We used two phosphorescent materials that give off two colors that are opposites of each other—greenish blue and reddish orange—and stacked them in OLEDs to make them give off pure white light. For greenish blue emission we used phosphorescentbis[(4,6-difluorophenyl)-pyridinato-N,C2']c(picolinate)iridium(III)(FIrPic) whereas for reddish orange emission we used phosphorescent bis(2-(2'-benzothienyl)pyridinato-N,C3')iridium (acetylacetonate) btp2Ir(acac)). Both of these phosphorescent emitters were treated in 4,4'-bis(9-carboxylyl)-biphenyl (CBP), which is a very common host material for phosphorescent emitters. For the devices to give off white light, the amount of dopants in the host material had to be carefully controlled. The devices have been shown to give off very steady white light, and the brightness of the light they give off was tried by changing the voltage that was put across the devices. When 10 V was put between the two ends of the WOLED, the CIE values were (0.28, 0.33). When 15 V was put across the device, the CIE coordinates changed by one minute to (0.25, 0.32). We also looked at the J-V and V-L functions and calculated how much power the WOLEDs use.

Industrial Engineering Journal
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2.0 Hypothetical of OLED

If all of the coloring agents, irrespective of whether they are the three basic colors or their opposites, have not been combined in the right amounts, one will emerge that is stronger than the others, and we won't be able to make white light. The complementary colors picked to mix for the WOLEDs had been greenish blue and reddish orange. In figure 1.1, the phosphorescent materials used for synthesis of these colors were FIrPic and $Ir(btp)_2$ (acac), respectively. The phosphorescent chemical substances were then introduced to the CBP provide, which possessed a high band gap. Fig. 2 shows a schematic diagram of the electrical power level of the WOLEDs built here. Each material's energy level is written on the energy level map. The energy levels of FiPic and $Ir(btp)_2$ (acac) are shown by the dashed lines between the CBP energy band.

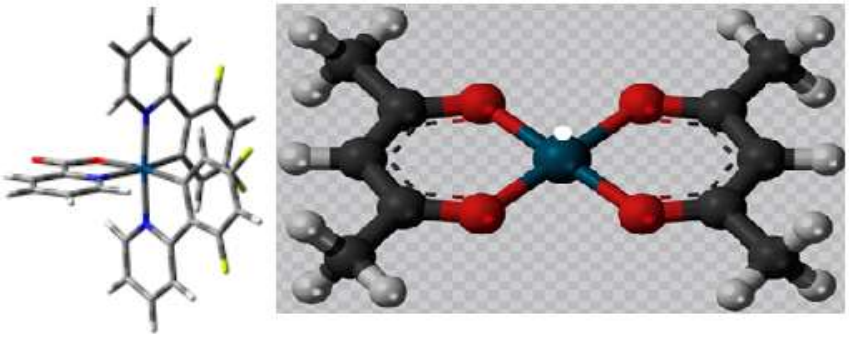

Fig 1.1 Basic Structure diagram of FIrPic and Ir(btp)2(acac)

The spectrum gaps during FIrPic and Ir(btp)2(acac) are a good complement for the band gap associated with the CBP molecule. When a forward bias (+ve voltage to both ITO and Al) was applied to the devices, electrons were injected from Al into Alq_3 and holes were injected from ITO into F_4TCNQ-doped α-NPD. LiF contributes to getting electrons into Alq_3, while doping α-NPD with F_4TCNQ helps get holes into α-NPD. When electrons are introduced, they go through Alq_3 and end up at the CBP : Ir $(btp)_2$ (acac) interface. Holes, on the other hand, go through α-NPD and end up at the CBP : Fir Pic interaction. Hole injection persists in the CBP : Ir $(btp)_2$ (acac) layer, while electron injection continues in the CBP : FIrPic layer.

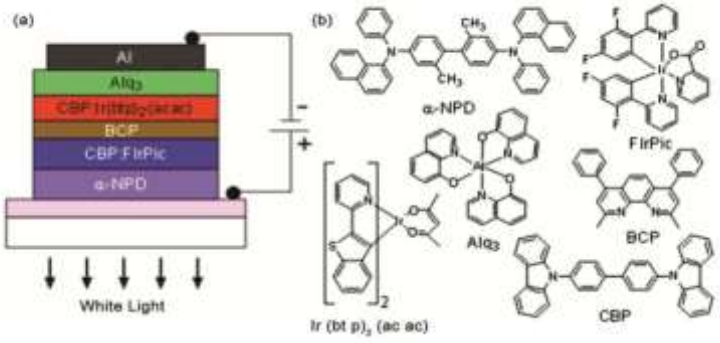

Fig. 1(a) illustrates the exploded view structure for the constructed WOLEDs, and (b) shows the molecular structures of each part used.

The majority of the electrons injected migrate through the inject toward CBP:FIrPic, whereas a portion of the holes move through the inject into CBP:$Ir(btp)_2$(acac). In the CBP:FIrPic layer, electrons and holes start out in the CBP energy spectrum, but they transfer right away to the FIrPic energy level, where they join to make greenish blue light. The electrons in CBP's LUMO are moved to FIrPic's LUMO, and the holes in CBP's HOMO are moved to FIrPic's HOMO. In the CBP:$Ir(btp)_2$(acac) layer, the electrons and holes start out in CBP but are quickly moved to $Ir(btp)_2$(acac) energy levels. They then combine in $Ir(btp)_2$(acac) to make a reddish orange color.

Industrial Engineering Journal
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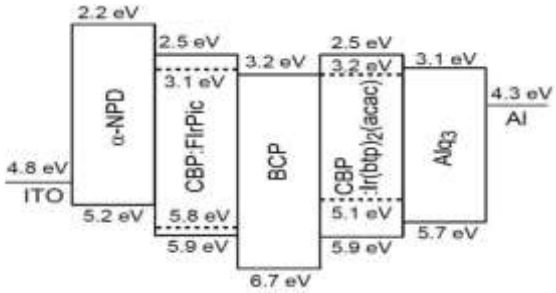

Fig. 2 is a picture of the amount of energy levels of the WOLEDs that were built.

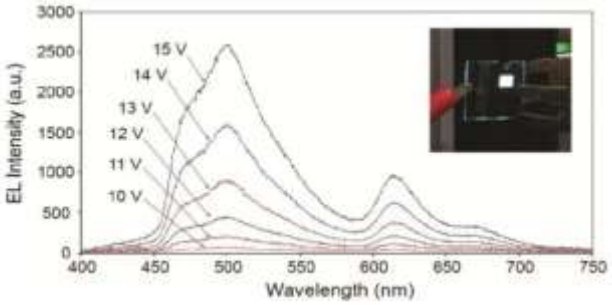

Fig. 3 demonstrates the EL bands of a WOLED when different voltages are applied. The picture of the WOLED working at 10 V is shown in the inset.

This LUMO electrons for CBP have been transferred to the LUMO electrons of Ir(btp)2(acac), as well as the HOMO holes of CBP have been migrated to the HOMO holes of Ir(btp)2(acac). The Dexter energy transfer process [11] is how vitality moves through the CBP host to the phosphorescent guest. Dexter energy transfer makes it possible for potential to move from a singlet to another singlet or from a triplet to another triplet. If there hadn't been a BCP layer between the two different emissive layers, electrons and holes might readily move around CBP and rejoin to make light come out of both layers in a random way, since both layers are made of CBP. In the present situation, it demonstrates a basic process for making WOLEDs (see figure 1.2). It would have been problematic to control the quantity of light each layer poured out, and the light that was given out would not have turned out white.

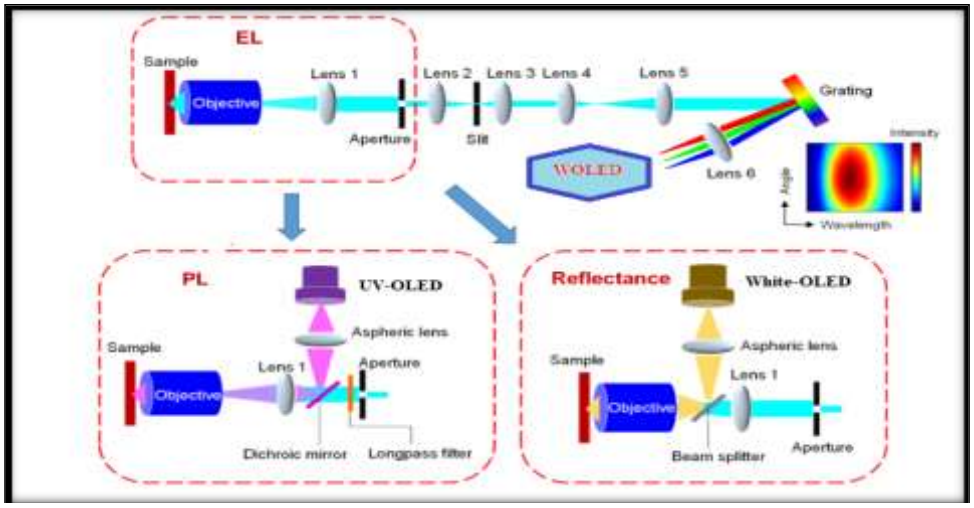

Fig.3. (a) Basic Step of Generation of white Organic Light Emitting diode

Due to this, it was of the utmost significance to control the mixing of electrons and holes in each layer so that the color that was released could be fully controlled. We put a small layer of BCP between the two layers that give off light to control which electrons and holes come together again in each layer.When compared with CBP, the HOMO energy of BCP is quite high, which means that there is a 0.6 eV barrier between CBP and BCP that makes it hard for holes to travel from CBP to BCP. Since the barrier at the interface is high, the holes try to tunnel through BCP to get to the other

side. But the width of BCP can be altered to control the number of holes let flux pass through it. If the BCP layer is thicker, less holes can get through it. But if you change the electric field, you can also change whether or not holes pass through a BCP layer of a certain width. BCP controls how the holes move from the greenish-blue emitter to the reddish-orange emitter in OLEDs that have been developed today. In other words, BCP controls how the holes and electrons in the two layers the fact that permit light out are dispersed out. We found that 5 nm of BCP gave the best exchange of electrons and holes in both of the emissive layers. The light from both emissive layers was mixed together to make white light. Figure 3 shows how the WOLED's EL spectrum changes when the voltage is changed. In the inset, you can see a picture of the WOLED at 10 V. The WOLED's EL spectrum was quite wide. It went from about 420 nm to 720 nm, which is the whole visible range. The EL spectrum of WOLED showed two peaks, one at 500 nm and the other at 624 nm, no matter what voltage was used. The emission from FIrPic causes the EL peak at 500 nm, and the emission from Ir(btp)2(acac) causes the EL peak at 624 nm. It's important to know that the EL spectrum of each CBP:FIrPic emissive layer goes from about 420 nm to 600 nm, and the EL spectrum of CBP:Ir(btp)2(acac) goes from about 520 nm to 720 nm. The Spectrum of the WOLED was the overlap of the light from the two layers, which gave off two different colors that don't go together. At 10 V, the light that came out had CIE coordinates of (0.28, 0.33), which are very close to the coordinates of pure white light (0.33, 0.33). From EL spectra, it's easy to see that FIrPic's emission added more to white light than Ir(btp)2(acac). This is because blue light is more important for white light than red light. Because of this, the amount of light Ir(btp)2(acac) gave off was kept low by keeping its doping amount and film thickness lower than those of FIrPic. We looked at how changing the power made the light coming out of the WOLED change color. The EL spectra were taken at different voltages between 10-15 V, and the results are shown in Fig.3. When the power was turned up, the light got brighter. As the voltage goes up, there is more electron-hole input and, as a result, more electron-hole recombination in each emissive layer. This is why the EL power goes up. But it was interesting to see that the light didn't change color very much as the power went up. Table 1 shows the CIE coordinates of the light given off at different volts, which we also tested. The CIE values of the WOLED changed from (0.28,0.33) to (0.25,0.32). We usually think that the discharge from different layers of a device could change if electrons and holes came in at different rates. People also thought that when the voltage was changed, the electrons and holes would move through BCP at different speeds. But in the current structure, changing the voltage had a small effect on the CIE coordinates, and the color of the light that came out was still pretty close to white on the CIE diagram. When the power was changed, the mixing zones did not change. Even though it increased the amount of electrons and holes that were injected, it could not change the ratio of the lights that came out because of how the gadget was made. This meant that the light strength did not change.

Table 1 lists the WOLED's CIE coordinates based on different applied voltages.

Applied Voltage	**CIE Coordinates**
10 V	(0.28, 0.33)
11 V	(0.27, 0.33)
12 V	(0.26, 0.32)
13 V	(0.26, 0.32)
14 V	(0.25, 0.32)
15 V	(0.25, 0.32)

We examined the WOLED's J-V along with V-L characteristics to figure toward how efficiently it used power. Figure 4 demonstrates the WOLED's J-V and V-L features. Both the current and luminescence changed non-linearly with increment in the applied voltage. At 15 V, the WOLED had a brightness of 1580 cd/m^2. Based on the J-V and V-L curves, we were able to figure out that the power efficiency at 14 V was 0.35 cd/A. We made a WOLED number display for the

public show. The display was made using the same device design and the same process as described in the experimental part. The glass substrates were coated with ITO. The display worked very well and was controlled by an electrical circuit with an electronic countdown from 000 to 999. Figure 5 shows at a numerical count of 005; a picture of the WOLED monitor was acquired.

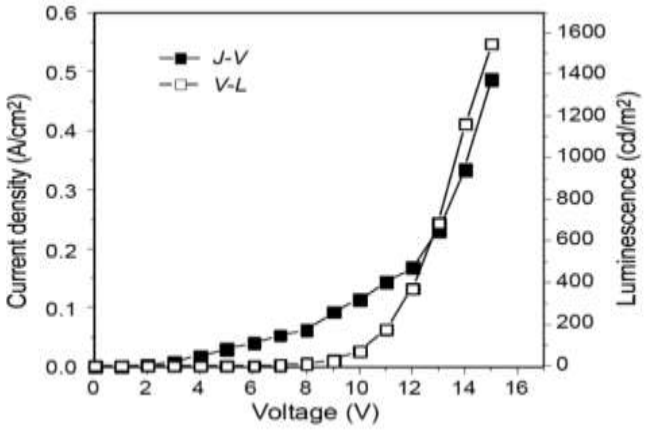

Fig.4. J-V and V-L features of the WOLED are shown in Researchers estimated the power efficiency of WOLED using the J-V and VL parameters.

Fig. 5 Photograph from the WOLED number display rendered in the comparable device establish and in similar circumstances as those of small area WOLED shown in Fig. 1.

Conclusion

We have demonstrated in this instance the manner in which to make WOLEDs in a way that is extremely easy. When the WOLEDs were manufactured, the opposite way of mixing colors was used. We used both phosphorescent sources when making tools with layers. One gave off light that was greenish blue (FIrPic) and the other gave off light that was brownish orange (Ir(btp)2(acac)). The two emitters were filled with CBP, and the right amount of a hole-blocking layer was put between them to carefully control how much light came out of each layer. Changing how much dopant was in the two emissive layers and how wide the films were also helped control the ratio of the two colors of light that came out. At 10 V, the WOLED's CIE readings were between 0.28 and 0.33. The WOLED construction that was recommended gave off a steady white light. This is because the mix of electrons and holes in the two radiating layers had been changed. Whenever the voltage went from 10 V to 15 V, the light didn't move. The investigation illustrated here are intended to

assist researchers make WOLEDs that give off pure white light no matter what quantity of bias voltage is put into them.

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