Possibility of white organic electroluminescent device for full-color displays

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Abstract

We reported the possibility of color filtering of white method for achieving full-color displays using OELDs. Here, we fabricated white organic electroluminescent devices (OELDs) and drove moving images with a 384×160 pixel.

1. Introduction

Since an organic electroluminescent display (OELD) introduced by C.W. Tang and S.A. Vanslyke [1], it has become attractive flat panel displays (FPDs). In order to achieve full-color OEL display application, there are several methods [2], such as side-by-side patterning of Red, Green, and Blue, down conversion of blue OELDs, color filtering of white OELD and microcavity filtered OELDs. Among these methods, white OELDs attract the most interest in applications, such as full-color displays, backlights of liquid crystalline displays and portable panel light sources. In order to use the white OELDs as full-color FPDs, the light emission should be bright, efficient and have Commission Internationale d'Eclairage (CIE) chromaticity coordinates of (0.33, 0.33). For obtaining white emission from OELDs, different colors should be mixed with proper balances.

In this study, we will fabricate low-molecular-weight organic white-light-emitting device and show the potential possibility of white OELDs for achieving full-color flat panel displays.

2. Experimental

A glass substrate precoated with an ITO thin film with a sheet resistance of 10 Ω/□ was cleaned by the wet cleaning method and photolithographically patterned to form the transparent anode. On top of the anode a buffer layer of phthalocyanine copper complex (CuPc) was deposited by vacuum sublimation in order to enhance the hole injection from the anode. We used 4,4'-bis[N-(1-naphthyl)-N-phenyl-amino]biphenyl (α-NPD) as the HTL instead of TPD of which the glass transition temperature (T_g) is about 36 °C lower than α-NPD (96 °C). And α-NPD was used as an electron blocking layer between two emissive layers. We used IDE-120 as a blue emitting material, 5,6,11,12,-tetraphenylnaphthacene (Rubrene) as a yellow emitting dopant and tris-(8-hydroxy-chinolinato)-aluminum (Alq_3) as a yellow emitting host. The ratio of Alq_3:rubrene is 100:3. A reason why we select IDE-120 and rubrene-doped Alq_3 as emissive materials is that direct mixing of the two colors emitted from those materials could produce a white emission at a certain balance. According to the thickness of the carrier blocking layer and the thickness of the emitting layer with applied voltage, the spatial location of exciton recombination zone could change, and the color emitted from the OLEDs is subjected to change as the result. As an ETL, Alq_3 was used on top of the emissive layers. All the organic layers were thermally deposited with an approximate growth rate of 1-2 Å/s. For a cathode electrical contact, LiF was deposited before Al, cathode deposition. Current-voltage characteristics, electroluminescent spectra and luminescence intensities were measured with a Kethley 2043 measure unit and a silicon photodiode calibrated with a luminance meter (Minolta CS-1000). Current-voltage characteristics, luminance intensity and spectra were measured at the same time. We tested half-life time at constant current density. Also, we drove fabricated device with our own passive matrix drive circuit without using color filter.

3. Results and discussion

In order for white-light-emitting device, we fabricate two emitting layer yellow to blue sequentially. For balanced white light, we use an electron-blocking layer. Electron-blocking layer could split the exciton recombination zone for a certain balance. In case of this device, it emits blue and yellow color, respectively and mixed directly. Therefore, the device emits white. The fabricated OELD structure in this study is shown in Fig. 1.

Cathode(Al)	1800 Å
LiF	7 Å
ETL(Alq_3)	300 Å
Blue(IDE120)	100 Å
BL(a - NPD)	50-100 Å
Yellow(Alq_3:Rubrene,3%)	100 Å
HTL(α - NPD)	400 Å
HIL(CuPc)	100 Å
Anode(ITO substrate)	

Fig.1. The schematic diagram of fabricated OLED structures.

The CIE color coordinates of the resultant emissions from the OLED structure are shown in Fig.2. As shown in Fig.2, the color coordinates move from yellow to blue as applied voltage increase. However, the fabricated devices emit the white light except for the low applied voltage.

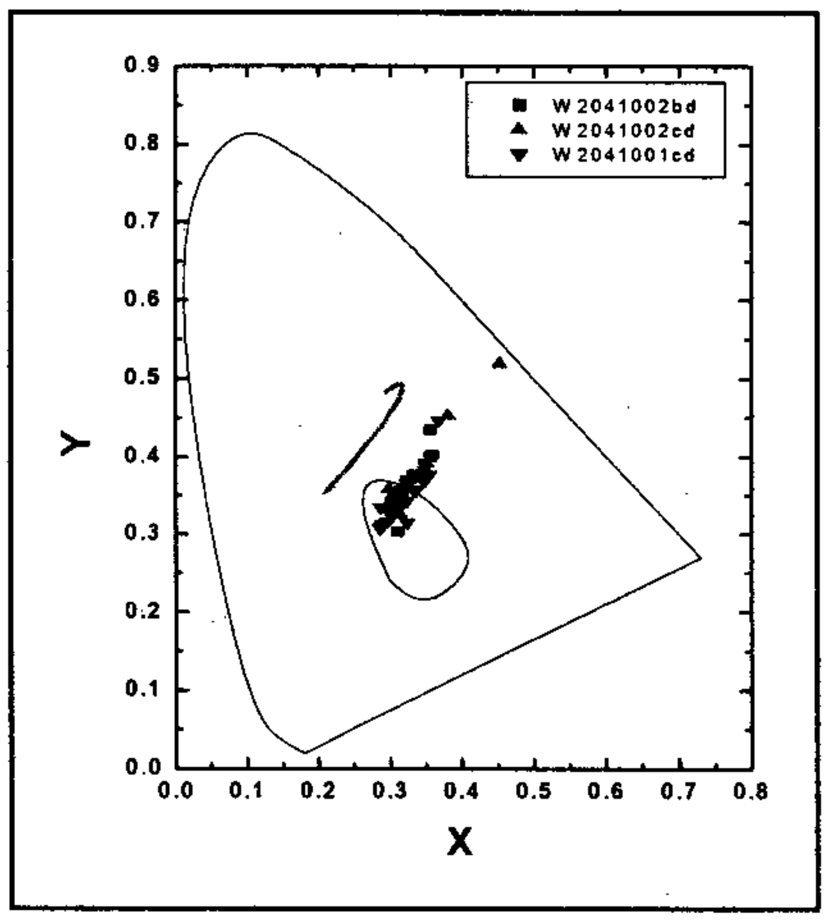

Fig.2. The CIE color coordinates of the fabricated OLED.

As shown in Fig.3 and Fig.4, maximum EL intensity is 31,630cd/m^2 at 11V and maximum power efficiency is 6.35lm/W. This result is much higher than previous reports [3-9]. As the typical characteristics, the luminance, the CIE coordinate, and the efficiency were 103cd/m^2, (0.34, 0.36), and 6.24cd/A at an applied voltage of 6V (current density = 1.65mA/cm^2), respectively.

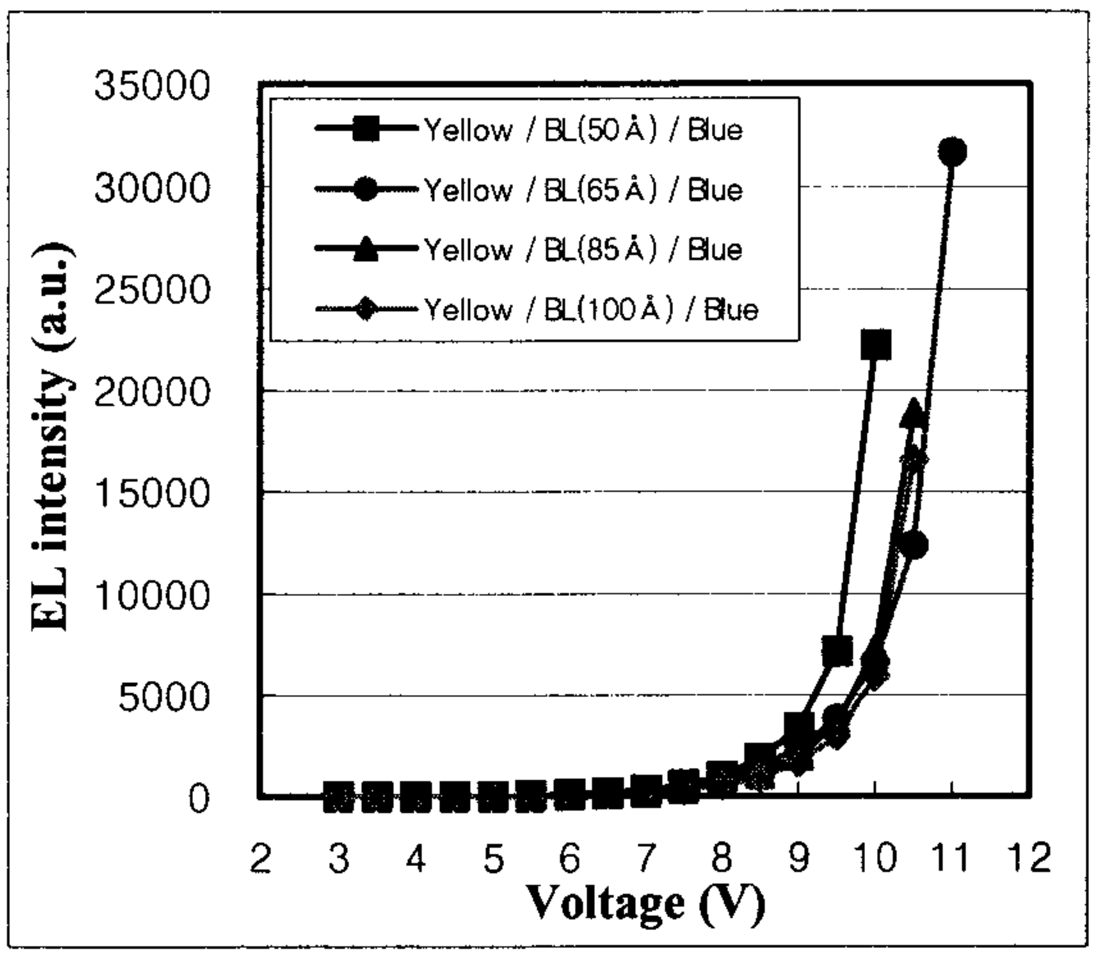

Fig.3. The emission intensities at thickness of blocking layer.

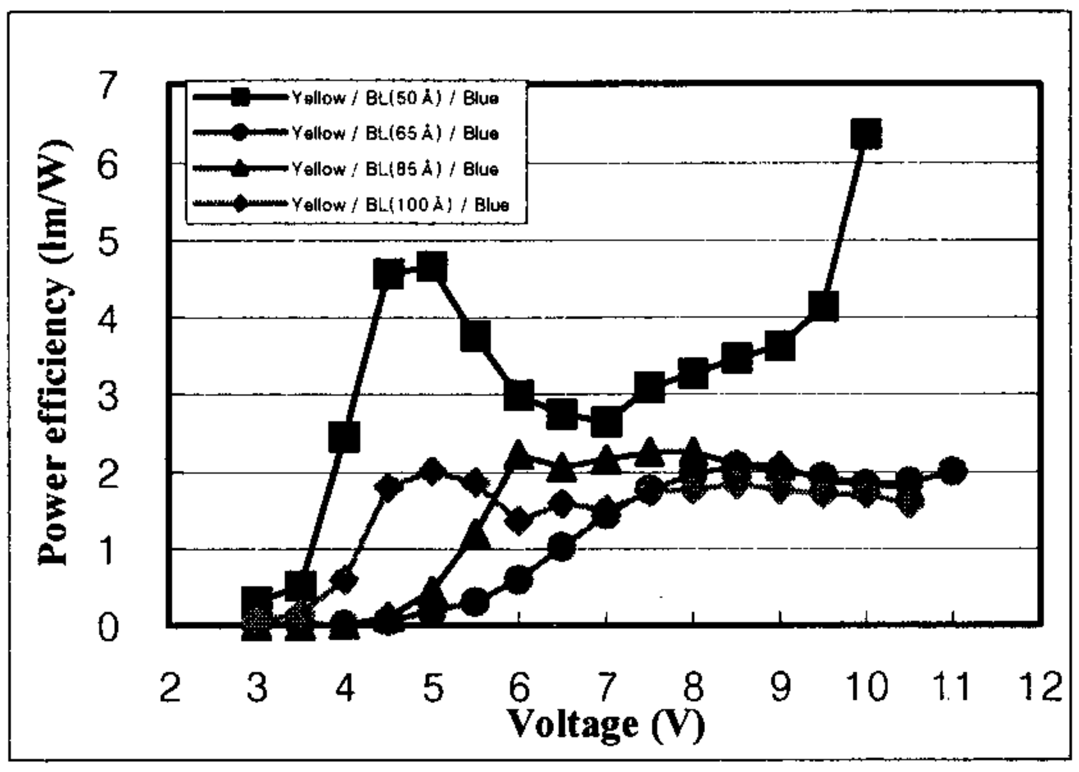

Fig.4. The power efficiencies at thickness of blocking layer.

Fig. 5 shows EL spectrum for the device whith two-layered EML. The EL spectrum consists of a 455nm band and a 560nm band.

In case of this device, as applied voltage increase, respective emission intensity did not change.

Also, we performed an acceleration test under the DC constant current density. The life time measured to be about 6640hr at an initial luminance of 100cd/m^2, as shown in fig. 6.

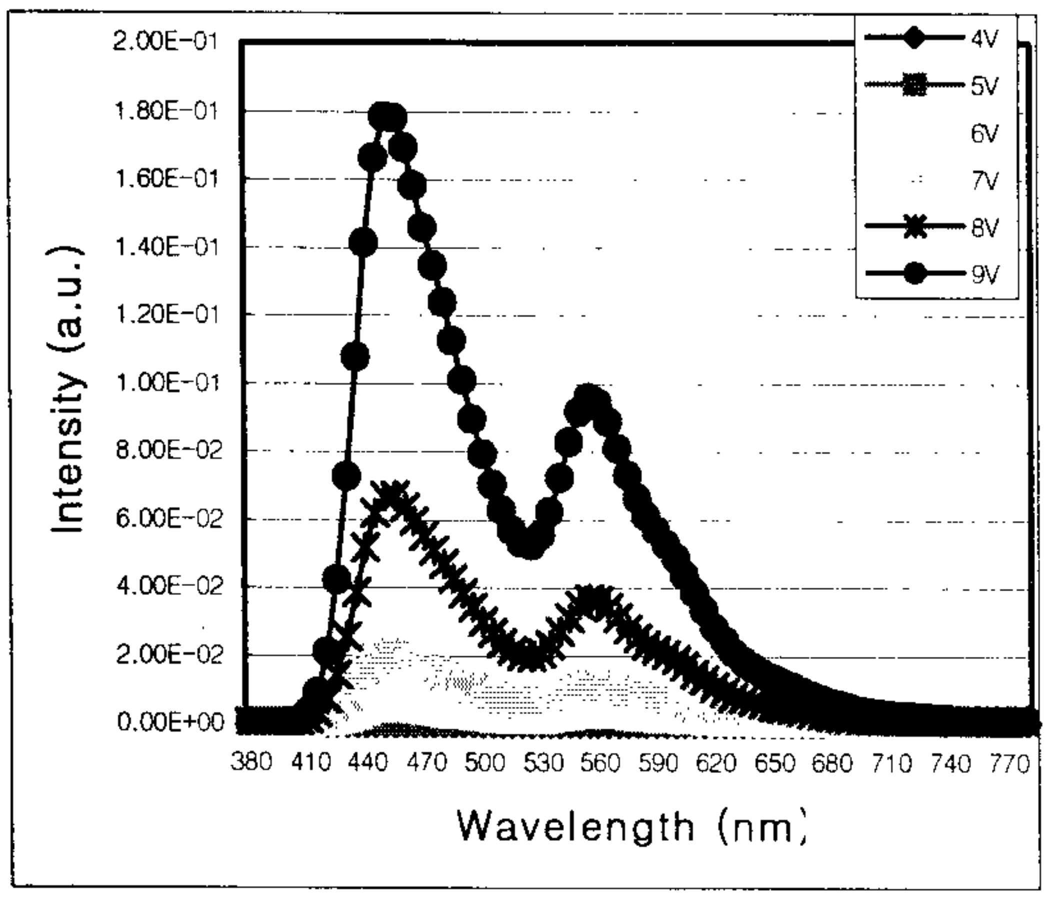

Fig. 5. EL spectrum of white EL

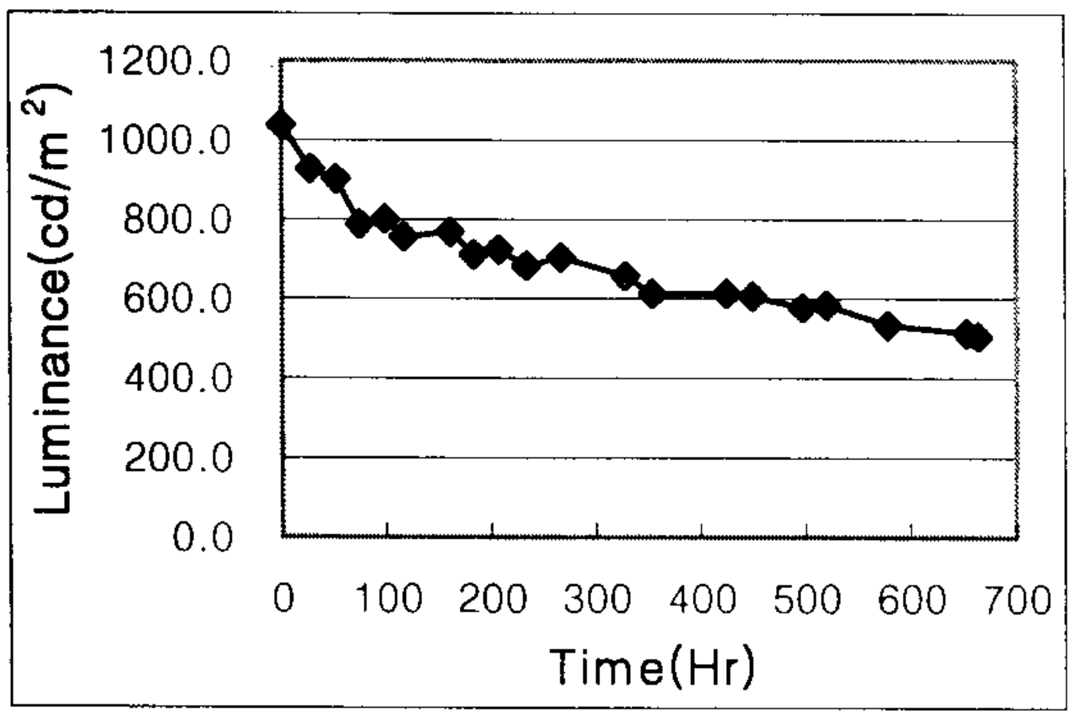

Fig.6. Acceleration life time test under DC constant current density.

Finally, we drove moving image with our own driving circuit unit. Fig. 7 shows block diagram of drive circuit system [10].

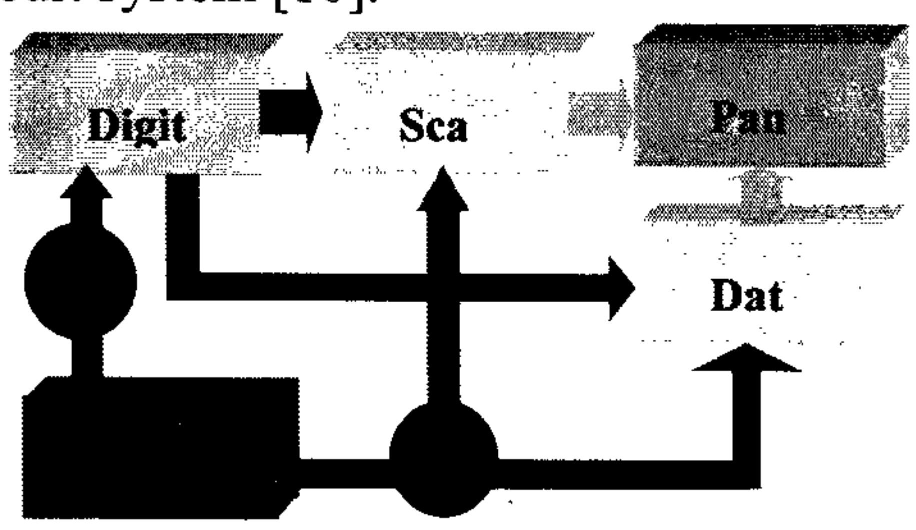

Fig.7. Block diagram of drive circuit

This system includes the digital system, which controls data and scan driver, scan driver selecting lines, data driver for the PWM (Pulse Width Modulation) control of gray scale, and power supply for the digital and analog power. Digital power is for the digital board and analog power is for the scan and data driving. We drove fabricated device with dual scan method and 1/80 duty pulse driving.

Fig. 8 shows picture of moving image. This panel has 384×160 pixels with an equivalent sub-pixel size of $200 \times 45 \mu m^2$.

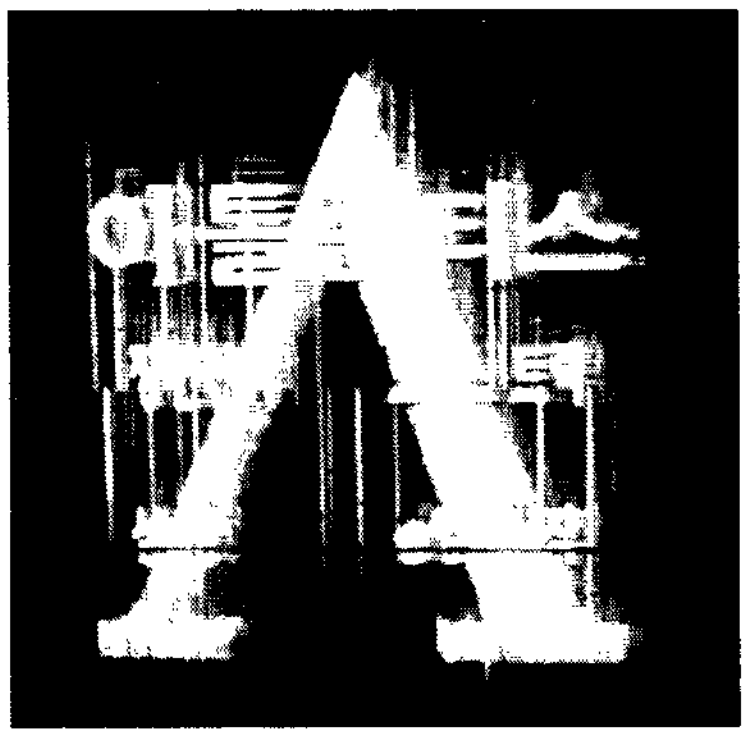

Fig. 8. An example of video image of the white OELD display.

4. Conclusion

We fabricated white-light-emitting organic electroluminescent device and drove moving image with our own driving circuit. Because white device don't need accurate shadow mask alignment system and decrease evaporation process time compare to patterning of R, G, and B method, white method should be suggested method for mass production. But, new white emitting materials and new structure should be further studied in order for mass production. Also, the cost price of color filtered ITO should be decrease.

5. References

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