Device Characteristics of white OLED using the fluorescent and phosphorescent materials coupled with interlayer

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Abstract

We fabricated white organic light emitting device (WOLED) with the layered fluorescent blue material and phosphorescent green/red dye-doped materials. Addition of the non-doped phosphorescent host material between the fluorescent and phosphorescent light emitting layers provided the result of broadband white spectrum, with improved balance, higher efficiency, and lower power consumption. In our devices, there was no need of exciton-blocking layer between the each emission layer for the further confinement of the diffusion of excitons.

1. Introduction

White organic light emitting devices (WOLED) have many benefits that can be applicable to illumination light source, back-lights for liquid crystal displays, and full-color flat-panel displays with color filters. With the ability to be self-emissive and both extremely thin and light, WOLED are particularly suitable for flexible light sources. Great advances have been made, including conjugated polymers [1-3], metallic chelate compounds [4-6], and fluorescent dyes [7,8] in electroluminescent materials. Especially, the electrophosphorescent OLED are rapidly developed in recent years due to their high external quantum efficiency and power efficiency [9, 10].

The white emission of the multi-layered dye-doped system can be explained by energy transfer characteristics from the host to the dye which occurs by the formed exciton in the interface of fluorescent/phosphorescent light emitting layers and change transport layers. The majority of excitons are formed in the host material with a singlet-to-triplet formation ratio 25% to 75%. Note that the energy of singlet states in the host be also transferred to singlet states in the blue fluorescent dye via the Forster transfer, and triplet states in the host be transferred to triplet states in the green/red phosphorescent dye via the Dexter transfer in the same methods.

In this work, we have fabricated the WOLED composed of blue, green and red emitting layers of fluorescent and phosphorescent dye-doped small molecules. The color spectrum of these devices can be precisely tuned by varying the concentration of the dopants and the thickness of each layer. We found that the addition of interfacial layer play a major role to generate a balanced white emission in our composite device structure utilizing fluorescent blue and phosphorescent green/red emission.

2. Experimental

We have fabricated for blue, green and red emitting WOLED with three emission layer, which consisted of the blue, the green, the red dopants and the same host.

At first, EL devices based on N, N'-diphenyl-N, N'-bis(1-naphthyl)-(1,1'-biphenyl)-4,4'-diamine [NPB, 40nm] as a hole transport layer. The single host, 4, 4-*N*, *N*–dicarbazolebiphenyl [CBP], doped with 4,4’-bis (9-ethyl-3-carbazovinylene)-1,1’-biphenyl [BCzBVi 1.5% 5nm], fac-tris (2-phenylpyridine) iridium [Ir(ppy)$_3$ 5% 12nm] and tris(1-phenyliso-quinoline) Iridium(3) [Ir(piq)$_3$ 7% 8nm] for blue, green and red emitter was evaporated with variable thickness.

Thin interlayer of CBP [3nm] was inserted between blue emitting layer and green emitting layer. 4, 7-diphenyl-l, 10-phenanthroline [Bphen 25nm] was deposited both for hole blocking and electron transporting layer and LiF/Al was used by cathode.
The device architecture and energy levels of each components for our white OLED were shown in Fig. 1.

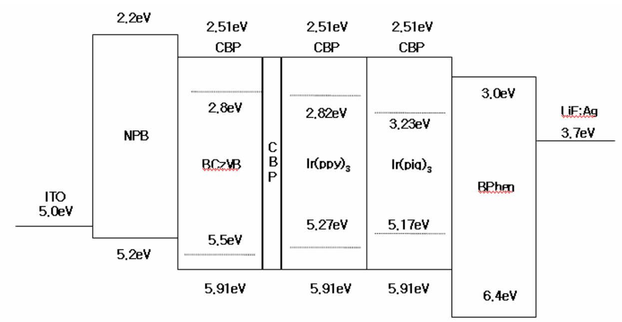


Fig.1 Device structures and their energy level diagram of NPB/ CBP: BCzBVi / CBP/ CBP: Ir(ppy)$_3$/ CBP : Ir(piq)$_3$/ Bphen.

3. Results and discussion

The spectrum data of WOLED with three emission layers are shown in Fig.2. The Characteristic peak of fluorescent blue emission from CBP:BCzVBi[5nm], phosphorescent green emission from CBP:Ir(ppy)$_3$ [12nm] and phosphorescent red emission from CBP:Ir(piq)$_3$ [8nm] was observed in case of 3nm interlayer of CBP was used.

Excitons that might be formed at NPB/CBP and Bphen/CBP interfaces seem to be efficiently utilized within this emitting layer doped with blue, green and red dopants. With proper thickness ratios of the blue and the red dopants, which were 5nm and 8nm for the blue and the red thickness, comparably balanced emission of blue, green and red lights was obtained. Eventually, the important design factor of white emission is to make a broad recombination region for holes/electrons pairs. In addition, due to using the same host material, we could reduce interfacial barrier in the multi-emission layers.

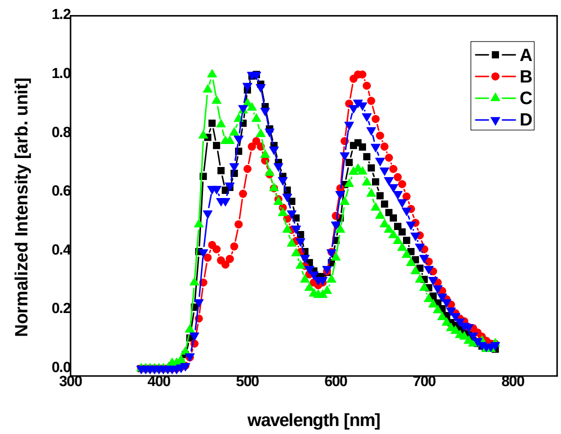
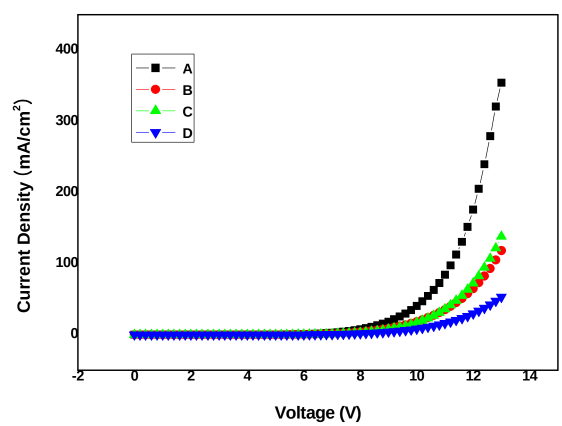
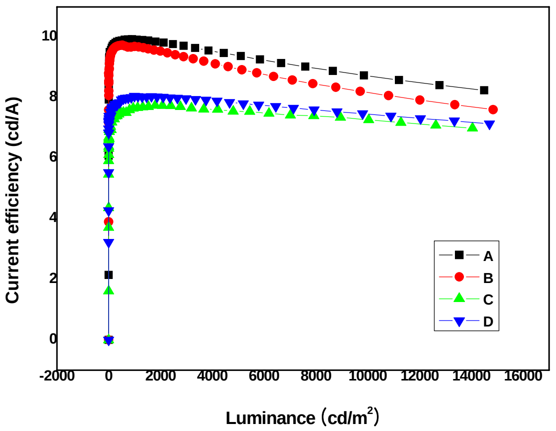


Fig.2 The electroluminescence spectra of the three EML WOLED with change each layers thickness (at6V).A:Blue(5nm,1.5%)/CBP/Green(12nm,5%)/ Red(8nm,7%),B:Blue(5nm,1.5%)/CBP/Green(12nm,5%)/Red(15nm,7%),C:Blue(10nm,1.5%)/CBP/Green(12nm,5%)/Red(8nm,7%),D:Blue(10nm,1.5%)/CBP/Green(12nm,5%)/Red(15nm,7%).

Figure 3 shows the applied bias voltage-current density and voltage-luminance properties of the WOLED devices with the same structure as Figure 2. At a current density of 100mA/cm^2, maximum luminance of 10000cd/m^2 was reached at the bias of 11.3V. The luminance reaches about 200cd/m^2 at 6.8V and 3850 cd/m^2 at 10V.



(a)



(b)

Fig.3 (a) Current density-voltage characteristics and (b) voltage-luminance characteristics of WOLED with fluorescent blue/interlayer/ phosphorescent green/red emission layers.

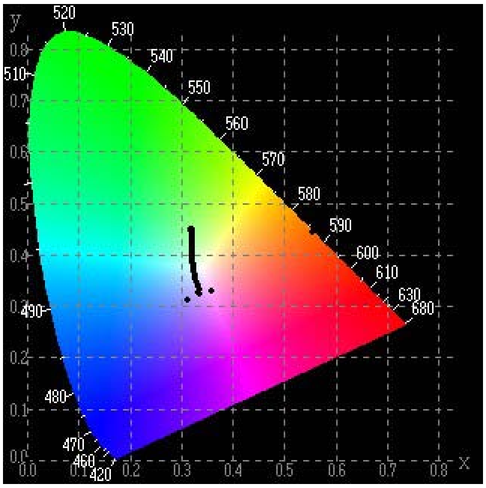


Fig.4 Evolution of CIE 1931 coordinates of the WOLED with fluorescent blue/interfacial/ Phosphorescent green/red emission layers (with variation of device's voltage)

Figure 4 illustrates the locus of the CIE 1931 color coordinates of WOLED, which was measured at a luminance of 10, 100, 1000cd m^{-2} .The white color gamut, mostly relied on the enhancement of relative intensity of green/red emission, was improved by the addition of CBP interlayer. By comparing the emission behavior of devices with and without interlayer, it is expected that the recombination region might move to the green light emitting layer, which resulted in the overall increase of current density and further increase of the green emission.

Obviously, the singlet excitons in the phosphorescent host are transferred to the blue fluorescent dye through the Forster energy transfer, and the triplet excitons in the phosphorescent host are transferred to the green and red phosphorescent dye through the Dexter energy transfer. Without usage of an exciton-blocking layer between each of the emissive layer, balanced white emission could be obtained. Further design of more efficient, balanced white device is understand by changing the combination of host materials.

4. Summary

We have achieved the balanced white emission ranging from CIE1931 color coordinate 0.31<x<0.36 and 0.31<y<0.45 with 3 peak devices. Insertion of additional interlayer between blue fluorescent dye and green phosphorescent dye layer effectively improved the color gamut, resulting in a broadband white spectrum without any requirement of charge-blocking interlayer.

5. References

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