

## White organic light emitting diode with single emission layer DPVBi partially doped with rubrene

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### Abstract

In this study, we fabricated white organic light emitting devices (WOLEDs) to use single emission layer, DPVBi with partially doped Rubrene. To realize white color, rubrene with 3.6% was partially doped with the gap from interface between DPVBi and hole transport layer NPD in a definite DPVBi layer. As the gap was increased, the intensity of orange peak grows less and less. The WOLED with gap of 5 Å has the best color stability and its color coordination is (0.345, 0.321) at 6V.

### 1. Introduction

White organic light emitting device (WOLED) has a variety of applications such as illumination light sources, light signs, and backlight in liquid-crystal displays [1]. Also a full color display has also been proposed using the WOLED and color filters. This approach has advantage that there is no need of fine shadow mask.

Many researchers have suggested various structures and materials to realize WOLED [2-4]. Since it is difficult to obtain all the three primary emissions from a single molecule with balance, more than one organic species are required, and these organic materials are arranged to be efficient energy transfer. Ideal white point is defined as (0.33, 0.33) in the Commission Internationale de l'Eclairage (CIE). To improve efficiency and color, structures of devices have been complex and increased the number of layers. But the color of WOLED is not sufficient yet, especially the color change as the driving voltage and the driving time is remained serious problem [5, 6].

In this study, we fabricated white to use very simple structure having only single emitting layer,

DPVBi. The DPVBi emission peaks at ~460nm; the rubrene absorption spectrum peaks at 460, 490 and 529nm. Thus, energy transfer should efficiently occur by the Förster energy transfer [5,7,8]. As rubrene was doped partially in a definite DPVBi, energy transfer happened partially from DPVBi to rubrene. We controlled the degree of energy transfer by the distance between a hole transport layer and a doped layer and made white emission devices.

### 2. Results

Figure 1 shows the structures of fabricated devices used in this work. The anode, ITO with resistance of 10Ω/sq. was patterned by photolithography and wet etching processes. The organic and metal cathode layers were deposited sequentially with shadow mask by thermal evaporation in a background pressure of 10<sup>-7</sup> Torr and with a deposition rate of 1-2Å /s. WOLED was composed ITO, 4,4',4''-tris[2-naphthyl(phenyl)amino] triphenylamine (2-TNATA), 4,4-bis[N-(1-naphthyl)-N-phenyl-amino]biphenyl (α-NPD), 4,4-bis(2,2-diphenylvinyl)-1,1-biphenyl (DPVBi) : 5,6,11,12-tetraphenyl-naphthacene (Rubrene) (0.1%), tris-(8-hydroxyquinoline) aluminum (Alq3), 2,9-dimethyl-4,7 diphenyl-1,10-phenanthroline (BCP) and LiF-Al. DPVBi was used as the blue emitting material and the host for Rubrene. The Rubrene was partially doped in DPVBi layer. Here, "X" is defined as the distance from the interface between a hole transport layer, NPD and starting point of doped layer with Rubrene in DPVBi. The position of doped Rubrene layer in DPVBi makes color control with an orange and sky blue-emitting. The doping concentration was fixed as 3.6% and the thickness of doped layer was 50 Å.

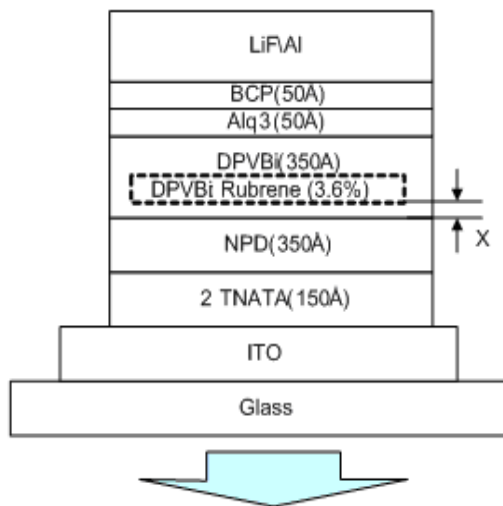


Fig. 1 Structure of fabricated WOLED

Fabricated devices were encapsulated with a glass cap and UV sealant. All the devices have the emitting area of  $0.4 \times 0.6 \text{ mm}^2$ . A Spectroradiometer (Minolta CS1000) was employed for measurements of the electroluminescence spectrum. Current-Voltage (I-V) characteristics were measured with an experimental set-up consisting of a Keithley 2400 source meter with calibrated photodiode. Measurements and data acquisition were controlled by National Instrument's LabVIEW software.

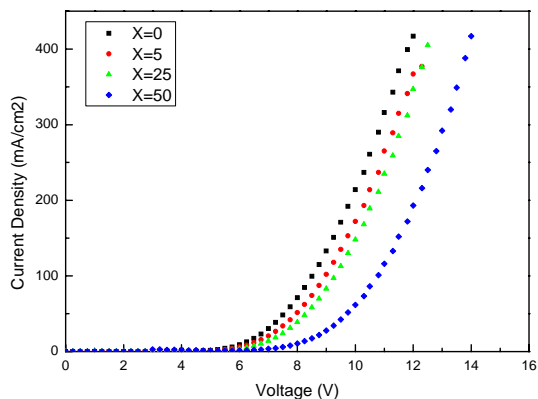


Fig. 2 Current density versus voltage as X

Figure 2 shows the characteristic curve of WOLEDs as a function of X. When the doped layer contacts with HTL, that is X is  $0 \text{ \AA}$ , it has a lowest turn-on voltage, 4.25V and a highest current density at the same voltage. The gaps between doped layer and HTL cause the turn-on voltage to increase. It seems that the rubrene acts a significant trap site and alter the I-V characteristics. Especially, rubrene traps mainly electrons [9]. Therefore, as X is increased, a doped layer with rubrene is close to cathode and electron transporting is obstructed.

The device with X=0 has a highest peak efficiency, 9.92cd/A at 6V and a high brightness, 10670cd/m<sup>2</sup> at 9V. However very thin gap, X=5 Å affects the device properties. That has the lower efficiency, 6.04cd/A at 9V, 3253cd/m<sup>2</sup>.

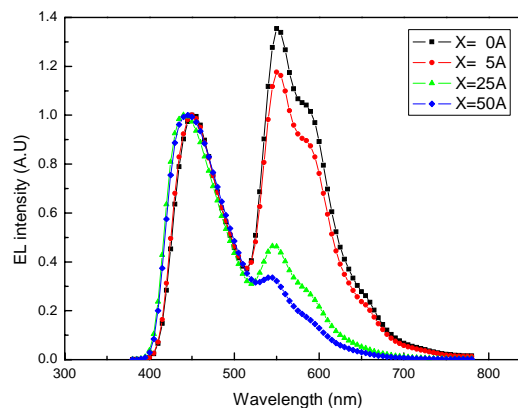


Fig. 3 EL spectra of fabricated device as a function of X at 9V

EL spectra of devices with different X are represented at fig. 3. The applied voltage is 9V. A blue peak is used as standard to normalize. In the devices with X=0 Å and 5 Å, orange peak is higher than blue peak. When X=0, EL spectrum shows two dominant two peaks, 445nm with a full width at half maximum (FWHM) of 77nm and 550nm with a FWHM of 72nm, respectively. And in the red region, the peak has a shoulder at 585nm. As the distance X is increased, intensity of red peak is hypersensitively changed. When X=5 Å, the intensities of the two main peak become alike. In the red region, the intensity of the shoulder gets weaker and FWHM of the peak is narrower. As X is increased over 25 Å, the peak at

550nm is rapidly diminished. So these devices have near blue color, (0.225, 0.227) and (0.197, 0.196) at X=25 Å and X=50 Å, respectively. The excited energy at the near interface of HTL and EML uses mainly to generate blue emission. However if the position of doped layer exceeds in the range of energy transfer, it is difficult for the emission from rubrene to occur.

Color stability is an important issue in WOLEDs. Figure 4 shows color coordination of device with X= 0 Å and X=5 Å as a function of applied voltage. When X=0 Å, as applied voltage increase, color coordination is shifted with the axis connected from inherent Rubrene emission (0.46 0.53) to DPVBi emission (0.15, 0.16).

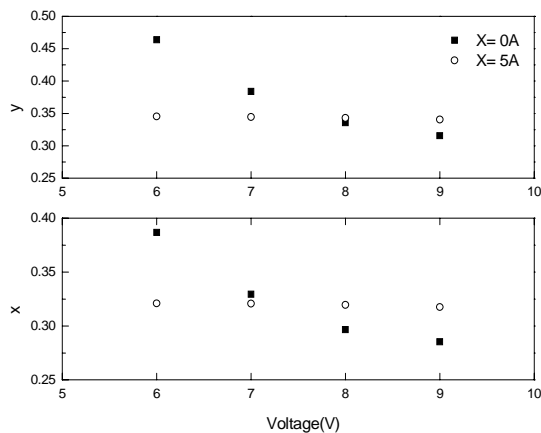


Fig. 4 Color coordination of WOLEDs of X= 0 Å and X= 5 Å as applied voltage

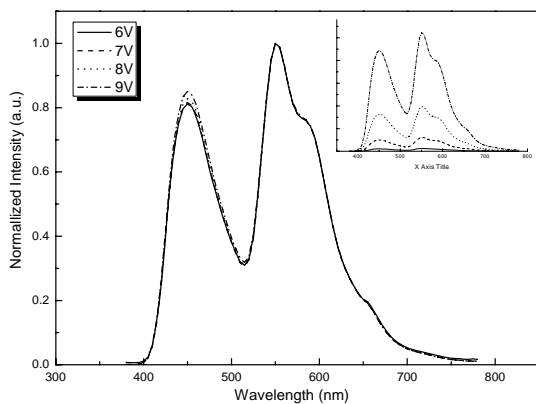


Fig. 5 EL spectra of device with X=0 Å as applied voltage

The device with X=5 Å keeps excellent color stability in applied bias range. The deviations of color coordination, x and y are 0.0035 and 0.0046, respectively. Fig. 5 is second evidence about excellent color stability as applied voltage. EL spectra are hardly changed without regard to applied voltage.

### 3. Conclusion

In this study, we fabricated WOLEDs that was used two colors, blue and orange. DPVBi was used as host and blue emission material. To realize WOLED, rubrene was doped in DPVBi with concentration of 3.6% and doped layer was restricted within 50 Å and located with distance, X. In this way, we controlled the degree of energy transfer from DPVBi to rubrene. As X is increased, rubrene operated as the trap site of electron and its contribution to the emission gets lowered.

When a doped layer was contacted to HIL, that's X was 0 Å, device has the best efficiency, 9.92cd/A at 6V and highest brightness. However, this device had still problem that EL spectrum shifted as an applied voltage.

In case of device with X=5 Å, although efficiency is lower than X=0 Å, it has high stability of color coordination under various driving voltage. The color coordination of this device was (0.345, 0.321) at 6V and nearly constant without regard to applied voltage.

### 4. Acknowledgements

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### 5. References

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