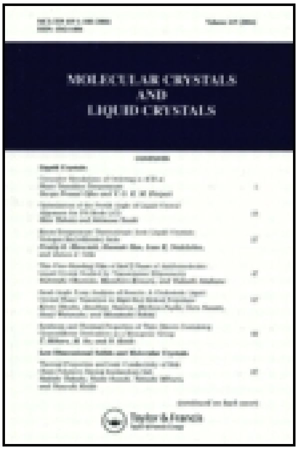

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A STUDY FOR LUMINESCENT PROPERTIES OF OLEDs USING Alq_2-Ncd AS AN EMITTING LAYER

Hee-Chan Yoon [a] , Ki-Sung Yang [a] , Hoon-Kyu Shin [a] , Byung-Sang Kim [a] , Young-Soo Kwon [a] & Chungkyun Kim [b]

[a] Dept. of Electrical Engineering, Dong-A Univ. Busan, 604-714 Korea

[b] Dept. of Chemistry, Dong-A Univ. Busan, 604-714 Korea

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A STUDY FOR LUMINESCENT PROPERTIES OF OLEDs USING Alq_2-Ncd AS AN EMITTING LAYER

Hee-Chan Yoon, Ki-Sung Yang, Hoon-Kyu Shin, Byung-Sang Kim, and Young-Soo Kwon
Dept. of Electrical Engineering, Dong-A Univ. Busan, 604-714 Korea

Chungkyun Kim
Dept. of Chemistry, Dong-A Univ. Busan, 604-714 Korea

New luminescent material, 6,11-Dihydroxy-5,12-naphthacenedione (Alq_2-Ncd) was synthesized. And extended efforts have been made to obtain high-performance electro-luminescent (EL) devices, since the first report of organic light-emitting diodes (OLEDs) based on tris-(8-hydroxy-quinoline) aluminum (Alq_3). Current-voltage characteristics, brightness-voltage characteristics, luminous efficiency and external quantum efficiency were measured at room temperature. The maximum wavelength of the EL is at around 504 nm and the brightness is up to 2702 cd/m^2 with the maximum efficiency up to 3.91 lm/W.

Keywords: external quantum efficiency; luminous efficiency; naphthacenedione derivatives; OLEDs

1. INTRODUCTION

A number of organic materials have been synthesized and extended efforts have been made to obtain high performance electroluminescence (EL) devices, since the first report of the light-emitting diodes based on 8-Hydroxyquinoline aluminum (Alq_3) [1–5]. We have also investigated electroluminescent properties of partially conjugated organic molecules, 6,11-Dihydroxy-5,12-naphthacenedione (Alq_2-Ncd). And, an intensive research is going on to improve the device efficiency using the buffer layer, different electrodes, and etc. By using the buffer layer, the charge-injection can be controlled and the stability could be improved [6–7]. In this study, we characterized luminescent properties of Alq_2-Ncd (Figure 1) and

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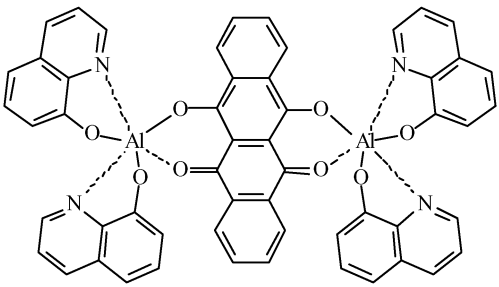

FIGURE 1 Structure of Alq_2-Ncd.

reported the effects of CuPC layer in organic light-emitting diodes (OLEDs) based on TPD/Alq_2-Ncd thin film.

2. EXPERIMENTAL

(1) Synthesis of Alq_2-Ncd [8]

6,11-Dihydroxy-5,12-naphthacenedione 2.1 g (8.3 mmol) was dissolved in THF(25 ml) and Tris(8-hydroxyquinoline)aluminum 7.6 g (16.6 mmol) was stirred heating up by slow at room temperature. Then refluxed for 1 hr: at this time, the material which did not melt well thaws out perfectly changing gradual from reddish to yellowish. To complete the reaction, it refluxed

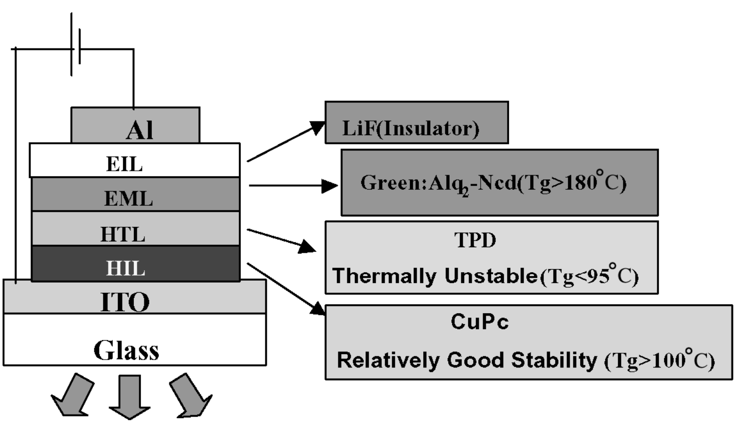

FIGURE 2 Device structure.

stirring for 2 hrs after removing unchanged reagents. The structure was identified by NMR and UV-Vis spectroscopies. Uv-vis (nm, in THF): 243, 261, 390, 478, 505, 541.

Reference: 6,11-Dihydroxy-5,12-naphthacenedione: 263, 455, 482, 516. Alq_3: 237, 260, 320, 335, 392.

^{1}H-NMR (ppm, $CDCl_3$): 6.99 ~ 7.18, 7.18 ~ 7.28, 7.28 ~ 7.76, 7.76 ~ 7.92, 7.92 ~ 8.04, 8.14 ~ 8.28, 8.28 ~ 8.54, 8.76 ~ 8.90.

(2) The fabrication of OLEDs

We have fabricated the OLEDs with a use of Phthalocyanine Copper (CuPc) as a hole-injection, N,N-diphenyl-N,N-bis(3-methylphenyl)-1,1-biphenyl-4,4-diamine (TPD) as a hole-transport 6,11-Dihydroxy-5,12-naphthacene-dione (Alq_2-Ncd) as an electron transport and emissive material. Two device structures were made; one is ITO/TPD/Alq_2-Ncd/Al as a reference and the other is ITO/CuPc/TPD/Alq_2-Ncd/Al (Figure 2) to investigate the effects of buffer layer.

The organic materials were successively evaporated under 10^{-6} torr with a rate of about 1.0 ~ 1.5 Å/s. The film thickness of CuPc, TPD and Alq_2-Ncd was made to be 5 nm, 15 nm and 25 nm respectively. And Al cathode [120 nm] was deposited at 1.0×10^{-5} torr. Light-emitting area was defined by using a shadow mask to be $0.3 \times 0.5\ cm^2$.

3. RESULTS AND DISCUSSION

(1) Optical and Photoluminescent Properties

The film showed characteristic relatively stronger green PL emission at 539 nm than that of typical conjugated molecule's and, typical rectifying diode characteristics. Figure 3(b) shows the EL spectrum in ITO/CuPc/TPD/Alq_2-Ncd /LiF/Al structure when the operation voltage is around at 7 V. It shows that there is a green light emission with $\lambda_{max} = 504$ nm, which is almost the same as PL of Alq_2-Ncd.

(2) Electrical Properties

Current-voltage characteristics and Brightness-voltage characteristics of OLEDs were measured using Keithley 2400 SMU source-measure unit, 617 electrometer and Si-photodiode. Luminance-voltage characteristics, luminous efficiency and external quantum efficiency were also measured at the same time when the current-voltage characteristics were measured. Luminous efficiency and external quantum efficiency were calculated based on the Brightness, EL spectra and current densities.

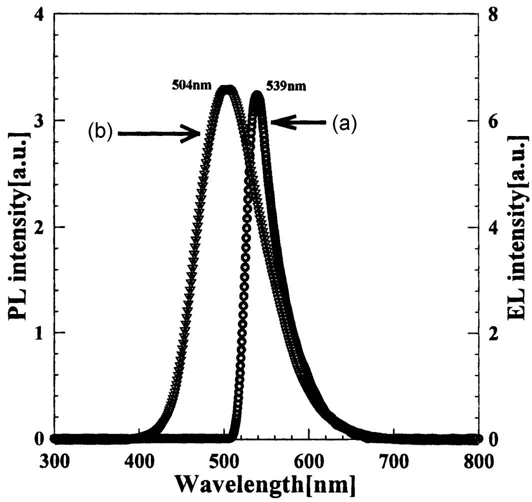

FIGURE 3 (a) Photoluminescence spectra of Alq_2-Ncd thin film on quartz substrate(excitation wavelength 400 nm) and (b) EL spectrum in ITO/CuPc/TPD/Alq_2-Ncd /LiF/Al device.

Figure 4 shows typical nonlinear current-voltage characteristics of ITO/TPD/Alq_2-Ncd/Al (reference) and ITO/CuPc/TPD/Alq_2-Ncd/LiF/Al devices with several different layer. In case of (a), as the voltage increases above 5 V, the current density increase rapidly.

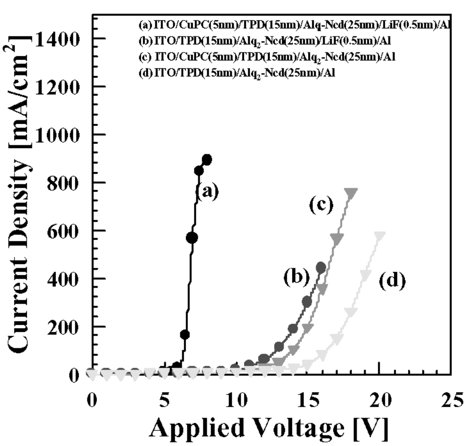

FIGURE 4 Current-voltage characteristics of (a) ITO/CuPc/TPD/ Alq_2-Ncd /LiF/Al (b) ITO/TPD/ Alq_2-Ncd/LiF/Al (c) ITO/CuPc/TPD/ Alq_2-Ncd /Al (d) ITO/TPD/Alq_2-Ncd /Al devices.

In Figures 4(a) and 5(a), the current density and the corresponding Brightness are increased by using the CuPc(5 nm) and LiF(0.5 nm). However, as the applied voltage increases above 7.5[V], the current density drops and the Brightness decreases a little bit.

Using Figures 4 and 5, the luminous efficiency was calculated depicted in Figure 5 using the relation $\eta = \pi L/JV$, where η is luminous efficiency [lm/W], L is Brightness [cd/m^2], J is current density [mA/cm^2], and V is applied voltage [V].

Figure 6 shows the luminous efficiency as a function of voltage when the CuPc buffer layer are used. The luminous efficiency starts to increase from 5 V and becomes a maximum near 7.5 V. As the CuPc and LiF/Al use for devices, the luminous efficiency increases. While the maximum efficiency of reference device (without buffer layer) is close to 1.11 lm/W, the maximum efficiency of device with CuPc and LiF/Al layers is about 3.91 lm/W. That is, there is an improvement of efficiency by factor three and half. It helps more holes to be injected into the emissive layer. Thus, the CuPc could be a useful hole buffer layer to enhance the device performance.

Figure 7 shows the external quantum efficiency as a function of voltage. To see how the electrical current affects on the brightness, the external quantum efficiency of device was calculated using Figures 4 and 5. The external quantum efficiency relates the number of emitted photons out of device to the number of injected carrier. The number of injected carrier is calculated from the current density and the number of photon is obtained from the Brightness and electroluminescent spectrum of device.

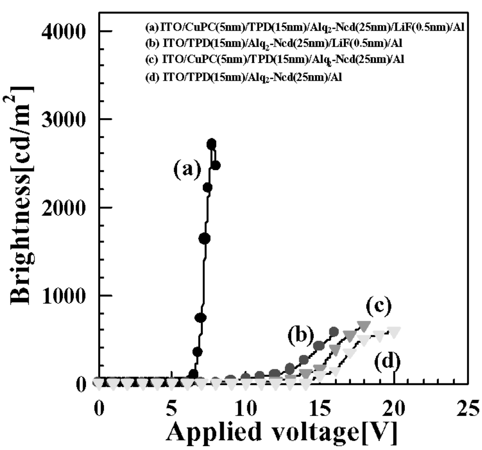

FIGURE 5 Brightness-voltage characteristics of (a) ITO/CuPC/TPD/Alq$_2$-Ncd/LiF/Al (b) ITO/TPD/Alq$_2$-Ncd/LiF/Al (c) ITO/CuPc/TPD/Alq$_2$-Ncd /Al (d) ITO/TPD/Alq$_2$-Ncd /Al devices.

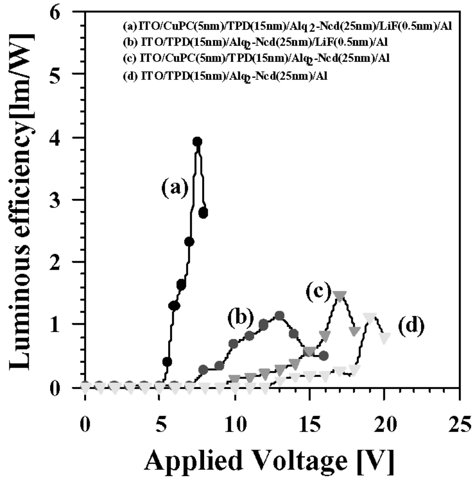

FIGURE 6 Luminous efficiency-voltage characteristics of (a) ITO/CuPc/TPD/Alq_2-Ncd/LiF/Al (b) ITO/TPD/Alq_2-Ncd/LiF/Al (c) ITO/CuPc/TPD/Alq_2-Ncd/Al (d) ITO/TPD/Alq_2-Ncd/Al devices.

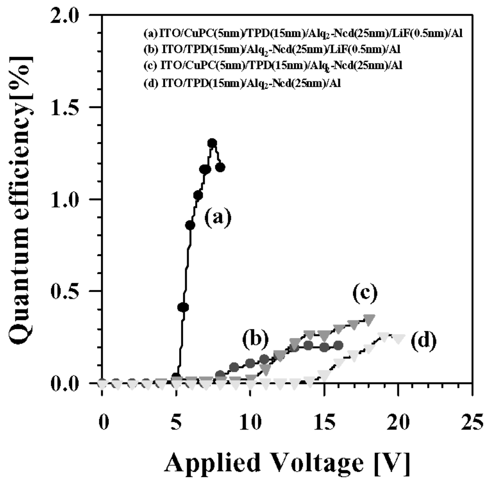

FIGURE 7 External quantum efficiency-voltage characteristics of (a) ITO/CuPc/TPD/Alq_2-Ncd /LiF/Al (b) ITO/TPD/ Alq_2-Ncd/LiF/Al (c) ITO/CuPc/TPD/ Alq_2-Ncd/Al (d) ITO/TPD/Alq_2-Ncd /Al devices.

As shown in Figure 7(a) for CuPc buffer layer, the external quantum efficiency starts to increase from 5 V and reaches a maximum near 7.5 V. While the maximum efficiency of reference device (without buffer layer) is close to 0.25%, the maximum efficiency of device with CuPc layer is about 1.3%. That is, there is a significant enhancement of efficiency by a factor of five.

The device with CuPc layer not only gives an improvement of efficiency but also reduces the operating voltage as well.

4. CONCLUSION

We synthesized the new green material as a Alq_2-Ncd, and observed PL and EL spectrum with λ_{max} at 504[nm]. We have fabricated the efficient OLEDs using the CuPc buffer layer in a device structure of ITO/CuPc/TPD/Alq_2-Ncd/LiF/Al. By using the CuPc buffer layer, the luminous efficiency of device has improved by factor three and half.

And which means that the Alq_2-Ncd is good candidate for green-emitting material. We have obtained an improvement of luminance and the external quantum efficiency by using that buffer layer.

The improvement of performance could be achieved by using the buffer layer which works hole-injection layer. We are going to study further how the buffer layer affects on the stability of the device.

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