



The Investigation in N-type Doping as well as Stamped Transfer Mechanisms of Organics Light-emitting Diodes' Electron Transport Layer

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Abstract:

The present investigation proposes the use of 2-(hydroxyl) quinoline lithium (Liq) in the form of an n-type doping agent to improve the accomplishment of white hybrid-OLED (WHOLEDs). One of the crucial factors for device applications is the improved electron injection and efficient balancing of holes & electrons in the emitting layer, which is achieved by doping the Liq in the tris(8-hydroxyquinolino) aluminum (Alq_3) layer. This investigation examines the optimal composition (liquid enthrallment and breadth) of the Alq_3 : Liq n-type inebriate (intoxicate) electron injection layer (EIL) due to white hybrid-OLED (WHOLEd) devices. In investigation involves correlate the current density and efficiency outcomes including those obtained using the traditional Alq_3 /LiF approach. To prevent exciton quenching, a inutility layer or interloper is often introduced in the midst of the emitting layer & the electron injection layer (EIL). This study examines the appropriate material and optimal thickness for the obstructing layer white small molecule organic light-emitting diode (SM-OLEDs) using of the 1,3,5-tris (N-phenylbenzimidazol-2-yl) benzene (TPBi) Stamp fetch technique. In Suggested Stamp fetch procedure offers a means to circumvent the intricacies associated with the vacuum deposit technology.

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Keywords: ETL, Solution analyze, Stamping manipulate, OLEDs, n-type OLEDs

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1.0 Introduction

Over the course of several years, Organic light-emitting materials have gained considerable praise as accompanying frontrunner in forthcoming phase of flexible information surfaces. Still, it is important to highlight that the voltage required for operation of the

instrument continues to be higher than normal although in conductive bearer engrossment of organic resources appears comparatively squat [1]. Several investigations provide evidence indicating that the efficiency of OLEDs is significantly influenced by the contact that is established between the electrode, which



involves the anode as well as the cathode, and the organic layer [2, 4]. According to prior investigations, there have been assertions made about the potential benefits of Utilize 2-(hydroxyl) quinoline lithium (Liq) in organic electron freightage medium in facilitating electron immunization through metal electrodes [5,7]. The overall picture of the Alq₃/LiF/Al manufacturing process, it is necessary to achieve LiF thicknesses as little as 0.5 nm. The accurate regulation of such a small layer on a per-run basis presents significant challenges. Consequently, the execution of an effective n-doping methodology is a crucial technological advancement in the field of OLED industrial applications. The investigation focused on the use of Liq-doped Alq₃ as an n-doped system for the purposes of electron injection and transport. The present research examines the optimal recipe, including the immersion and broadness of the Alq₃: Liq n-type doping electron injection layer (EIL), for OLED utensil at correlation the current density and efficacies outcome including the ordinary Alq₃/LiF methodology. Our research focuses on comprehending the mechanisms involved in electron injection and transit inside n-doped EIL. Based on the findings and citation [8], it has been shown that excitons have a high propensity for diffusion from the emissive layer (EML) to the electron injection layer consisting of a blend of Alq₃ and Liq, resulting in their subsequent quenching. In order to mitigate the quenching of excitons, it is necessary to provide impeding surface or interlayer in the midst the emissive layer (EML) & electron injection layer (EIL). This study also examines the optimal resources and thickness for the impeding surface. Enhance of the power efficiency of white hybrid organic light emitting diodes (WHOLED), an optimal n-type doping formula was used to generate semiconductors. Furthermore, the fabrication technology for Explanation based small molecule organic light-emitting diode (SM-OLEDs) has been in the

appropriate for Extensive scale management in quantities at inexpensive prices [9, 11]. This approach usually incorporates solutions containing high-dissolution emission materials. When used in the fabrication of multi-layered structures, the remedies have the potential to corrode the underlying layers, hence posing challenges in achieving the required layer [9,12]. The intensify performance of SM-OLED was achieved by the use of the stamping transfer process for fabrication, hence escaping the challenges associated with intermixing. The use of the stamping approach has the potential to provide cost-effective and high-performance solution-processed SM-OLEDs. In this stamping transfer technique, planar poly-(dimethylsiloxane) (PDMS) thermoplastic is implemented. PDMS stamps is considered highly suitable for repetitive procedures for the reason to their low adhesive properties, durability, and flexibility.

2.0 Hypothesis

2.1 Fabrication of N-type Doping OLEDs

ITO-coated substrates made of glass were allowed to soak for 15 minutes each in an acetone and isopropyl alcohol ultrasonic bath, before being given a rinse in DI water for one hour. Prior to usage, the below-ground strates were blasted dry with nitrogen gas and then treated with oxygen plasma for 1 minute. WHI112 is used as the hole injection layer, HTG-1 is used as the hole transport layer, UBH-15 is used as the color of the host substance that EPH-31 is utilized as the red host substance, EB-502 is used as the blue dopant, and EPY-01 is used as the yellow dopant. Figure 1(a) are shown Tris(8-hydroxyquinolinato) aluminum (Alq₃) and tris (2,4,6-triMethyl-3-(pyridin-3-yl)phenyl) borane (3TPYMB) are two of the most frequently utilized compounds for enhancing electron transport. 3TPYMB is also used as a hole blocking layer for holes and as an interlayer between EML and EIL to prevent excitons from being quenched. e-Ray Op to Electronics Technology supplied all materials.



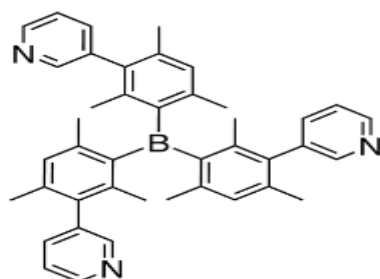
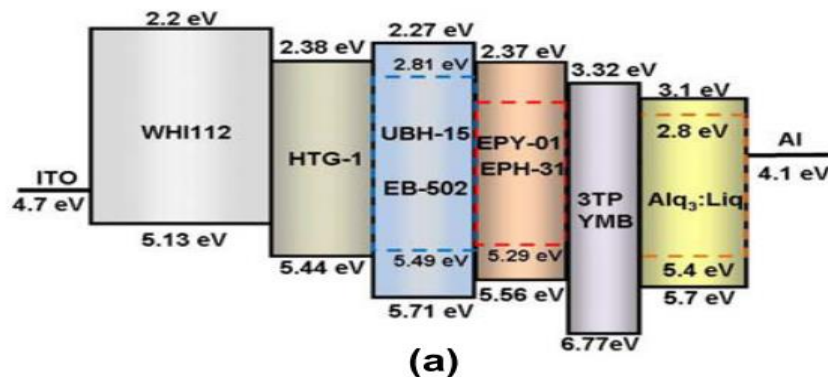
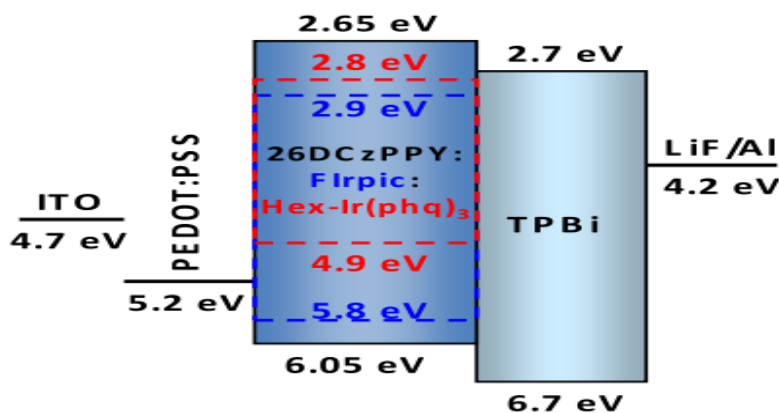


Figure 1(a) The basic Structure of 3TPYMB



(a)



(b)

Figure 1: (a) White HOLED structure and energy level graphs, (b) White SM-OLED structure and energy band diagrams.

The equipment utilized during this research is an electron-only device characterized by a subsequent construction: ITO/Al (200 nm)/x(30 nm)/Al (150 nm). In device A, the material x is Alq₃. In device B, the material x is a mixture of Alq₃ and Liq (10 wt%). In device C, the material x is a mixture of Alq₃ and Liq (50 wt%). In device D, the material x is a mixture of Alq₃ and Liq (80 wt%). The co-deposition approach was used to introduce Liq as a dopant into Alq₃. In the fabrication process of the n-type layer in

WHOLED, a mixture of Alq₃ and Liq at varying proportions was first prepared and dissolved in a chlorobenzene solvent. After being drained, the substance was put into a vacuum chamber and then subjected to evaporation. The setup for experimentation utilized during the current research has a WHI112 (70 nm) layer as the bottom electrode, followed by an HTG1 (10 nm) layer. On top of this, a UBH15:EB502 (10 nm, 2wt%) layer is deposited, followed by an EPH3:EPY01 (45 nm, 2 wt%) layer. The



subsequent layer, denoted as y, is composed of Alq₃/Alq₃:Liq with varying thicknesses of 0/30, 5/25, 10/20, and 15/15 nm. Ultimately, a layer of aluminum (with a thickness of 150 nm) operates as the outermost electrode. The energy band schematics for the WHOLED are depicted in Figure 1 (a). The technique in which heat evaporation was implemented to deposit the entirety of organic layers, doped layers, including the cathode layer.

2.2 Development of OLEDs with Stamping Transfer Processing

The beginning of the procedure involves pre-preparation of Poly-(di-methylsilane) (PDMS) (silgard 184A). The process for the manufacture of poly-dimethylsiloxane (PDMS) necessitates the combining of a pre-polymer and a curing agent in a volumetric proportion of 10:1. During fulfillment the whole stirring procedure, the solution was meticulously poured on a silicon wafer with the goal of a uniform surface stamp. After the above, the wafer underwent a process of being exposed to a vacuum environment in order to efficiently remove any air bubbles that may have been trapped. Following that, the chemical solution was meticulously applied onto a silicon wafer with the intention of attaining a consistent and flat surface. A poly-dimethylsiloxane (PDMS) plate is fabricated using a thermal treatment lasting one hour in an oven maintained at a heat of 100°C. A Surfaces Poly-(3,4-ethylenedioxythiophene)-poly-(styrenesulfonate) (PEDOT : PSS) has a applied in ITO glass substances termed of hole injection layer (HIL) through using the technique of a spin-coating the strategy.

In each experimental operate, spin-coating momentum characteristic is to begin with configured for a time interval approximately 30 seconds. After a spin-coating procedure has been finished, the specimen has been promptly subjected to a baking treatment on a Scalding plate at a temperature 130°C for a period of 10 minutes. This treatment was performed with the purpose of removing the last of the solvent. The process for the creation of the emitting layer involved the combination and breakdown of the moderator substance, 2,6-bis(3-(9H

carbazol-9-yl)-phenyl)-pyridine (26DCzPPy), as well as the blue dopant bis[2-(4,6-difluorophenyl) pyridinato-C2,N] (picolinato)-iridium(III) (Flrpic) alongside the red dopant species tris[2-(4-n hexyl-phenyl) quinoline] iridium (III) (Hex-Ir(phq)₃) in chloro-benzene. Subsequently, the ensuing mix was deposited onto PEDOT : PSS layer by spin-coating methodology, therefore establishing the emitting membrane. With that, the Surfaces responsible for the emission underwent a baking process at a warmth/ temperature of 80°C for duration of 15 minutes in order to improve the characteristics of the organic material.

Subsequently, in procedure of stamping is utilized to administer the 1,3,5-tris(N-phenylbenzimidazol-2-yl)-benzene (TPBi) electron transport layer (ETL) onto the outside of the emissive layer (EML). The interim substrate that was utilized in this research had been poly-dimethylsiloxane (PDMS). The implementation of an intermediary ultraviolet ozone treatment (UV) is used to tweak/ adapt in the layer of poly-dimethylsiloxane (PDMS), hence facilitating the consistent production of a 4, 4', 4''-tris(N-carbazolyl)-triphenylamine (TPBi) surface using in solution-based technique on the PDMS surface. A little amount of an Extract, Transform, and Load (ETL) solution was combined with chlorobenzene and afterwards applied onto the surface of a Poly-dimethylsiloxane (PDMS) stamp. Following this, the stamps underwent a spin-coating execution, which was then followed by a drying process. Following this, the poly-dimethylsiloxane (PDMS) stamp, which was coated with ethylene tetra-fluoroethylene (ETL), was brought into thermal contact with the substrate that was coated with the emissive layer (EML), while ensuring a temperature of 100°C. Following that, the poly-dimethylsiloxane (PDMS) stamp was carefully extracted, leading to the preservation of the electron transport layer (ETL) in substrate. Following the taking away from the coating, the sample was put through in annealing a temperature in 120°C for a time of 30 m. on a warmer plat. During in last phase of



the instrument fabrication procedure, the materials lithium fluoride (LiF) and aluminum (Al) were exposed to thermal evaporation to fulfill the role of the cathode electrode. The instrument construction exhibited in Figure 1(b) was used for the measurements of current, voltage, and luminescence parameters. These measurements were performed using a Keithley 2400 source meter. The spectrum transmission and CIE coordinates of the gadgets were analyzed using a spectrometer known as the PR650. All measurements were performed under controlled environmental term at a temperature that was maintained at the average ambient temperature.

3. 0 Results and Discussion

3.1 Doping of OLEDs with N-type Compounds

The initial investigation was the fabrication of electron-only electronics using Alq₃ doped with varying amounts of Liq. In this study, three electron-based devices were built, each having the following configurations: The structure consists of an ITO / Al (200 nm) / x (30 nm) / Al (150 nm) configuration, whereas x represents different compositions of Alq₃, namely Alq₃: Liq (10 wt%), Alq₃: Liq (50 wt%), and Alq₃: Liq (80 wt%). Figure 2(a) displays the voltage characteristics of the electron-only gadgets at the ambient temperature, specifically illustrating the association between current density and voltage. The devices containing pure Alq₃, Alq₃: Liq (10 wt%), and Alq₃:Liq (50 wt%) attained a current density of 20 mA/cm² at voltages of 3.2 V, 2.9 V, and 1.8 V, respectively. This observation suggests a significant decrease in material resistance with the introduction of doping. The facile release of lithium during cathode deposition in a Liq arrangement may be attributed to the low binding energy involving lithium and the hydroxyquinoline ligand [5, 13]. The incorporation of Liq into Alq₃ leads to an electron transfer from Liq to Alq₃, as reported in reference [5]. This transfer of electrons results in an elevation of the electron concentration

inside Alq₃ films and causes the Fermi level to get near the LUMO energy level of Alq₃, which is explained in reference [14]. An increase in doping concentrations to 80 wt% led to a rise in the operating voltage to 3.0 V for a current density of 20 mA/cm². This voltage exceeds the injection limit for electrons, which may be attributed to an excessive quantity of Liq in the Alq₃ material. At greater doping concentrations (80wt%), liquid dopants assume dominance in the electron injection process from the aluminum cathode. The injection barrier at the interface between highly doped Alq₃:Liq and Al is found to be greater than that at the interface between weakly doped Alq₃:Liq and Al, when considering the correction for disorder-related barriers [15].

A comparison was made between the normal device using Alq₃/LiF and the n-doped device utilizing Alq₃:Liq (50 wt%) in the context of White Hybrid organic light-emitting diodes (WHOLEDs). Figure 2(b) illustrates the relationship between current density and voltage characteristics for the two devices under consideration. It is evident that, under identical operating voltage conditions, the Alq₃/LiF device exhibits a greater current density in comparison to the Alq₃: Liq device. If the majority of the current flow in the Alq₃/LiF device is attributed to electron injection, it will result in an imbalance between the number of electron and hole carriers. The outcome of this phenomenon is a reduced yield for the Alq₃/LiF device, as seen in Figure 2(b). In this context, yield refers to the ratio of luminance to current density. The use of Alq₃/LiF as a conventional device structure may not be the most optimum approach for achieving an efficient electron injection layer (EIL). This is primarily attributed to two factors: the challenge of consistently depositing LiF with a thickness as thin as 0.5 nm, and the imbalance in the quantity of electron and hole carriers inside the emitting layer.

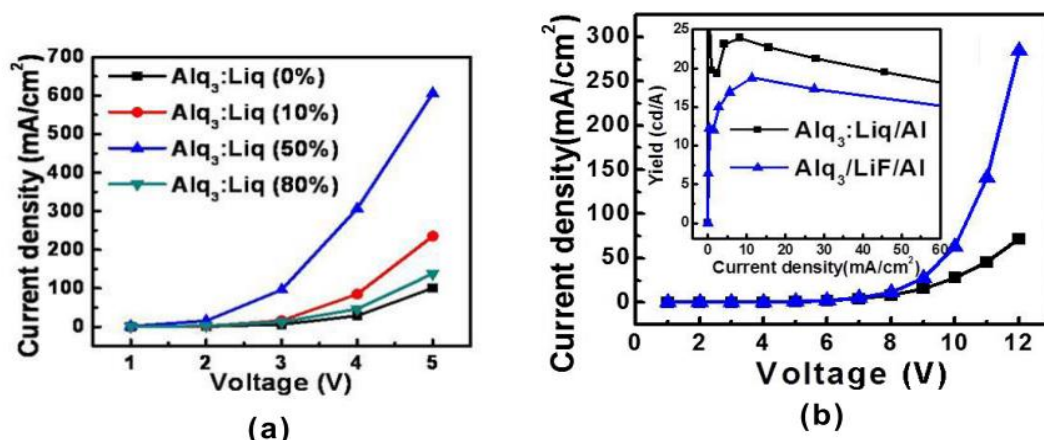


Figure 2: Current density vs voltage characteristics in electron-only components, (b) current density versus voltage characteristics in WHOLEDs. The illustration above shows the current density vs current efficiency characteristics of WHOLEDs.

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In an effort to investigate additionally into the processes of improved electron-injection & transport, thicknesses of Alq₃:Liq-type layers got generated. The doping dosage of Liq was maintained at 50 wt% in all WHOLED devices. An interlayer of undoped Alq₃ was introduced between a layer of Alq₃ doped with Liq and the emissive layer (EML). The thickness of the undoped interlayer was modified to Alq₃/Alq₃:Liq (0/30nm), Alq₃/Alq₃:Liq (5/25nm), Alq₃/Alq₃:Liq (10/20nm), and Alq₃/Alq₃:Liq (15/15nm), correspondingly. Figure 3 illustrates the relationship between current efficiency and current density in WHOLEDs, wherein varying thicknesses of Alq₃/Alq₃:Liq are used. A notable enhancement in the current efficiency was seen with the introduction of Alq₃ as an interlayer, particularly in the low current density range of 0-15 mA/cm². It is evident that the present efficiency exhibits an upward trend as the concentration of undoped Alq₃ grows, whereas it shows a downward trend as the thickness of the Alq₃:Liq layer decreases. Through our experimental procedures, we have determined the optimal thickness for the Alq₃/Alq₃:Liq layer

to be 10/20 nm. The device demonstrated the maximum brightness and current efficiency, measuring 3760 cd/m² and 18.8 cd/A at a current density of 20 mA/cm², respectively. Based on the conducted tests and the cited reference [8], it has been shown that excitons have a high propensity for diffusion from the emissive layer (EML) to the electron injection layer composed of a blend of Alq₃ and Liq, resulting in their subsequent quenching. In addition to the adjustment of the n-doping layer, the inclusion of a blocking layer or interlayer between the emissive layer (EML) and the electron injection layer (EIL) is necessary in order to prevent the quenching of excitons. The compound 3TPYMB has a greater electron mobility compared to Alq₃ and possesses a high highest occupied molecular orbital (HOMO) energy level of 6.77 eV, as seen in Figure 1(a). This characteristic enhances electron injection and effectively prevents hole confinement inside the emissive layer (EML). The interlayer material 3TPYMB was used and its performance in WHOLEDs was compared with that of Alq₃.

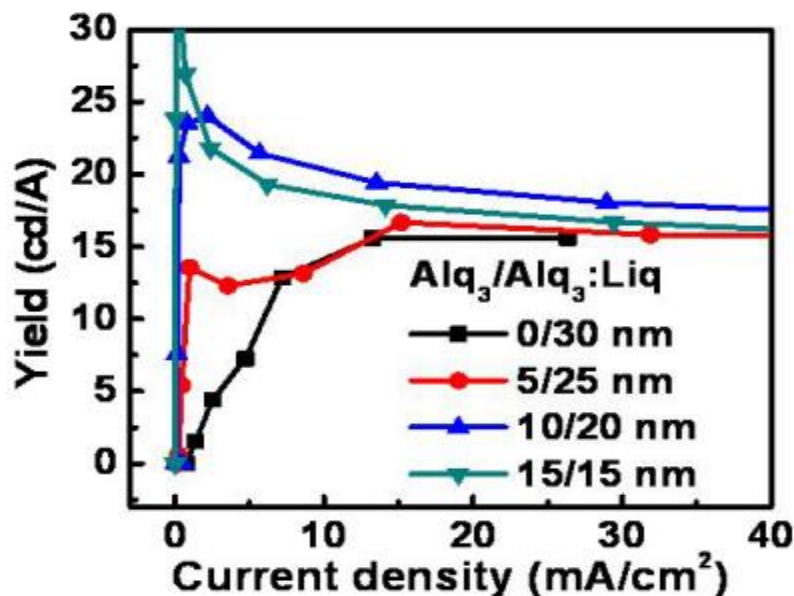


Figure 3 shows the features of WHOLED current efficiency compared to current density.

The structure being referred to is denoted as WHOLED, which consists of the following layers: WHI112/HTG1 (10 nm)/ UBH15:EB502 (10nm, 2wt%)/EPH3:EPY01 (45 nm, 2 wt%)/y/Al (150 nm). In this structure, the variable y represents either Alq₃/Alq₃:Liq or 3TPYMB/Alq₃:Liq. Initially, the hole injection layer WHI112 was maintained at a thickness of 70 nm. Two different combinations of materials, namely Alq₃/Alq₃:Liq (10/20 nm) and 3TPYMB/Alq₃:Liq (10/20 nm), were used to assess and evaluate the current density against voltage characteristics. These results are shown in Figure 4(a). The experimental results indicate that the WHOLED device including WHI112 with a thickness of 70 nm and a 3TPYMB/Alq₃:Liq

composite layer with a thickness of 10/20 nm exhibits a lower current density compared to the WHOLED device with WHI112 at 70 nm and an Alq₃/Alq₃:Liq composite layer with a thickness of 10/20 nm. The observed reduction in current density, as seen in Figure 1(a), may be attributed to the obstructive effect of the high highest occupied molecular orbital (HOMO) of 3TPYMB, which effectively hinders the passage of holes. Hence, it can be shown from Figure 4(b) that the power efficiency of WHOLED with WHI112 70nm and 3TPYMB/Alq₃:Liq 10/20 nm [16] is comparatively lower than that of WHOLED with WHI112 70nm and Alq₃/Alq₃:Liq 10/20 nm.

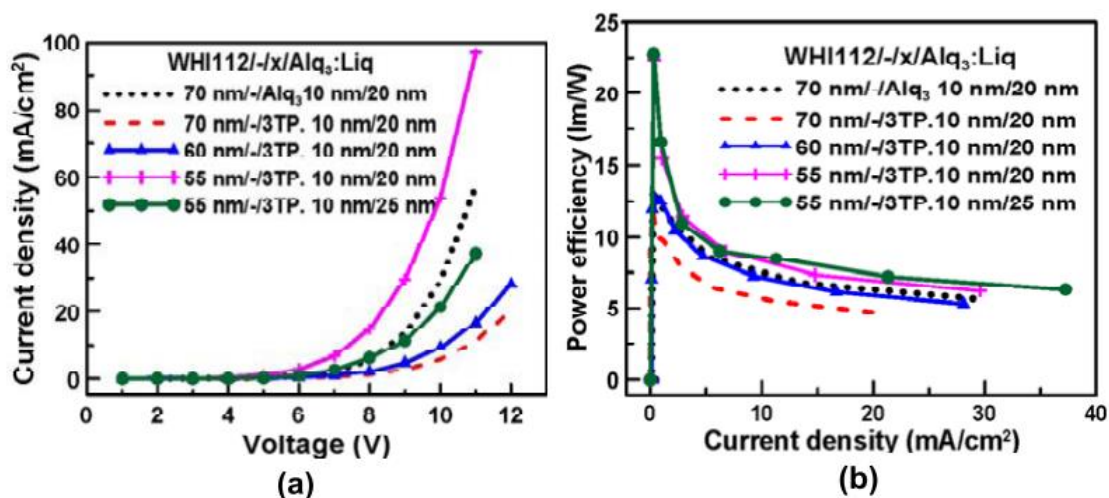


Figure 4 (a) illustrates the relationship between current density and voltage for WHOLEDs. (b) Specifications of power efficiency versus current density for WHOLEDs with varying interlayer and hole injection layer thicknesses.

Furthermore, in order to enhance the current flowing through the hole in WHOLED, the thickness of the HIL was adjusted by reducing it from 70 to 55 nm, while slightly increasing the thickness of the n-doped layer from 20 to 25 nm. When the thickness of the HIL was reduced from 70 to 55 nm, there was a drop in the driving voltage from 11.9 to 8.3 V, and an apparent rise in the current density, as seen in Figure 4(a). Figure 4(b) illustrates the relationship between power efficiency and current density in WHOLEDs that have been enhanced by the optimization of hole injection and n-type doping layers. In order to conduct a more comprehensive examination of the impact of the Alq₃:Liq n-doped layer's thickness on charge injection and transport in whole-organic light-emitting diodes (WHOLEDs), a device with an Alq₃:Liq thickness of 25 nm was built. The device with an HIL thickness of 55 nm and an n-doped Alq₃:Liq thickness of 25 nm achieved a maximum current efficiency of 23.2 cd/A, as shown by the undisclosed data. The power efficiency saw a significant improvement, rising from 4.5 to 7.4 lumens per watt (lm/W) while operating at a current density of 20 milliamperes per square centimeter (mA/cm²). The increase in current efficiency can be attributed to the enhanced charge balance

resulting from the greater injection of electrons from the Alq₃:Liq n-type doping layer. These electrons are then transported through the 3TPYMB interlayer into the EML, effectively blocking holes in the EML. This improved charge carrier balance ultimately leads to an enhancement in the efficiency of the device. This suggests that a reduction in the hetero-junction interface layer (HIL) and a rise in the n-doped layer may serve as effective means of enhancing hole and electron injection, hence improving the efficiency of the device via the equalization of hole and electron currents.

3.2 OLED Stamping Transferring Technique

In the subsequent research on the development of small molecular organic light emitting diodes (SM OLEDs) will be carried out by a solution-based synthesis approach that incorporates an impressive transfer technique. The organization in question is known as ITO/PEDOS. The PSS/26DCzPPy system is used as the host material for blue small molecule organic light-emitting diodes (SM-OLEDs), whereas the 26DCzPPy:Firpic system, supplemented with Hex Ir(phq)₃, is employed for white SM-OLEDs. The PEDOS, namely PSS HIL as well as EML, were created using the spin-coating technique.



Its ETL, known as TPBi, was produced by the use of a stamped transfer process. The TPBi electron transport layer film was spin-coated onto the surface of PDMS. The polydimethylsiloxane (PDMS) was next applied onto the electroluminescent (EML) surface using the stamping transfer technique. This study examines various ETL stamping durations for blue small molecule organic light-emitting diodes (SM OLEDs). The TPBi embossing times of 80s, 100s, and 120s were investigated. Figure 5 illustrates the current efficiency vs current density characteristics of blue small molecule organic light-emitting diodes (SM-OLEDs) with different imprinting periods for the TPBi electron transport layer. When the current density of the devices is less than 10 mA/cm²,

their current efficiencies are found to be zero. The drop in brightness seen in these devices may be attributed to their high working voltage of 6.2V. The gadget that had a stamping period of 100 seconds had the most favorable attributes. The luminance value of the object under consideration is measured to be 1240 candela per square meter (cd/m²). Additionally, it exhibits a current efficiency of 2.48 candela per ampere (cd/A) and operates at a voltage of 6.2 volts (V) when subjected to a current density of 40 milliamperes per square centimeter (mA/cm²).

Furthermore, it was also demonstrated that the performance of the electronics improves as a consequence of reducing the thickness of the electron transport layer (ETL) from 32 to 27 nm,

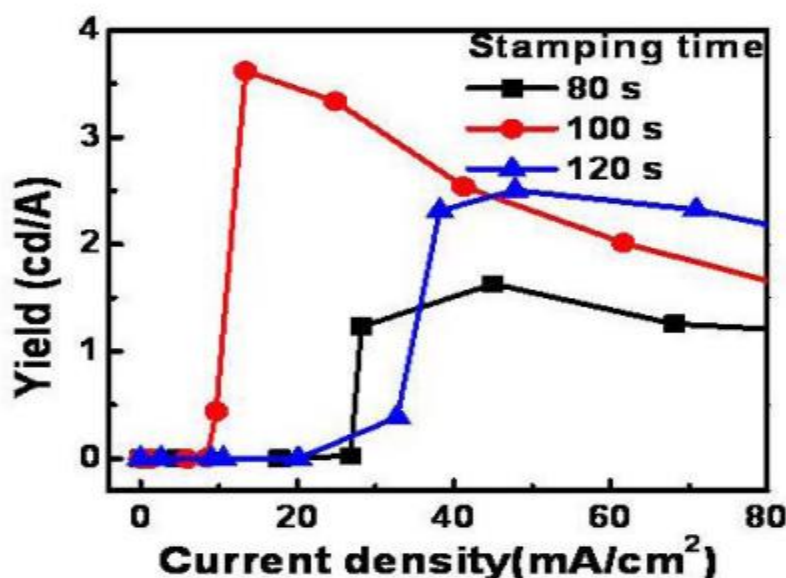


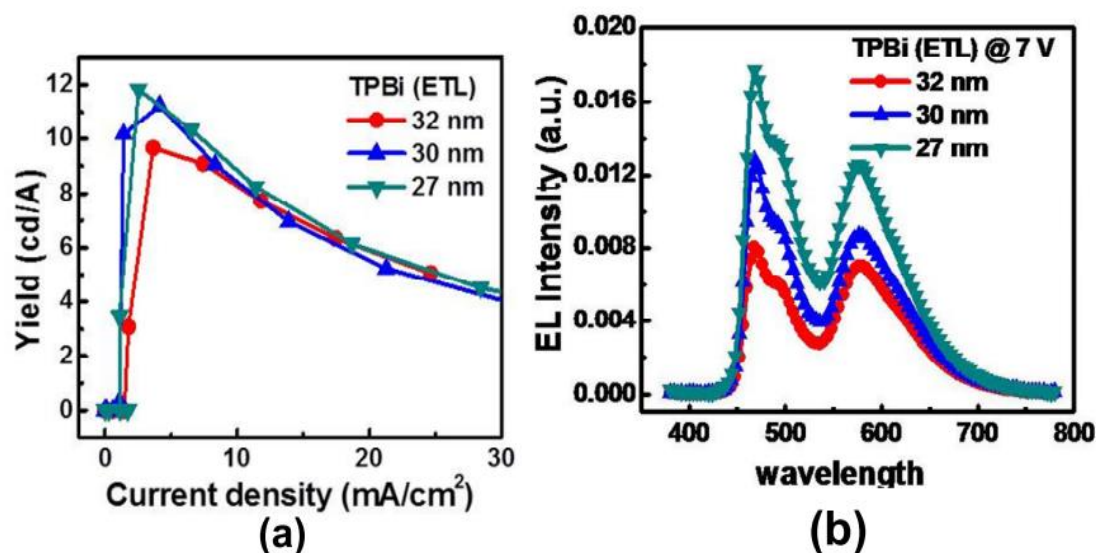
Figure 5 illustrates the current efficiency vs current density characteristics of blue blue SM-OLEDs with varying ETL stamping periods.

While maintaining a constant thickness for the active layer. The thicknesses of the ETL were manipulated by altering the spin coating speed, while consistently using the TPBi the solution on PDMS. Figure 6(a) illustrates the relationship between current efficiency and current density for white SM-OLEDs. It has been shown that the performance of white small molecule organic light-emitting diodes (SM OLEDs) has a significant correlation with the thickness of the

electron transport layer (ETL). The device that used an electron transport layer (ETL) with a thickness of 27 nm demonstrated superior performance due to its effective electron injection into the emissive layer (EML). The brightness of the given system is measured to be 892 candela per square meter (cd/m²), while the current efficiency is determined to be 8.9 candela per ampere (cd/A) at a current density of 10 milliamperes per square centimeter

(mA/cm²). The reduction in TPBi thickness from 32 to 27 nm resulted in a drop in operating voltages from 7.7 to 6.2 V. Based on the findings presented, it can be concluded that the optimal thickness for ETL in SMOLED is 27 nm. The surface topography exhibits a decrease in roughness when the film thickness is decreased to 27 nm. It is noteworthy that in the context of film thickness, thick films are often spun at moderate speeds, whereas thin films are spun

at high speeds. The impacts may be categorized as either direct, resulting from the change in the characteristics of the ETL itself, or indirect, arising from the impact of the surface properties of the ETL on the stamping transfer qualities. The external quantum efficiency (EQE) of TPBi thick films with thicknesses of 32 nm and 27 nm exhibited a change in values from (0.36, 0.38) to (0.33, 0.37).



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Figure 6(b) displays the electroluminescence (EL) spectra of the white small molecule organic light-emitting diodes (SM-OLEDs) that were produced using various electron transport layer (ETL) stamping transfer thicknesses.

The electroluminescence spectra were recorded at a voltage of 7 volts. The device including the solution emitting layer exhibited a characteristic electroluminescent emission in the blue and yellow regions, which was attributed to the presence of Flrpic and Hex-Ir(phq)₃. Nevertheless, the device exhibited a high intensity electroluminescent (EL) spectrum when the electron transport layer (ETL) had a thickness of 27 nm, surpassing the intensities achieved with ETL thicknesses of 30 nm and 32 nm under identical operating voltage conditions. This observation implies that the efficiency of charge transfer is higher for the 27 nm thickness. This suggests that the transfer of charge from the cathode to the emissive layer (EML) takes place inside the reduced electron

transport layer (ETL) layers. Incorporating a thinner electron transport layer (ETL) might potentially boost the electron injection and transport capability to a greater extent.

4.0 Conclusion

The effective enhancement of electron injection with hole blocking capability was accomplished with the deployment of a 10 nm thick Liq-doped Alq₃ obstacle as well as an n-doped layer, in combination with a 25 nm wide 3TPYMB interlayer/hole blocking obstacle. Consequently, the enhancement in the injection of electrons and transport effectiveness occurred due to an improvement in the electron injection barrier and an improvement in electron mobility. The previously mentioned enhancements played a

significant role in attaining a more favorable equilibrium of charge carriers inside whole-hybrid organic light-emitting diodes (WHOLEDs), eventually leading to enhanced device effectiveness. The total efficiency of the entire gadget, denoted as WHOLED, saw a substantial improvement, rising from 18.1 to 22.3 cd/A, when the electron injection layer (EIL) was altered from Alq₃/LiF to Alq₃:Liq, while maintaining a current density of 20 mA/cm². The system's efficiency shown a significant enhancement, increasing from 15.6 to 18.8, when subjected to a current density of 20 mA/cm². This increase coincided with a modification in the thickness of the Alq₃/Alq₃:Liq layer, transitioning from 0/30 to 10/20 nm. Furthermore, it was noted that the overall efficiency of the device, referred to as WHOLED, saw a rise from 18.8 to 23.2 when the thickness of the hole injection layer (HIL) was decreased from 70 to 55 nm. The enhancement was accomplished by the implementation of a 3TPYMB interlayer positioned between the emissive layer (EML) and the electron injection layer (EIL). The concept asserts that the utilization of Liq-doped Alq₃ demonstrates potential as a proficient electron injection barrier within the category of white hybrid organic light-emitting diodes (WHOLEDs). Suspension based refining and ETL stamped pass on can be used as another methods in the fabrication of white-SM-OLEDs. The efficiency in blue SM OLED in increased from 1.02 to 2.48 cd / A at a current density of 50 mA / cm² by changing the duration of the stamping time from 80 to 100 a second. Moreover, an increase in the efficiency of white SM-OLEDs was noted, with in value rising from 8.25 to 8.9 cd / A when the current density reached 10 mA/cm². Moreover, an alteration in the coordinates of the CIE (Commission Internationale de l'Eclairage was observed, specifically shifting from (0.36, 0.38) to (0.33, 0.37), in conjunction with a decrease in the measured width in electron transport layer (ETL) from 32-27 nm. The use of stamping transfer has made possible the development of efficient multilayered SM-OLEDs, consequently

which will enable the replacement by thermal evaporation as the deposition technique for organic layers in potential electronic displays.

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