Fabrication of Red, Green, and Blue Organic Light-emitting Diodes using m-MTDATA as a Common Hole-injection Layer

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Abstract

Organic light-emitting diodes (OLEDs) of metal-semiconductor-metal (MSM) structure have been fabricated by using m-MTDATA [4,4',4"-tris (3-methylphenylphenylamino) triphenylamine] as a hole-injection layer (HIL). The m-MTDATA is shown to be an effective hole-injecting material for the OLED, in that the insertion of m-MTDATA greatly reduces the roughness of anode surface and improves the device performance.

1. Objectives and Background

Organic light-emitting diodes (OLEDs) have recently drawn much attention in the flat-panel display (FPD) industry due to their characteristics of fast response speed, no viewing-angle dependence, and full-color capability. OLEDs can be made thin and flexible with relatively low driving voltage (< 5 V), which makes the attractive for the flexible display applications.[1] The m-MTDATA [4,4',4"-tris (3-methylphenylphenylamino) triphenyl amine] has been recently investigated as a candidate for hole injecting and transport material, and it was shown that m-MTDATA can form an excellent amorphous film with suitable material as hole-injection layer(HIL).[2]

In this study, the use of m-MTDATA as HIL for OLEDs was revisited to further elucidate the distinctive property of m-MTDATA as HIL and to seek the feasibility of using m-MTDATA as the invariant HIL for multi-color OLED displays. Comparison of m-MTDATA with other commonly used hole-injecting materials such as PEDOT (poly-3,4 ethylene dioxythiophenes) and CuPc (copper phthalocyanine) was made in the context of surface reconstruction and device performance. Three different-color (red, green, and blue) OLEDs were fabricated using m-MTDATA as the common HIL in these devices, and their device characteristics were analyzed

2. Results

The surface morphology of ITO-glass before and after coating the three HIL materials (i.e. PEDOT, m-MTDATA and CuPc) were analyzed and compared by AFM. The RMS (root-mean-square) roughness decreased upon coating of hole-injection layer, and substrates coated with m-MTDATA showed the lowest surface roughness (1.096 nm) among the three hole-injecting materials tested in this study. In the CuPc case, surface roughness was only slightly improved (2.519 nm) from that of bare ITO (2.737 nm). It is interesting to note that thermally evaporated m-MTDATA film shows comparable or even better surface roughness compared with the roughness (1.118 nm) of spin-coated PEDOT surface. The improvement of surface roughness by m-MTDATA coating is attributed to its dense and amorphous film forming capability as observed by previous investigators,[2, 3] and such an improvement in surface morphology can help enhance the device performance by allowing more uniform charge transport from the anode to the hole-transport layer, resulting in the reduced short-term device degradations mostly caused by local joule-heating effects.

The electrical and optical characteristics of the green OLEDs fabricated with or without using HIL were investigated and compared. As clearly shown in the figure, the turn-on voltage was lowered when HIL was inserted, indicating that the charge injection from the anode was facilitated by the presence of HIL. The lowest turn-on voltage (2.3 V) was obtained with m-MTDATA among three HIL materials tested in this study.

Improvement in the luminous efficiency was also observed with the insertion of HIL. Brightness measured at 6 V increased from 2750 cd/m2 (without HIL) to 4510 cd/m2 (with CuPc). In the m-MTDATA case, the brightness measured at 6 V was 3910 cd/m2, and the calculated luminous efficiency was 1.4 lm/W at 100 cd/m2. Among the three HIL materials tested, m-MTDATA showed the best characteristics in surface roughness and turn-on voltage. These results clearly indicate that the HIL enhances the OLED performance by smoothing the anode surface (allowing more uniform charge transport) and facilitating the injection of holes (by lowering the energy barrier between the anode and hole-transport layer).

Red, green, and blue OLEDs were fabricated by using m-MTDATA as HIL. As stated earlier, m-MTDATA was used as the invariant HIL material for all these OLEDs, and the material combinations were designed in such a way that unnecessary change of materials is minimized. The fabricated OLEDs showed fairly good and comparable device characteristics among different color devices in the turn-on voltage (< 5 V) and luminous efficiency (> 1 lm/W), even though the material combination is not individually optimized for the best performance. The OLEDs made with m-MTDATA also showed suitable characteristics as commercial devices, in that the devices were less sensitive to the variation of HIL thickness (10 nm to 50 nm), interfacial integrity, and process reproducibility.

3. Impact

In this research, red, green, and blue OLEDs using m-MTDATA as a common hole injection layer were fabricated, and their device characteristics were measured and compared. It was found that the m-MTDATA could be successfully incorporated as a common hole injection layer for multi-color OLED display devices in the commercial applications. The improved device performance by the m-MTDATA could be explained by the improved anode surface morphology and lowered hole injection barrier height. The m-MTDATA also provided suitable characteristics for mass production such as process reproducibility and controllability.

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5. References

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