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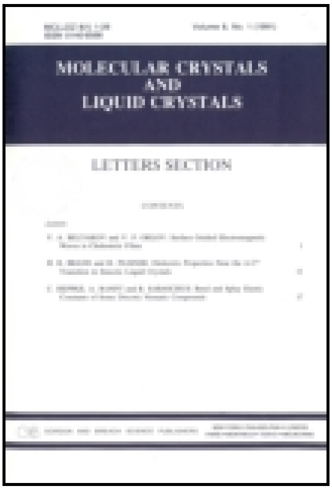

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Single-layered White Organic Light Emitting Diodes Using Solution Process Based on Co-Host Emitter System

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Single-layered White Organic Light Emitting Diodes Using Solution Process Based on Co-Host Emitter System

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Two color white organic light-emitting diode (WOLED) that uses a co-host system in a solution process method was achieved. The device configuration was ITO/PEDOT:PSS (40 nm)/emitting layer (50 nm) / BCP (10nm) / Alq3 (20 nm) / LiF (1 nm) / Al. The emitting layer consists of two co-hosts of TATa and NPB and dopants of DPAVBi (blue) and rubrene (yellow). As the ratio of the host material NPB was increased, the operating voltage of the device was reduced. Luminance efficiency and power efficiency were also increased according to the NPB ratio. For the white device using host of TATa 40%:NPB 60%, the efficiency was 5.17 cd/A and 3.23 lm/W with color coordinates of (0.29, 0.38).

Keywords White organic light-emitting diodes (WOLEDs); co-host; solution process

Introduction

The interest about organic light-emitting diodes (OLEDs) based on white OLEDs (WOLEDs) has rapidly grown in display and lighting application fields [1, 2]. Until now, WOLEDs have been produced by using the vacuum evaporation method, which involved such drawbacks as high cost and difficulties for large-scale production, and adjusting doping concentrations [3–6]. Consequently, there are many ongoing studies on methods of producing solution processed WOLED such as spin-coating, screen-printing, and the ink-jet printing method, to take advantage of benefits of mass production and relative low cost [7–10].

Disadvantages of such methods in fabricating solution process devices are that they involve difficulties in making mutilayer device systems since the second layer solvent can dissolve the pre-coated layer from excessive solvent power. Thus, the solution process device has limitations in using hole transporting layer (HTL) or electron transporting layer (ETL). Finally, solution process devices show lower basic efficiency data compared to the

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*Address correspondence to Prof. Jongwook Park, Department of Chemistry/Display Research center, The Catholic University of Korea, 43-1, Yeokgok, Wonmi, Bucheon, 420-743, Korea (ROK). Tel.: (+82) 2-2164-4331; Fax: (+82)2-2164-4764. E-mail: hahapark@catholic.ac.kr vacuum process devices. In order to overcome the drawbacks of solution process OLED, several methods such as reducing solubility of organic layer by crosslinking and providing hydrophilic property to HTL or ETL, have been proposed. These approaches have other limitations in their design and synthesizing of molecules [9, 10].

Recently, a system that promises high efficiency simply with a hole or electron transporting material blended with emitting compounds is being seriously considered as a co-host system [11]. However, systematic research on co-host material component is insufficient both quantitatively and qualitatively. Especially, role of each components using solution process for WOLED device was not understood clearly. In order to achieve highly efficient WOLED device, systematic study on each component role is extensively needed.

In this study, a two color white emitting layer (EML) is proposed by using a blending and spin-coating method in a co-host/dopant system. Moreover, different ratios of co-host materials to TATa and NPB were examined to verify corresponding characteristics of device efficiency.

Experimental

A structure of the device was fabricated as ITO / PEDOT (40 nm) / TATa + NPB+ dopants (50 nm) / BCP (10 nm) / Alq3 (20nm) / LiF (1 nm) / Al.

4-(10-(3′,5′-diphenylbiphenyl-4-yl) anthracen-9-yl)-N, N-diphenylaniline (TATa), N,N’-Bis (naphthalen-1-yl)-N,N′-bis(phenyl)-benzidine (NPB) were used as the host substances for the emitting layer. 4,4′-Bis [4-(di-p-tolylamino) styryl] biphenyl (DPAVBi) and (5,6,11,12)-Tetraphenylnaphthacene (Rubrene) were used as each blue and yellow as the dopant substances. TATa:NPB was mixed in a mass ratio of 100:0, 75:25 or 40:60 for host substances, and DPAVBi with a ratio of 4% and Rubrene with a ratio of 0.2% were mixed for dopant substances based on the mass of co-host. Toluene was used as solvent. A water-dispersed PEDOT/PSS mixture (Baytron P VP CH8000, H. C. Starck GmbH) was spin-coated on top of indium tin oxide (ITO) in air to achieve films (40 nm). The spin-coated films were baked on a hot plate at 110°C for 5 minutes in air and at 200°C for 5 minutes in an N_2 glove box. The emitting layer was spin-coated to obtain a thickness of 50 nm. The solution-processed films were baked on a hot plate (110°C, 30 min) in an N_2 glove box. Hole-blocking layer (2,9-dimethyl-4,7-diphenyl-1,10-phenanthroline, BCP) with a thickness of 10nm and electron-transporting layers (2,9-dimethyl-4,7-diphenyl-1,10-phenanthroline, Alq3) with a thickness of 20nm were deposited by vacuum evaporation (at pressure about 10^{-6} Torr). LiF (1 nm) and Al films were sequentially deposited on the electron-transporting layer under vacuum (at a pressure about 10^{-6} Torr). I–V–L characteristics of the OLED devices and EL spectra were obtained by using a Keithley 2400 sourcemeasure unit and a Minolta CS-1000A spectrophotometer. The optical absorption spectra were obtained by HP 8453 UV-VIS-NIR spectrometer. Perkin Elmer luminescence spectrometer LS50 (Xenon flash tube) was used for photo-spectroscopy(PL).

Results and Discussion

Figure 1 shows the chemical structures of host and dopant materials. TATa is a blue host emitter with high EL quantum efficiency [12]. NPB was used as a co-host material with good HTL property and a wide band gap similar to blue emitter. DPAVBi and Rubrene were used as blue dopant and yellow dopant, respectively.

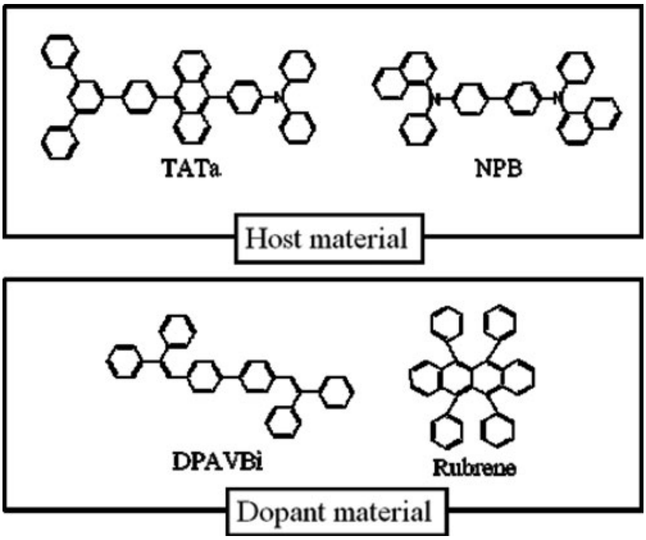

Figure 1. Chemical structures of materials.

Figure 2 shows PL spectra of host compounds (TATa, NPB) and UV-visible (UV-Vis.) absorption spectra of DPAVBi and rubrene which are dopants. As shown in the graphs, it can be verified that PL spectra of host materials and UV-Vis. absorption spectra of dopant materials showed a good overlap. Thus, it can be expected the foster energy transfer from host substances to dopant substances to be good.

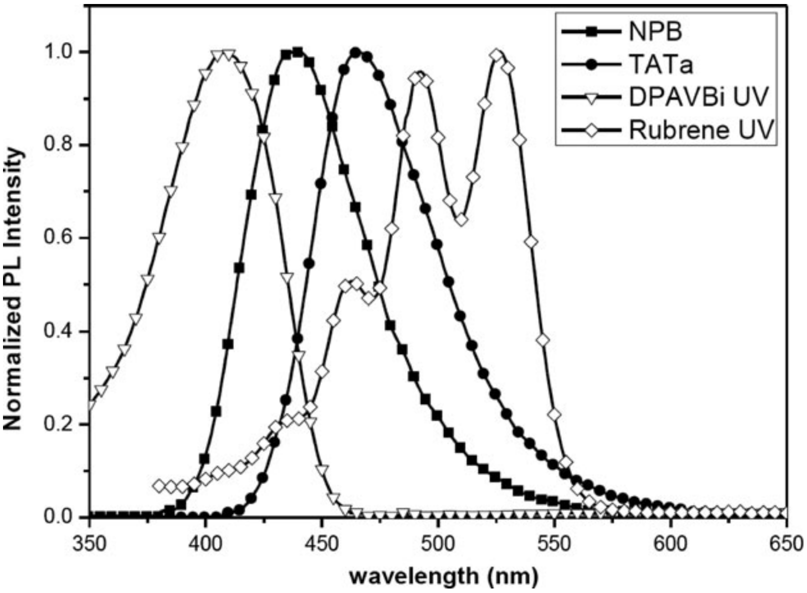

Figure 2. UV-Visible absorption spectra of rubrene and DPAVBi in toluene solution and PL spectra of TATa and NPB in film state.

Table 1. EL performances: ITO / PEDOT (40nm) / Emitting layer (50nm) / BCP (10nm) / Alq3 (20nm) / LiF (1nm) / Al (200nm) at 100 mA/cm^2

Host of emitting layer					
TATa (%)	NPB (%)	Operating voltage (V)	L. E.[a] (cd/A)	P. E.[b] (lm/W)	CIE (x, y)
100	0	6.35	4.44	2.42	(0.26, 0.36)
75	25	6.15	4.93	2.78	(0.27, 0.35)
40	60	5.55	5.17	3.23	(0.29, 0.38)

a) Luminance efficiency, b) power efficiency

In this study, PEDOT:PSS and the emitting layer were fabricated by spin coating method and ETL layer and LiF/Al electrode were fabricated with vapor deposition method. Device performance of co-host of TATa and NPB are summarized in Table 1 and Figure 3.

BCP was used as a hole blocking layer as shown in Figure 3(c) to confine electron and hole into co-host emitting layer.

As shown in Table 1 and Figure 3(a), the operating voltage was decreased from 6.35V to 5.55V as NPB ratio increases. It is considered to be from the hole transporting characteristics of NPB, where carrier movement inside the device becomes easier as the NPB ratio increases.

Device luminance and power efficiencies for co-host layer ratio of TATa 100%, TATa 75%:NPB 25%, and TATa 40%:NPB 60%, were 4.44, 4.93, 5.17 cd/A and 2.42, 2.78, 3.23 lm/w, respectively. It shows that as NPB ratio was raised in co-host layer, efficiency was increased as shown in Figure 3(b). In doped device, there was a report that charge trapping at dopant decreases EL efficiency.[13] Therefore, it can be expected that as NPB ratio increased, hole transporting property also is increased and charge trapping effect is decreased at dopant. Also, it might be explained by that NPB and TATa mixed co-host system provides the expanded recombination zone. It causes the increased luminescence efficiency.

In power efficiency, it was also increased according to the ratio of NPB. Power efficiency can be described by the following formula.

$$\text{Power efficiency(lm/W)} = [\text{Luminance efficiency(cd/A)} \times \text{steradian(sr)}]/\text{Volt(V)}$$

This was analyzed to be from a significant decrease to the operating voltage for each device as the NPB ratio was raised. According to the increased NPB ratio and hole transporting property of emitting layer inside, operating voltage was decreased and power efficiency was automatically increased.

Figure 4 shows the EL spectrum of the fabricated white device. White emission consists of two major peaks of 467 nm and 550 nm, which are due to DPVABi and rubrene dopants [14]. It means that energy transfer from two hosts to two dopants is available to show stable white emission although it has a little difference in yellow region according to NPB ratio. However, there was no big difference in color coordinate value as shown in Table 1. It was in the range of (0.26, 0.36) to (0.29, 0.38).

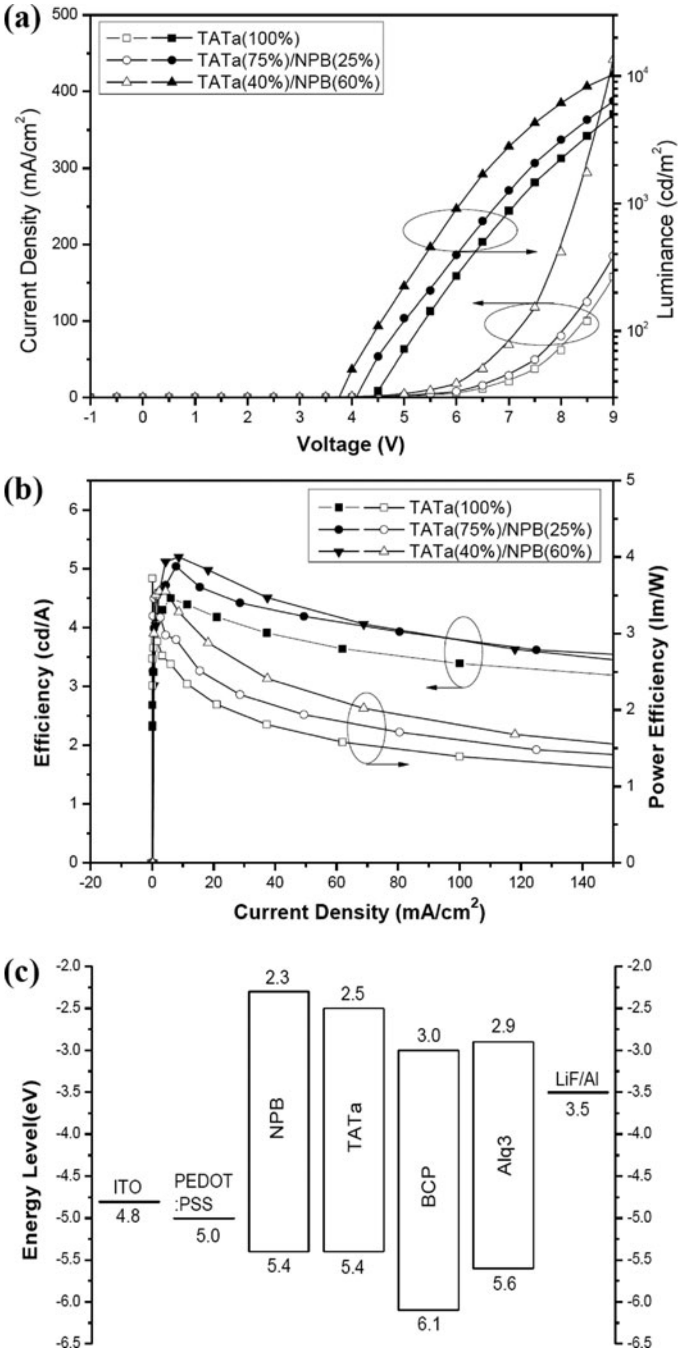

Figure 3. (a) I-V characteristics, (b) luminance efficiency and power efficiency, (c) energy diagram of the compounds.

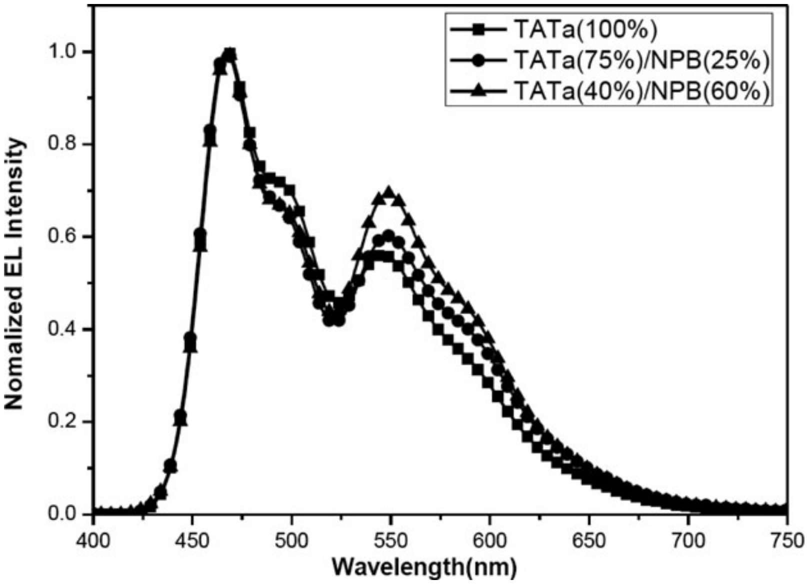

Figure 4. EL spectra of OLED devices.

Conclusion

A white organic light emitting device has been proposed by using solution device of production, based on co-host such as a TATa and NPB system. A comparison was made for change in characteristics according to the ratio between TATa, a material of high-efficiency luminance, and NPB, a material capable of hole transporting.

As the ratio of the host material NPB was increased, the operating voltage of the device was reduced. Luminance efficiency and power efficiency were also increased according to the NPB ratio. For the white device using host of TATa 40%:NPB 60%, the efficiency was 5.17 cd/A and 3.23 lm/W with color coordinates of (0.29, 0.38) suitable for application as illumination of white light. In conclusion, it was identified that for single layered white OLED devices, control of the operating voltage and efficiency is made possible by adding hole characteristic material to the EML layer.

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