Organic Light-Emitting Diodes based on m-MTDATA as Hole Injection Layer

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Abstract

Three-color organic light-emitting diodes (OLEDs) of metal-semiconductor-metal (MSM) structure have been favricated by using m-MTDATA [4,4',4"-tris (3-methylphenylphenylamino) triphenylamine] as hole injection layer(HIL). The m-MTDATA is shown to be an effective hole injecting material, in that the insertion of m-MTDATA greatly reduces the roughness of anode surface and improves the device performance. Red, green and blue OLEDs were fabricated, and their color coordinates in CIE chromaticity were found to be (0.600, 0.389), (0.240, 0.525), and (0.171, 0.171), respectively. The luminous efficiencies of the fabricated OLEDs were 1.4 lm/W at 106 cd/m^2 for red, 1.4 lm/W at 100 cd/m^2 for green, and 2.0 lm/W at 104 cd/m^2 for blue.

1. Objectives and Background

Organic light-emitting diodes (OLEDs) have recently drawn much attention in the display industry due to their characteristics of fast response speed, no viewing angle dependence and full-color capability. OLEDs can also be made thin and flexible with low driving voltage, which makes them more attractive. Since the bilayer OLED that is consisted of hole transport layer and emitting layer was first reported by Tang and VanSlyke[1] in 1987, a great deal of research efforts were made to achieve higher brightness and luminous efficiency.

Brightness of OLEDs can be enhanced at relatively low driving voltage if luminous efficiency is improved, and it is desirable to have thinner layers of evaporated organic emitting material to lower the driving voltage at otherwise same conditions.

If thickness of emitting material becomes too thin, however, leakage current may develop caused by pinholes in the emitting layer during the deposition process. And if thickness of emitting material becomes too thick, the luminous efficiency usually decreases due to the increased resistance and light absorption in the emitting layer, which in turn requires higher driving voltage. The difference in energy band structures between electrodes and emitting materials can cause the resistance at the interfaces which also deteriorates the device performance.

A method of inserting charge injection layer between electrode and emitting layer is widely used to cope these problems, and most of the commercialized OLEDs include some type of charge injection layers in their device structures. The charge injection layer should have proper energy band structure which reduces energy barrier between electrode and emitting layer. Also, it is desirable for the charge injection layer to be less sensitive to the thickness variation. Amorphous film formation without pinholes is also critical for charge injection layers.

In this study m-MTDATA [4, 4 ', 4" - tris (3-methylphenylphenylamino)triphenyl amine][2,3] , PEDOT (Poly-3, 4 – ethylene dioxythiophenes)[4] and CuPc (copper phthalocyanine)[5] were tested and compared as candidate hole injection layers, and m-MTDATA was incorporated in 3-color(red, green, blue) OLEDs to improve the device performance.

2. Results and Discussion

The surface roughness before and after coating the coated PEDOT, m-MTDATA and CuPc on ITO-glass substrate was first

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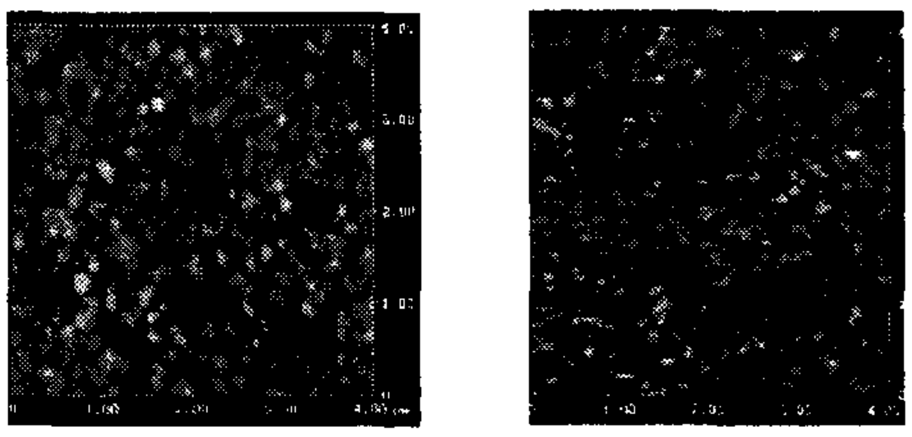
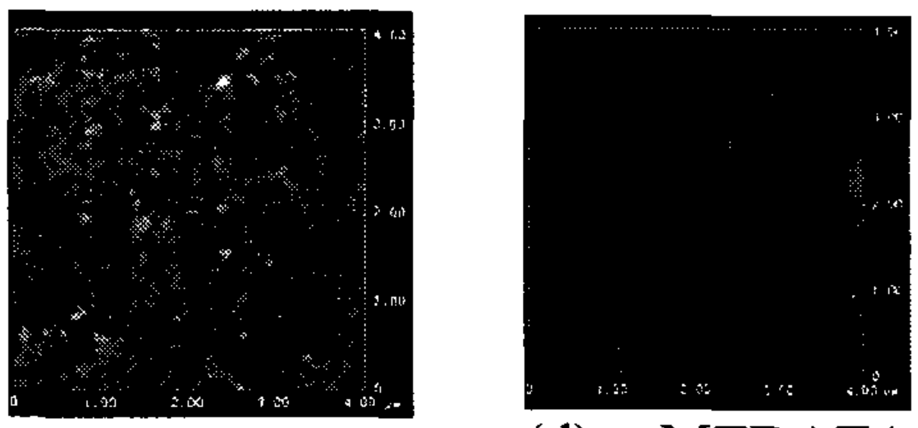
analyzed by AFM.

Fig. 1 shows the AFM images of surface coated by various HILs, and it was found that rms (root-mean-square) roughness generally decreases by coating of HILs. Substrate coated with m-MTDATA showed the best surface roughness (1.097 nm) among the three HILs tested in this study. It is also found that the m-MTDATA film shows the least thickness variation effect on the device performance among the three HILs tested.



(a) bare ITO (b) ITO/CuPc



(c) ITO/PEDOT (d)m-MTDATA

Fig. 1. AFM images of substrate surface; (a)bare ITO surface (rms roughness: 2.737 nm) (b)ITO/CuPc surface (rms roughness: 2.591 nm), (c)ITO/PEDOT surface (rms roughness: 1.118 nm), (d)ITO/m-MTDATA surface (rms roughness: 1.097 nm).

The electrical and optical characteristics of red, green and blue OLEDs using m-MTDATA as HIL were then measured. The device structures and performances are listed in Table 1, and it shows that the use of m-MTDATA greatly lowes the turn-on voltage and improves luminous efficiency in all cases. In the case of green OLED, the turn-on voltage has been lowered by 3.5 V when m-MTDATA is inserted, compare to that without the m-MTDATA. This turn-on voltage decrease was believed to be caused by the improvement of injection efficiency by insertion of m-MTDATA layer. Brightness at 6 V was increased from 2850 cd/m^2 to 3910 cd/m^2 when m-MTDATA was used as HIL, yielding luminous efficiency of 1.4 lm/W at 100 cd/m^2.

The device performances were similarly improved by the insertion of m-MTDATA for red and blue OLEDs.

3. Acknowledgements

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4. References

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Table 1. Characteristics of OLED structures

Structure	Turn-on (V)	Maximum Luminescence (cd/㎡)	Luminous Efficiency (lm/W)
Red (ITO/m-MTDATA /TPD/Alq_3:DCM2:Rubrene/Al:Li)	4.6	1,900 at 16 V	1.4 at 106 cd/m^2
Green (ITO/m-MTDATA/TPD/Alq_3/Al:Li)	2.3	3,910 at 6 V	1.4 at 100 cd/m^2
Blue (ITO/m-MTDATA/TPD/Bathocuproine/Alq_3/Al:Li)	3.4	125 at 10 V	2.0 at 104 cd/m^2