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2005 J. Phys. D: Appl. Phys. 38 1136

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INSTITUTE OF PHYSICS PUBLISHING JOURNAL OF PHYSICS D: APPLIED PHYSICS

J. Phys. D: Appl. Phys. **38** (2005) 1136–1139 doi:10.1088/0022-3727/38/8/006

White organic light-emitting diodes based on bis(2-methyl-8-quinolinolato) (*para*-phenylphenolato)aluminium(III) doped with tiny red dopant

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Received 16 December 2004, in final form 4 February 2005
Published 1 April 2005
Online at stacks.iop.org/JPhysD/38/1136

Abstract
A bright white electroluminescence (EL) emission can be achieved using a minimum doping technique, that is, the concentration of the dopant DCJTB (4-(dicyanomethylene)-2-*t*-butyl-6-(1,1,7,7-tetramethyljuloli-dyl-9-enyl)-4H-pyran) was controlled to be 0.5 wt% of the host BAlq (bis(2-methyl-8-quinolinolato)(*para*-phenylphenolato)aluminium(III)). The white EL device structure is ITO/copper phthalocyanine (CuPc) (5 nm)/*N*, *N*′-bis(naphthyl)-*N*, *N*′-diphenyl-1,1′-biphenyl-4,4′-diamine(NPB)(50 nm)/BAlq : DCJTB(0.5 wt%, 30 nm)/tris(8-hydroxyquinolinato) aluminium(III)(Alq_3)(20 nm)/LiF(0.5 nm)/Al(100 nm). The white emission is composed of a red band from DCJTB and a blue emission from BAlq. A maximum luminance of 21 000 cd m^{-2} at the direct current driving voltage of 15 V, with a power efficiency of 1.10 lm W^{-1} at 11 V is achieved. The Commission Internationale de L'Eclairage coordinates of the white emission are well within the white zone which moves from (0.32, 0.34) to (0.30, 0.32) when the applied voltage is varied from 8 to 11 V.

1. Introduction

Organic light-emitting diodes (OLEDs) are quite promising for next generation of flat panel displays [1, 2] since Tang and VanSlyke [3] demonstrated efficient thin film electroluminescence (EL) devices driven by a low direct current (dc) voltage because of their excellent properties such as low driving voltage, high efficiency, light weight, thinness, and bright emission.

High brightness and efficiency in red (R), green (G), and blue (B) OLEDs were obtained. Generally, two approaches have been used to realize a full colour OLED display. One is based on the selective deposition of three primary colours (R, G, B), the other is the use of colour filters on white light OLEDs to change the emission into R, G, B colours. A thin white light source with light weight and high brightness properties is of great practical importance for display devices, and also as a back light in liquid crystal displays (LCD). A variety of methods have been proposed to achieve white OLEDs. One is to dope a single host emissive layer with dyes that emit in different wavelength ranges from the host material [4, 5] or to blend two different emissive polymers [6, 7]. Another is to use a microcavity structure of one emission layer [8]. The last is for small molecule-based multi-layer devices where different emission from different layers are combined to give the white colour [9–15].

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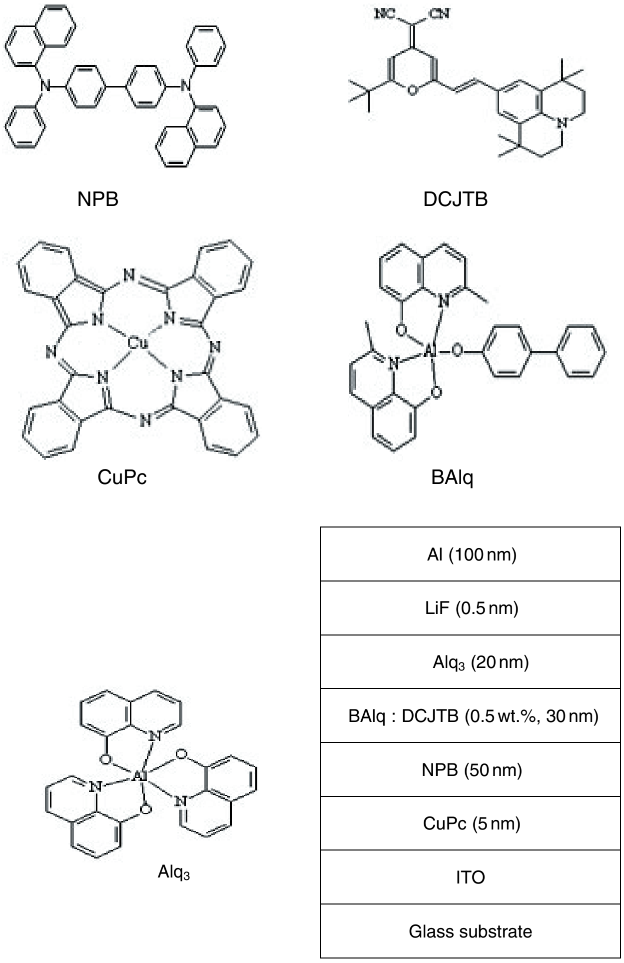

Figure 1. Device configuration and chemical structures of organic materials used.

However, the results have shown a serious problem in white EL devices, for which the emitted spectrum changes with increasing current density (or voltage). In this paper, we demonstrate white emission of OLEDs with CIE coordinates which are weakly dependent on the voltage and possess high brightness and luminous efficiency. The white OLEDs are based on co-luminescence of the two components in which the red emission is from DCJTB doped BAlq and the blue band is from host BAlq due to an incomplete energy transfer from the blue host BAlq to the dopant DCJTB.

2. Experiments

Figure 1 shows the device configuration and the molecular structures of copper(II) phthalocyanine (CuPc), *N*, *N*′-bis-(1-naphthyl)-*N*, *N*′-diphenyl-1,1′-biphenyl-4,4′-diame (NPB), tris(8-hydroxyquinolinato)aluminium(III) (Alq_3), BAlq, and DCJTB. ITO was used as a transparent anode; CuPc, NPB, DCJTB-doped BAlq (0.5 wt%), and Alq_3 were used as the buffer layer, the hole transport layer, the emission layer, and the electron transport layer, respectively; LiF and Al were used as the electron injection layer and the cathode material, respectively.

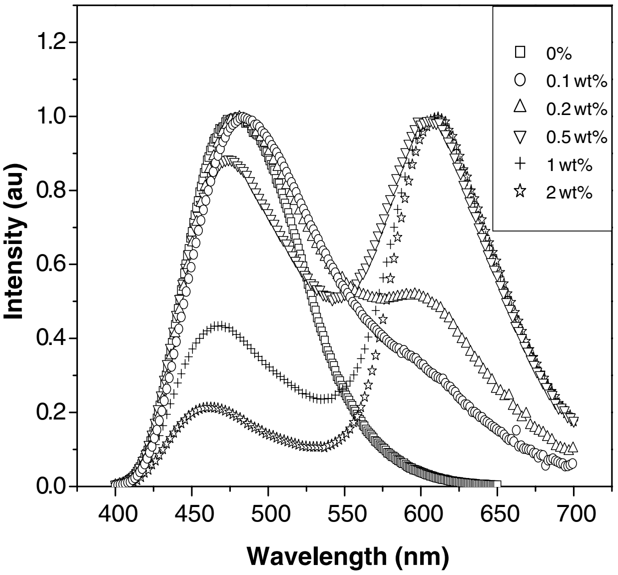

Figure 2. PL spectra of BAlq films doped with different weight concentrations of DCJTB.

ITO-coated glass substrates with a sheet resistance of approximate $100\,\Omega/\square$ were cleaned by successive ultrasonic treatments in acetone and isopropyl alcohol. Then, the organic layers were deposited using vacuum vapour evaporation at a vacuum pressure of 10^{-4} Pa. The DCJTB-doped BAlq layer was deposited by double-source evaporation. Then, a metallic aluminium layer (100 nm thick) was deposited on top of the organic layer without breaking the vacuum. Deposition of all layers was monitored by quartz oscillators and controlled at a rate of 0.2–0.4 nm s^{-1} for the organic layers and at 1.0 nm s^{-1} for the cathode. Photoluminescence (PL) and EL spectra and the CIE coordinates were measured with a Hitachi MPF-4000 fluorescence spectrophotometer. PL spectra of the organic films were measured using the 365 nm Xenon lamp line as the excitation wavelength. The brightness was measured by a 1980A spot photometer. All measurements were carried out in air at room temperature.

3. Results and discussions

To detect an optimum DCJTB dopant concentration, PL spectra of DCJTB-doped BAlq films with different DCJTB concentration were measured and the results are displayed in figure 2. It is clearly seen that there are two emission bands in the spectra, the blue band being from BAlq and the red band from DCJTB. The blue band decreases with increasing DCJTB concentration from 0.1 to 2 wt%. It indicates that the energy transfer from BAlq to DCJTB effectively occurs during photoexcitation.

According to the PL spectra, a successful white emission EL device based on the ITO/CuPc(5 nm)/NPB(50 nm)/BAlq: DCJTB(0.5 wt%, 30 nm)/Alq_3(20 nm)/LiF(0.5 nm)/Al(100 nm) structure has been demonstrated with 0.5 wt% DCJTB in BAlq. If the concentration of DCJTB is higher than 0.5 wt%, white emission cannot be obtained because blue emission from BAlq is lowered and the red band is enhanced due to the enhanced

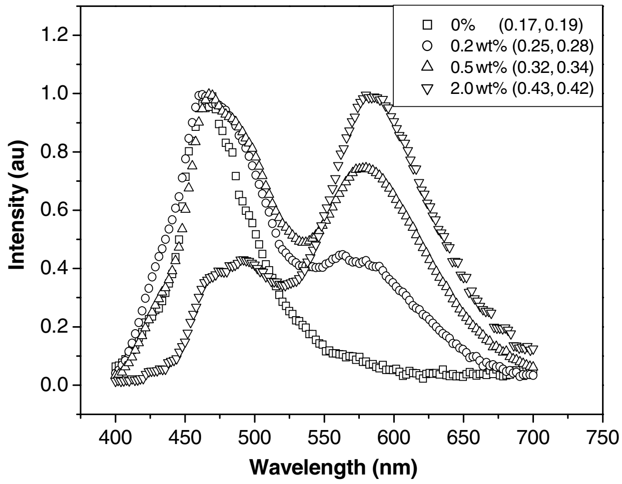

Figure 3. Normalized EL spectra of the devices using different DCJTB concentration doping of the BAlq layer.

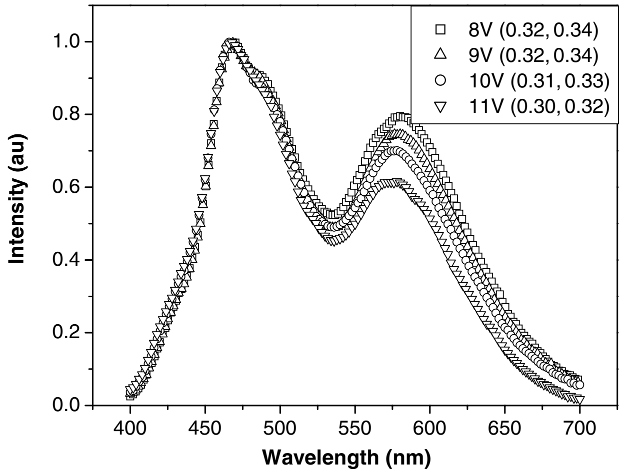

Figure 4. Normalized EL spectra and CIE coordinates of emitted white light for DCJTB (0.5 wt%)-doped BAlq under different driving voltages.

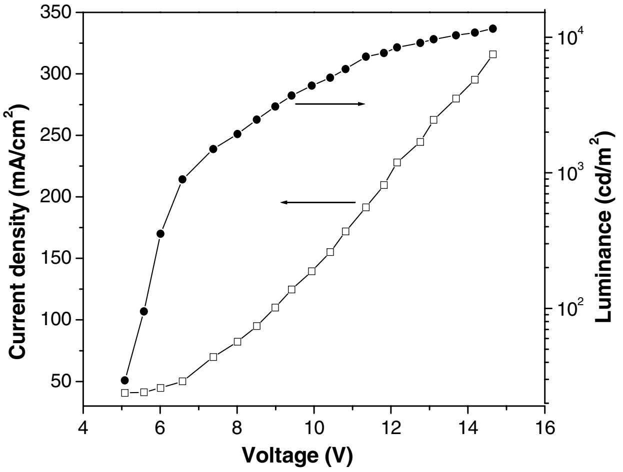

Figure 5. Luminance–voltage and current density–voltage characteristics of white OLEDs fabricated in this work.

energy transfer from BAlq to DCJTB. The spectrum would therefore deviate far from the white region.

Figure 3 shows the EL spectra of the device with different DCJTB dopant concentrations with the CIE coordinates shown in the insert. It can be seen that the device without DCJTB dopant gives a blue emission with the CIE coordinates (0.17, 0.19), which is same as the PL of BAlq, showing that the blue emission originates from BAlq. With increasing DCJTB concentration, the relative intensity of the blue emission decreases and that of the red emission increases owing to the increased energy transfer from the host, BAlq to the dopant DCJTB.

Figure 4 shows the EL spectra of the white EL device at different bias voltages. It is obvious that the emission spectra are insensitive to the changing bias, as the bias is varied from 8 to 11 V. The intensity of blue emission increases compared to that of the red emission with increasing bias. The CIE coordinates varied from (0.32, 0.34) at 8 V to (0.30, 0.32) at 11 V, suggesting that the white emission was relatively stable.

Typical luminance–voltage and current density–voltage characteristics of white EL device are plotted in figure 5. It can be seen that the turn-on voltage of the device is lower than 5 V. On increasing the applied voltage, the luminance and the current density increased rapidly, and the change in the current density is proportional to the voltage. The maximum luminance and luminous efficiency of the white EL device are 21 000 cd m^{-2} and 1.10 lm W^{-1}, respectively.

4. Conclusion

White OLEDs are fabricated with tiny amount of red dye DCJTB (0.5 wt%) and BAlq as host material. Energy transfer from the host BAlq to the dopant DCJTB is controlled by varying the dopant concentration. Blue band emission from the host BAlq and red band emission from the DCJTB combined to lead to white light emission with high performance. The results show a maximum luminance of 21 000 cd m^{-2} at 15 V, a power efficiency of 1.10 lm W^{-1} at 11 V and CIE coordinates of (0.32, 0.34) at 8 V to (0.30, 0.32) at 11 V. The application of a single white emissive layer would simplify the fabrication process.

Acknowledgment

This work was fund by the National Science Research Project of China (No 90201012).

References

[1] Adachi C, Tsutsui T and Saito S 1989 *J. Appl. Phys.* **55** 813
[2] Burroughes J H and Holmes A B 1990 *Nature* **347** 539
[3] Tang C W and VanSlyke S A 1987 *Appl. Phys. Lett.* **51** 913
[4] Kido J, Hongawa K, Okuyama K and Nagai K 1994 *Appl. Phys. Lett.* **64** 815
[5] Kido J, Shionoya H and Nagai K 1995 *Appl. Phys. Lett.* **67** 2281
[6] Tasch S, List E J W, Ekstrom O, Graupner W, Leising G, Schlichting P, Rohr U, Geerts Y, Scherf U and Mullen K 1997 *Appl. Phys. Lett.* **71** 2883
[7] Chao C I and Chen S A 1998 *Appl. Phys. Lett.* **73** 426
[8] Dodabalapur A, Rothberg L H and Miller T M 1994 *Appl. Phys. Lett.* **65** 2308

[9] Kido J, Kimura M and Nagai K 1995 *Science* **267** 1332

[10] Deshpande R S, Bulovic V and Forrest S R 1999 *Appl. Phys. Lett.* **75** 888

[11] Xie Z Y, Huang J S, Li C N, Liu S Y, Wang Y, Li Y Q and Shen J C 1999 *Appl. Phys. Lett.* **74** 641

[12] Strukelj M, Jordan R H and Dodabalapur A 1996 *J. Am. Chem. Soc.* **118** 1213

[13] Jordan R H, Dodabalapur A, Strukelj M and Miller T M 1996 *Appl. Phys. Lett.* **68** 1192

[14] Steuber F, Staudigel J, Stossel M, Simmerer J, Winnacker A, Spreitzer H, Weissortel F and Salbeck J 2000 *Adv. Mater.* **12** 130

[15] Liu S, Huang J, Xie Z, Wang Y and Chen B 2000 *Thin Solid Films* **363** 294