Optical and Electrical Properties of OLED with the Structure of ITO/ m-MTDATA/Meo-TPD/Alq3/LiF/Al

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Abstract. In this paper, the organic light emitting device (OLED) with the structure of ITO/m-MTDATA/Meo-TPD/Alq3/LiF/Al has been fabricated using Alq3 as a light-emitting layer, m-MTDATA(4,4’,4’’-tri(3-methyl-phenylphenylamino)triphenylamine) as a hole injection buffer layer and Meo-TPD (N, N’, N’-tetakis (4-methoxyphenyl)-benzidine) as a hole transport layer, as well as luminous and electrical properties were studied. The turn on voltage of device is about 6V. Its maximum brightness reaches 14300cd/m2 with applied voltage of 13V, sixteen times higher than that of the structure of ITO/Alq3/LiF/Al. When the applied voltage is 8V, the electroluminescence spectra peak is at 540nm, showing green.

1. Introduction
In recent years, OLED has been widely used because of its low driving voltage, wide viewing angle, fast response, wide range of alternative materials, flexible displays, etc [1-2]. 8-hydroxyquinoline aluminum (Alq3) is first used by Kodak as light-emitting layer of EL device materials, as a result of its high glass transition temperature, good film forming, good carrier transport properties, high luminous efficiency and good stability, which has been widely used in organic light-emitting device. Its electron mobility was about 10^{-5}cm^2 V^{-1} s^{-1}, which is lower by two orders of magnitude than hole mobility of the usual hole transport material TPD or NPB [3-4]. The LiF of appropriate thickness is added between the Alq3 and the Al electrode to form composite electrodes, which can reduce Al diffusion from the metal electrode to organic light-emitting layer, making electrode and organic layer form a good interface characteristic, delay the photochemical and electrochemical aging of the device, and improve the device stability; which can reduce the effective potential barrier height of interface, and enhance the efficiency of carrier injection.

High heat stability (high glass transition temperature Tg), reducing interface energy potential barrier of the anode and hole transport layer, and good film-forming properties, which are the main requirements of hole injection layer [5-9]. In this paper, organic light-emitting device of multi-layer structure ITO/m-MTDATA/Meo-TPD/Alq3/LiF/Al has been fabricated. The hole injection layer m-MTDATA (4,4’,4’’-tri(3-methyl-phenylphenylamino)triphenylamine) was added between the ITO and hole transport layer Meo-TPD (N, N’, N’-tetakis (4-methoxyphenyl)-benzidine), due to its relative stability, preventing effectively indium ions diffusing from the anode to hole transport layer, good film coating, as well as hole injection capability, which greatly reduce the barrier height between the anode and hole transport layer, in favor of improving the brightness of light-emitting device and the balance of carrier injection, and reducing turn-on voltage.
2. Experiment

2.1. Preparation of light-emitting device

First, selecting the size of 30mm × 30mm ITO glass as the substrate, cleaning it for 10 minutes with acetone, ethanol, deionized water ultrasonically, respectively, and then drying it for 5 minutes, again using ultraviolet radiation raying it for 1 minute. Using 2001 multi-source automatic temperature control system of organic molecules to deposit films, when air pressure of the main evaporation chamber is 3.9×10^-4 Pa, evaporating thin films of m-MTDATA, Meo-TPD, Alq3, and LiF on the ITO surface sequentially, and finally depositing Al with DM-300B vacuum evaporation machine. Deposition rate of m-MTDATA, Meo-TPD and Alq3 is 0.2 nm / s, that of LiF and Al is 0.1 nm / s and 1 nm / s, deposition thickness of m-MTDATA, Meo - TPD, Alq3, LiF, and Al are respectively 45 nm, 5 nm, 50 nm, 1 nm and 100 nm, with the FTM-V film thickness instrument monitoring thickness at the same time. The area of light-emitting device is 2×2 mm2.

Structure of the device is ITO / m-MTDATA/Meo-TPD/Alq3/LiF/Al is shown in Figure 1. ITO as the anode, m-MTDATA as hole injection layer, Meo-TPD as hole transport layer, Alq3 as the electron transport layer and light-emitting layer, LiF / Al as composite cathode.

![Figure 1. Schematic diagram of the device structure](image)

2.2. Experimental material

As a hole injection layer, m-MTDATA namely 4, 4', 4"-tri (3-methyl-phenylphenylamino) triphenylamine, star-type structure is shown in Figure 2, melting point is 203-207 °C, the glass transition temperature is 75 °C, ionization potential is 5.1 ev, affinity energy is 1.9 ev, its state is very similar to the glass material, so it can be deposited evenly on the ITO substrate.

![Figure 2. Star-type structure drawing of m-MTDATA](image)

2.3. Experiment and analysis

After fabricating the device, testing its Current - voltage (IV) characteristics, the brightness - voltage (BV) characteristics, electroluminescence spectra immediately at room temperature under atmospheric environment, using the PR-650 spectral luminance meter. Figure 3 shows the current - voltage characteristic curve, which can be seen from the figure, that the current sharply jumps as the voltage exceeds 6V, the curve shows a typical diode characteristics.
Figure 3. Current - voltage characteristics curve of device

Brightness - voltage curve of device is shown in Figure 4. The turn on voltage of the device is 6V, when the applied voltage is 13V, the device reaches its maximum brightness 14300cd/m². Owing to the Meo-TPD as hole transport layer and m-MTDATA as buffer layer, the light-emitting brightness of device is 16 times higher than that of simple structure of ITO / Alq3/LiF (1nm) / Al, whose light-emitting brightness is about 850 cd/m² with applied voltage of 13V[10].

Figure 4. Brightness - voltage curve of device

Light-emitting mechanism of organic light-emitting device is that electron from cathode and hole from anode inject into the light-emitting layer respectively, under the influence of external electric field, hole and electron encounter to form exciton, exciton shows radioluminescence in the light-emitting layer, but because of the imbalance of the hole and electron injection, as well as the difference of the migration rate, carriers from both electrodes can not effectively be limited in light-emitting layer to form exciton, leading some of the excess carriers reach electrode, then making the light quenching at the electrodes, reducing the luminescence efficiency.

Considering about ionization energy, the lower the potential barrier of interface between the hole transport layer and the anode is, the easier hole injecting is. In this paper, using the m-MTDATA of 45 nm thickness as a hole injection buffer layer, the highest occupied molecular orbital energy (HOMO) of m-MTDATA is -5.1 eV, higher than the HOMO level of the Meo-TPD (-5. 7 eV). Barrier height between ITO and m-MTDATA is 0.4 eV, but 1eV between ITO and Meo-TPD. The hole injection layer makes more holes inject into the transport layer, and holes and electrons combine more effectively in the light-emitting layer, increasing the brightness of the current and lowering turn-on voltage.

Figure 5 shows the electroluminescence spectra as the applied voltage is 8V, the maximum peak of the light-emitting device is 540nm, CIExy = (0.3629, 0.5309), light-emitting source is Alq3.
Figure 5. electroluminescence spectra of the device

3. Conclusion
m-MTDATA as a hole injection buffer layer improves the device's ability to enhance the hole injecting and boost the recombination rate of exciton, LiF / Al composite cathode enhances electron injection capacity of the device, thus the device current and brightness have been enhanced, as well as turn on voltage lowers. Owing to the Meo-TPD hole transport layer and m-MTDATA buffer layer, brightness of the device has been greatly improved, its maximum brightness reaches 14300cd/m² in the 13V, turn on voltage is about 6V, electroluminescence spectra peak is at 540nm when the applied voltage is 8V.

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