Color-stabilized organic light-emitting devices by using N, N'-bis-(1-naphthyl)-N, N'-diphenyl-1,1-biphenyl-4,4'-diamine/5,6,11,12 - tetraphenylnaphthacene multiple quantum well structures

Y.B.Yoon and T.W.Kim
Advanced Semiconductor Research Center, Department of Electronics and Computer Engineering, Hanyang University, 17 Haengdang-dong, Seongdong-gu, Seoul 133-791, Korea
H.W.Yang
Department of Information and Communications, Hanyang University, Seoul 133-791, Korea
H.G.Lee
Department of Information Display Engineering & COMID, Hong-ik University, Seoul 121-791, Korea
J.H.Kim
Department of Information Electronic Engineering, Hong-ik University, Seoul 121-791, Korea
Y.G.Kim
Department of Chemical Engineering, Hong-ik University, Seoul 121-791, Korea

Abstract

The efficiency and the optical properties of the yellow organic light-emitting devices (OLEDs) were significantly affected by the existence of the multiple quantum well (MQW) structures consisting of N, N'-bis-(1-naphthyl)-N, N'-diphenyl-1,1-biphenyl-4,4'-diamine(NPB)/5,6,11,12 - tetraphenylnaphthacene (rubrene). The maximum efficiency and the luminance of OLEDs with 3-periods of the NPB/rubrene MQWs at 41.6 mA/cm^2 were 3.66 cd/A and 1524 cd/m^2, respectively, and their Commission Internationale de l'Eclairage chromaticity coordinates were (0.34, 0.55), which indicates a yellow color. These results indicate that the efficiencies of the OLEDs by using MQW emitting layers can be improved.

.

I. Introduction

Potential applications of organic light-emitting devices (OLEDs) in promising next-generation full-color flat-panel displays have driven extensive efforts to enhance brightnesses and efficiencies [1,2]. OLED displays are particularly attractive because of their promising applications, which offer various advantages of a low driving voltage, a low power consumption, a high contrast, a wide viewing angle, a low cost, and a fast response [3, 4]. Even though some works on enhancing the OLED efficiency by using organic MQWs have shown an improved balance of holes and electrons in the emitting layers [5], systematic studies concerning on OLEDs utilizing MQW emitting layers are necessary for achieving good color stability.

This paper reports the electrical and the optical properties of OLEDs utilizing MQWs deposited by using organic molecular-beam deposition (OMBD). Current density-voltage, luminance-voltage, efficiency-current density, and electroluminescence (EL) measurements were carried out to investigate the electrical and the optical properties of the Al/Liq/Alq_3/MQWs/NPB/ITO/glass structures with and without MQWs. The MQWs consisted of both N, N'-bis-(1-naphthyl)-N, N'-diphenyl-1, 1-biphenyl-4,4'-diamine(NPB) and 5,6,11,12 - tetraphenyl-naphthacene (rubrene). The Commission Internationale de l'Eclairage (CIE) chromaticity coordinates corresponding to the emission color were determined.

II. Experimental Details

The two kinds of samples used in this study were deposited on ITO thin films coated on glass substrates by using OMBD with effusion cells and shutters and consisted of the following structures from the top: an Al (100 nm) cathode electrode, a Liq (2 nm) electron injection layer, an Alq_3 (60 nm) electron transport layer, zero period or a 3-period NPB/rubrene MQW emitting layer, an NPB hole transport layer, an ITO anode electrode, and glass substrates. The NPB/rubrene MQW emitting layer is used to enhance the OLED efficiency due to the existence rubrene molecules, which act as hole trap in the OLEDs. Schematic energy band diagrams of the Al/Liq/Alq_3/MQWs/NPB/ITO/glass structures (a) without and (b) with MQW emitting layers are shown in Figs. 1-(a) and 1-(b), respectively.

III. Results and Discussion

The efficiency of the OLEDs with 3 periods of MQWs is higher than those of the OLEDs without MQWs at all current density regions, and it starts to decrease gradually above 40 mA/cm^2. This enhancement of the OLED efficiency with 3 periods of MQWs at low current densities originates from more holes being accumulated in the MQWs. However, when the applied voltage is increased and the current density exceeds 40 mA/cm^2, the number of holes accumulated in the MQWs begins to decrease, as does the efficiency. The efficiency and the luminance of the OLEDs with 3 periods of MQWs at 41.6 mA/cm^2 are 3.66 cd/A and 1524 cd/m^2, respectively. The efficiency and the luminance of the OLEDs without MQWs at 10 mA/cm^2 are 2.2 cd/A and 230 cd/m^2, respectively. The efficiency and the luminance of the OLEDs with MQW emitting layers at 10 mA/cm^2 is much larger than those without MQW emitting layers. Since the holes emitted from the anode are trapped in the NPB/rubrene MQWs during transport, the output current of the OLEDs with MQWs at the same driving voltage is lower than that without MQWs, as shown in Fig. 2.

The full width at half maximum (FWHM) at 12 V of the EL spectrum for the OLEDs without and with a 3 period of MQWs are 80 and 77 nm, respectively. The FWHMs of the EL spectra for the OLEDs with 3 periods of MQWs studied in this work were narrower than that for the OLEDs without NPB/rubrene MQW emitting layers. Thus, the FWHM of the EL peak corresponding to the rubrene increases due to the existence MQWs. The CIE coordinates at 12 V for the Al/Liq/Alq_3/MQWs/NPB/ ITO/glass structures without MQWs and with 3 periods of MQWs are (0.31, 0.57) and (0.34, 0.55), respectively, as shown in Fig. 3. The coordinates for the OLED with 3 periods of MQWs corresponds to a stabilized yellow color, which is emitted from the rubrene layer.

IV. Summary and Conclusions

The efficiency and the optical properties of the yellow OLEDs are significantly affected by the existence of the NPB/rubrene MQW emitting layers. The maximum efficiency and the luminance of OLEDs with 3-periods of MQWs at 41.6 mA/cm^2 were 3.66 cd/A and 1524 cd/m^2, respectively, and their CIE chromaticity coordinates were (0.34, 0.55), which corresponds to a yellow color. These results indicate that OLEDs utilizing a NPB/rebrene MQW layer hold promise for potential applications as yellow sources in full-color displays.

V. Figure Captions

Fig. 1. Schematic energy band diagrams of the Al/Liq/Alq_3/MQWs/NPB/ITO/glass structures (a) without MQWs and (b) with 3 periods of NPB/rubrene MQW emitting layers.

Fig. 2. (a) Current density as functions of the applied voltage. The insert indicates luminances as a functions of the applied voltage. (b) Efficiencies as functions of the current density for the structures with 3periods of MQWs.

Fig. 3. Commission Internationale de l`Eclairage coordinates at 12V for the Al/Liq/Alq_3/MQWs/NPB/ITO/glass structures (a) without MQWs and (b) with 3 periods of NPB/rubrene MQWs.

Acknowledgement

This work was supported by a Korea Research Foundation Grant. (KRF-2004-015-000166)

References

[1]. C. W. Tang and S. A. Van Slyke, Appl. Phys. Lett. **51**, 913 (1987).

[2]. M. A. Baldo, D. F. O' Brien, Y. You, A. Shoustikov, S. Sibley, M. E. Thompson, and S. R. Forrest, Nature **395**, 151 (1998).

[3]. M. A. Baldo, M. E. Thompson, and S. R. Forrest, Nature **403**, 750 (2000).

[4]. T. A. Baldo and S. R. Forrest, Phys. Rev. B **62**, 10958 (2000).

[5]. Y. Qiu, Y. Gao, L. Wang, P. Wei, L. Duan, D. Zhang, and G. Dong, Appl. Phys. Lett. **81**, 3540 (2002).

Figures

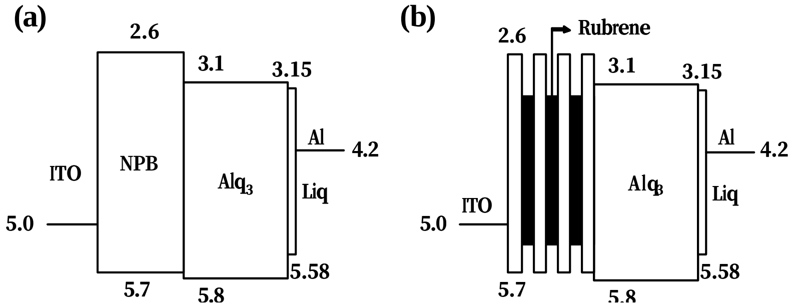

Fig. 1. **Schematic energy band diagrams of the Al/Liq/Alq_3/MQWs/NPB/ITO/glass structures (a) without MQWs and (b) with 3 periods of NPB/rubrene MQW emitting layers.**

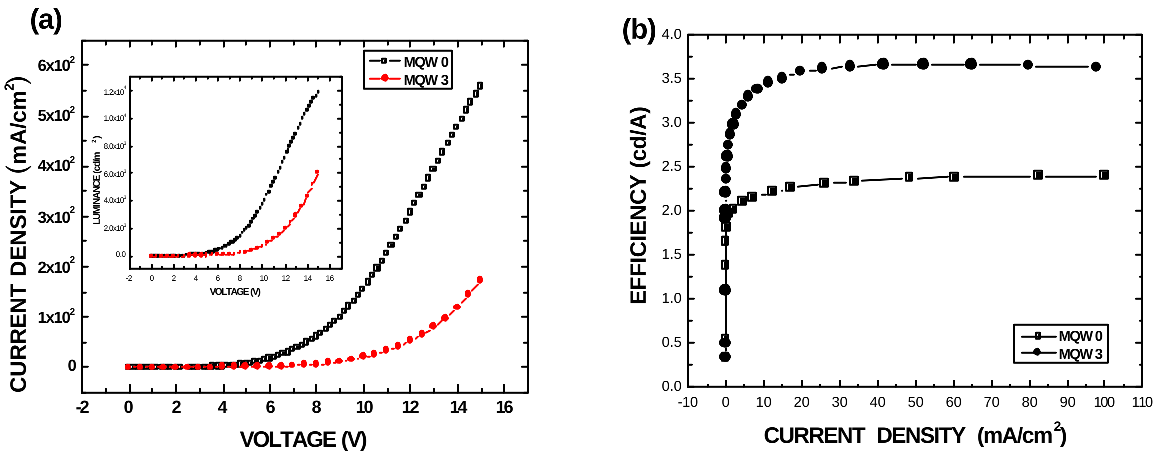

Fig. 2. **(a) Current density as functions of the applied voltage. The insert indicates luminances as a functions of the applied voltage. (b) Efficiencies as functions of the current density for the structures with 3periods of MQWs.**

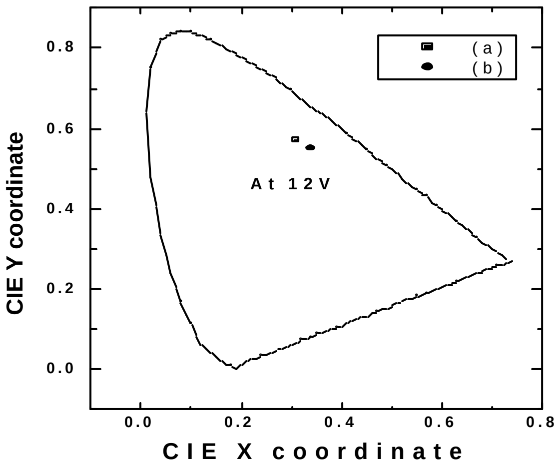

Fig. 3. **Commission Internationale de l`Eclairage coordinates at 12V for the Al/Liq/Alq_3/MQWs/NPB/ITO/glass structures (a) without MQWs and (b) with 3 periods of NPB/rubrene MQWs.**