Novel Bipolar Host Materials for Phosphorescent OLEDs

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Abstract

We have developed novel bipolar host materials, designed to have both electron transporting and hole transporting abilities, which show significant increase in luminance efficiency and decrease in driving voltage of green phosphorescent OLEDs. In case of the best host material, CheilGH-3, the driving voltage was decreased 27 % at a given constant luminance of 1000cd/m^2. Also the luminance efficiency was enhanced 44 % and the power efficiency was almost doubled compared to the reference device using CBP as a host.

1. Introduction

EL efficiency of organic light-emitting diodes (OLEDs) has advanced rapidly in recent years due to the development of phosphorescent guest molecules containing transition metals that can harvest both singlet and triplet excitons [1-4]. For efficient phosphorescent OLEDs, the transition metal guest materials are doped into host materials with charge transporting ability. Recently, tremendous efforts are focused on phosphorescent guest materials. However, no intensive effort has been made to develop host materials. One of the important properties of host materials for phosphorescent OLEDs is to balance electron and hole transporting ability [5-6]. CBP has been widely used as a host in PHOLEDs [7]. However, CBP showed better hole transporting capability than electron's because of carbazole moiety. Novel host materials with similar carrier transporting abilities of both hole and electron are required to improve EL efficiency of phosphorescent OLEDs.

EL performance of OLEDs having multilayer structure is greatly related to energy levels of HOMO and LUMO of each layer [8]. A host with wide HOMO-LUMO energy gap (E_g) causes an increase in driving voltage and a decrease in luminescence efficiency in OLEDs. Most of host materials for green phosphorescence, such as CBP and *m*CBP, have wide band gap whose triplet energy level is higher than that of guest material. Therefore, hole and/or electron injection into emitting layer with a wide band gap host becomes energetically unfavorable in green phosphorescent OLEDs resulting in increasing driving voltage and lowering luminance efficiency.

Recently, we have developed novel materials (CheilGH-2, CheilGH-3, CheilGH-4 and CheilGH-5) engineered with electron transporting units and hole transporting units attached to our unique backbone system to control the energy levels of HOMO and LUMO. In this paper, optical properties of these materials were characterized by UV-visible and photoluminescence (PL) spectra. Moreover, multi-layered EL devices were fabricated using these materials as host materials for EML.

2. Experimental

The optical absorption spectra were measured by HP 8453 UV-VIS-NIR spectrometer. Perkin Elmer luminescence spectrometer LS50 was used for photoluminescence spectroscopy.

The structure of ITO / N,N`-di(naphthalene-1-yl)-N,N`-diphenyl-benzidine (NPB) 40 nm / host : $Ir(ppy)_3$ 30 nm / bis(2-methyl-8-quinolinolato)(4-phenylphenolato)aluminum(III) (Balq) 5 nm / tris(8-hydroxy-quinoline) aluminum (Alq_3) 20 nm / LiF / Al was employed as a evaluation method of novel host materials in green PHOLEDs devices. The host thickness was 30 nm and doping concentration of $Ir(ppy)_3$ was 7~10% range. As a reference device, CBP with 30 nm thickness was used as a host material.

The Current-Voltage characteristics of the devices were measured using Keithley 2400 electrometer. The brightness was measured using chromameter CS-1000A (Minolta).

3. Results and Discussion

UV-visible absorption spectra and PL emission spectra of our new host materials, CheilGH-2, CheilGH-3, CheilGH-4 and CheilGH-5, are summarized in Table 1. The optical band gaps were determined from the analysis of UV-visible absorption edge.

Table 1. UV-visible absorption and PL emission spectral data

Material	UV (nm)	PL (nm)	Optical band gap (eV)
CheilGH-2	244, 286, 343	385	3.55
CheilGH-3	241, 328, 342	387	3.47
CheilGH-4	296, 331, 345	386	3.45
CheilGH-5	212, 238, 296, 330	381	3.49

We fabricated green phosphorescent EL devices fabricated having the structure (Figure 1) of ITO / N,N`-di(naphthalene-1-yl)-N,N`-diphenyl-benzidine (NPB) 40 nm / Host : $Ir(ppy)_3$ 30 nm / bis(2-methyl-8-quinolinolato)(4-phenylphenolato)aluminum(III) (Balq) 5 nm / tris(8-hydroxy-quinoline) aluminum (Alq_3) 20 nm / LiF / Al, to evaluate our new materials.

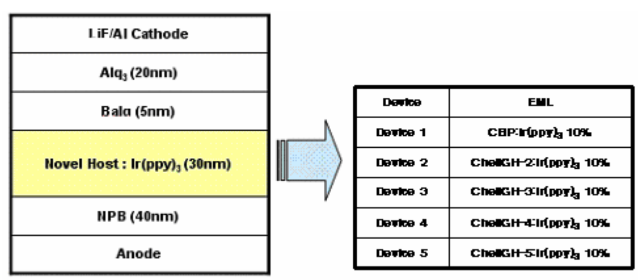

Figure 1. Device structure for evaluating novel host materials.

Figure 2 shows the current density (I) – voltage (V) characteristics (a), and the luminance (L) – voltage (V) characteristics (b) of the green phosphorescent OLEDs. As shown in Figure 2, Device 3 with CheilGH-3 as a host material shows the best I-V-L data. All the devices using our new materials show low turn-on voltages (V_{on}) which are 3.2 V for Device 2, 2.6 V for Device 3 (24 % reduction compared to the CBP's), 2.8 V for Device 4 and 3.0 V for Device 5. The V_{on} of the reference device, Device 1, is 3.4 V. Driving voltages of Device 3 at 100 and 1000 cd/m^2 are 4.4 and 6.0 V, respectively, which are 29 % and 27 % lower than those of Device 1 (6.2 V and 8.2 V).

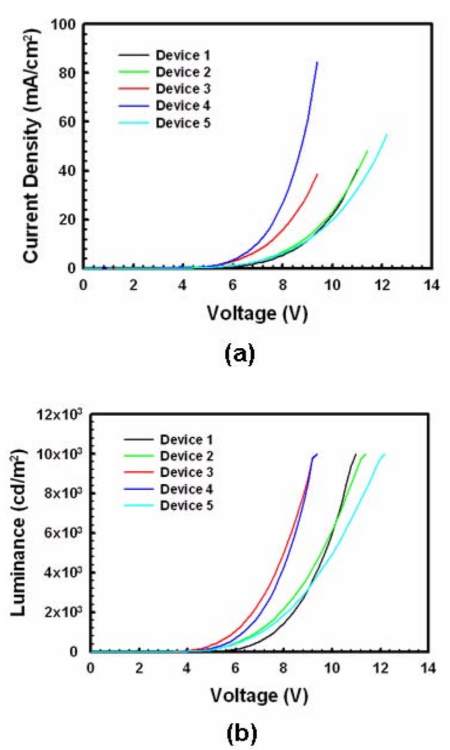

Figure 2. Device performance data of green POLEDs: (a) Current Density-Voltage Curves (b) Luminance-Voltage Curves

Figure 3 shows the current efficiency- luminance characteristics (a), and the power efficiency-luminance characteristics of the green phosphorescent OLEDs. As shown in Figure 3, Device 3 performed the best luminance efficiency. At a given constant luminance of 1000 cd/m^2, the current efficiency and the power efficiency of Device 3 are 36.8 cd/A and 19.3 lm/W. On the other hand, 25.8 cd/A of current efficiency and 10.6 lm/W of power efficiency are observed for Device 1 at the same luminance. The power efficiency of Device 3 was enhanced about two times.

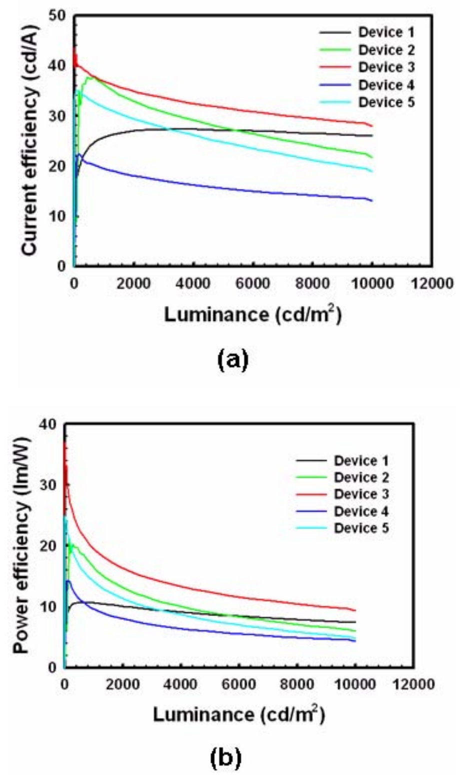

Figure 3. Device performance data of green POLEDs: (a) Current Efficiency-Luminance Characteristics (b) Power Efficiency-Luminance Characteristics

The performance data of Device 1 and 3 are summarized in Table 2.

Table 2. The performance data of Device 1 and 3

Device	V_{on}	at 1000 cd/m^2			
		V_d	cd/A	lm/W	x, y
1	3.4 V	8.2 V	25.6	9.8	0.30, 0.59
3	2.6 V	6.0 V	36.8	19.3	0.33, 0.60

4. Summary

We successfully developed high luminance efficiency of green phosphorescent OLEDs by using our novel bipolar materials as a host for EML. When CheilGH-3 was used as a host for EML of the green phosphorescent OLED, the low driving voltage (27 %

reduction), the high current efficiency (44 % enhancement) and the high power efficiency (97 % enhancement) were achieved.

5. References

[1] B. W. D'Andrade, S. R. Forrest, *Adv. Mater*. **16**, 1585 (2004).

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

[3] M.A. Baldo, S. Lamansky, P.E. Burrows, M.E. Thompson, S.R. Forrest, *Appl. Phys. Lett*. **75**, 4 (1999).

[4] C. Adachi, M.A. Baldo, S.R. Forrest, *Appl. Phys. Lett.* **77**, 904 (2000).

[5] C. Adachi, R. Kwong, S.R. Forrest, *Organic Electronics* **2**, 37 (2001)

[6] X.H. Yang, F.Jaiser, B. Stiller, D. Neher, F. Galbrecht, U. Scherf, *Adv. Funct. Mater.* **16**, 2156 (2006)

[7] Y. Kim, J. Kim, E. Nam, S. Hong, B. Kim, S. Kim, S. Yoon, J. Suh, Y. Ha, *Material Science & Engineering C* **24**, 167 (2004)

[8] Y.T. Tao, C.W. Ko, E. Balasubramaniam, *Thin Solid Films* **417**, 61 (2002)