Study of White Polymer Light Emitting Diode with Blending Method

Byong-Wook Shin[1], Sung-Youp Lee[2], Eui-Wan Lee[1], and Hyeong-Rag Lee[1]
[1]Dept. of Physics, Kyungpook National University, Daegu, 702-701, Korea
TEL:82-53-950-5321, e-mail: phyhrlee@knu.ac.kr.
[2]Dept. of Nano-science & Technology, Kyungpook National University, Daegu, 702-701, Korea
Keywords : White, PLED, Polymer, Blend

Abstract

In this study, we report the luminescent properties of white polymer light emitting diode (WPLED) fabricated by soluble methods with poly-fluorene-based polymers blends which emit blue and yellow light. A device structure of ITO/PEDOT:PSS/ Emissive Layer (EML)/Al was employed.

1. Introduction

Since the Cambridge group published the electro-luminescence (EL) property of a conjugated polymer in 1990[1], many research groups have devoted their efforts to polymer light-emitting diode (PLED). Compared to other technologies, PLED have several advantages such as light weight, large emitting surface, wide view angle, full color capacity, high luminance and high efficiency. Recent investigations have demonstrated that flexible devices could be realized using polymer substrates.

White polymer light-emitting diode (WPLED) have attracted interest for their potential applications in active matrix displays with color filters and solid-state lighting systems for general illumination. WPLED have been successfully fabricated by means of solution processing of polymers. Therefore, WPLED would result in cutting costs and simple manufacturing process than vacuum deposition. Recent attempts have focused on the blending of two or more well-known polymer emitters for WPLED.[2-5]

Here, we report the luminescence properties of WPLED fabricated by solution process using our synthesized poly-fluorene-based polymer blends which emit yellow and blue light. As application of WPLED, we designed and fabricated mobile phone keypad backlight.

2. Experimental

We synthesized blue emitting polymer (EMC5) and yellow emitting polymer (EMC10) based on poly-fluorene by Suzuki coupling reaction[6]. The properties of polymers were measured by gel permeation chromatography (GPC), differential scanning calorimeter (DSC), thermogravimetry (TGA), and photoluminescence spectroscopy (PLS). The white emitting polymer solutions were made by blending the two polymers with different ratio by weight.

The devices were fabricated on the 0.7mm thickness glass substrate coated indium tin oxide (ITO). The ITO thickness was about 150nm. The substrates were cleaned with several solvents in an ultrasonic bath and then patterned by photolithography. Poly(3,4-ethylenedioxythiophene) / poly-(styrene sulfonate) (PEDOT/PSS) as hole injection layer (HIL) was spin-coated at 2500rpm and dried on hot plate at 150℃. Emissive layer (EML) was spin-coated with polymer blends from a toluene solution at 3000rpm and dried in vacuum oven at 60℃ for 6 hours. Aluminum (Al) as the air stable electrodes was vacuum deposited by thermal evaporator.

The electrical and optical properties of the devices were measured by I-V-L measurement system that is composed of XANTRAX power supply (model XDL35-5TP) and MINOLTA chroma meter (model CS-100) in dark chamber.

3. Results and discussion

Table 1 and Fig. 1 show the physical properties and structure of polymers respectively.

TABLE 1. Physical properties of polymers.

	M_w	M_n	PDI	UV	T_g	TGA
EMC5	42,048	12,693	3.312	385nm	219.9℃	436℃
EMC10	36,983	14,363	2.574	388nm	188.1℃	437℃

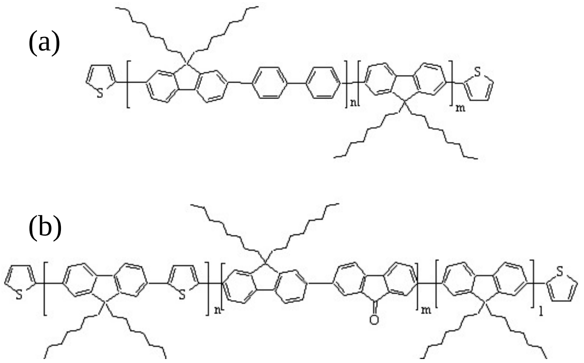


Fig. 1. Structure of polymers. (a) EMC5 blue emitter (b) EMC10 yellow emitter.

The photoluminescence (PL) spectra of polymers are shown in Fig. 2. The maximum intensity wavelength of polymers are 447nm(blue) and 548nm(yellow).

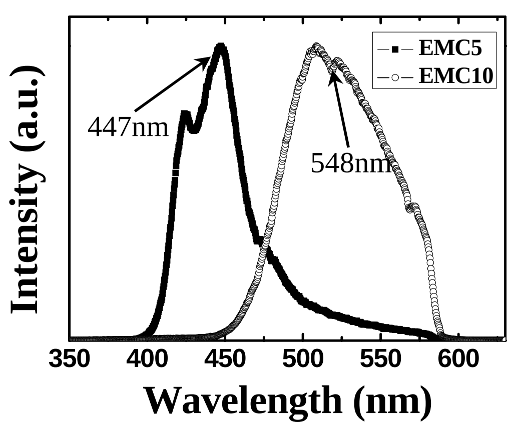


Fig. 2. PL spectra of polymers.

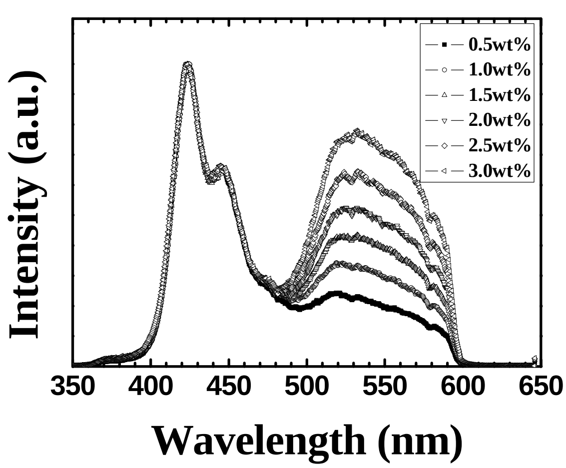


Fig. 3. PL spectra of white emitting polymers. The percentage in the box indicates the quantity of EMC10 by weight in white emitting polymers.

The quantity of EMC10 was much less than it of EMC5 because the polymer with less bandgap has more probability of exciton recombination in blending system. The quantity of EMC10 was from 0.5wt% to 3.0wt% by weight in white emitting polymers.

The PL spectra of white emitting polymers are shown in Fig. 3. The intensity of yellow was increasingly changed as increase of blend ratio.

Fig. 4 and 5 shows the current density–voltage (I–V) and luminance–voltage (L–V) characteristics of a WPLED

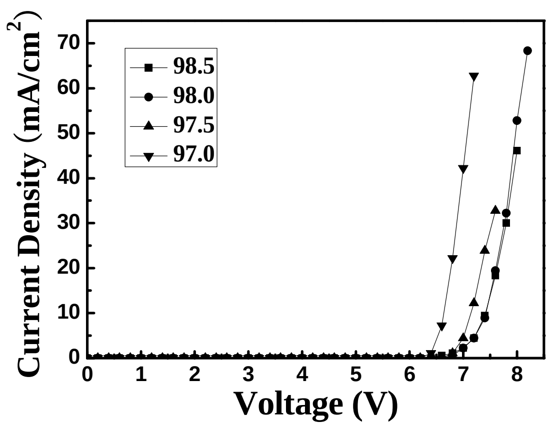


Fig. 4. Current density–Voltage (I–V) characteristics

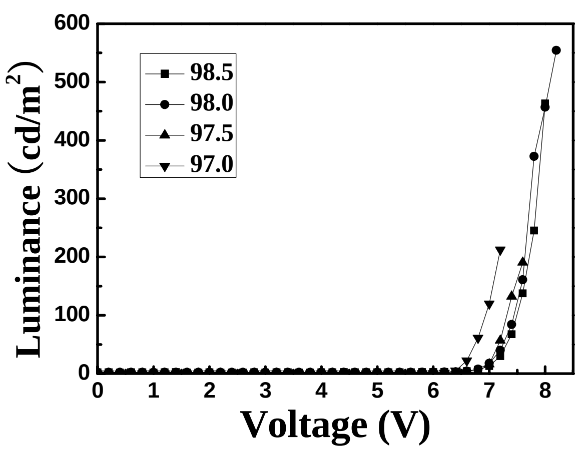


Fig. 5. Luminance–Voltage (L–V) characteristics

Fig. 6 shows the I-V-L characteristics of the optimized WPLED with 2.0wt% EMC10. The maximum efficiency reaches 1.4cd/A and maximum brightness is about 550cd/m^2. As the blend ratio increase from 0.5wt% to 3.0wt%, the Commission Internationale de I'Eclairage (CIE) coordinates of WPLEDs change from (0.209, 0.325) to (0.365, 0.498). The color of the emitted light was changed from bluish to yellowish white due to the increase of blend ratio.

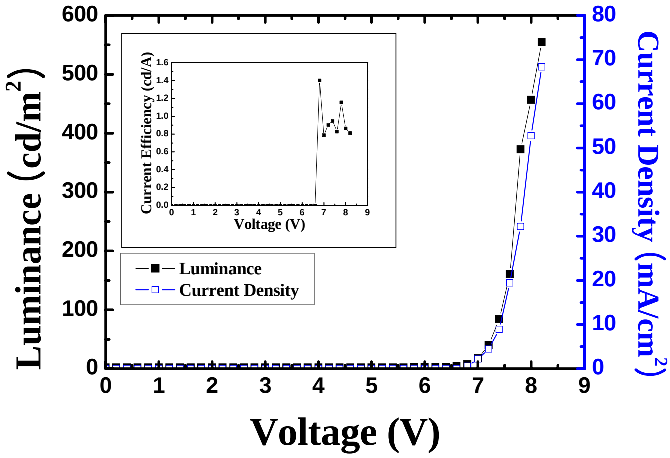
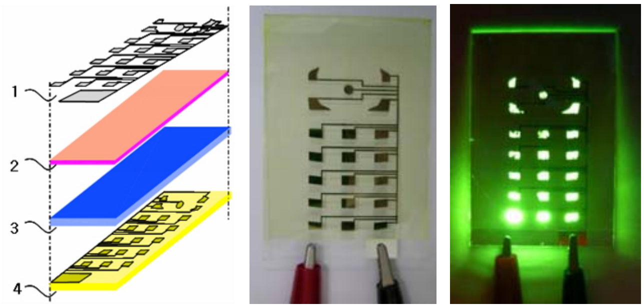


Fig. 6. I-V (open square) and L-V (solid square) characteristics of WPLED with EMC10 2wt%. The current efficiency (inset) of WPLED.

We designed the keypad backlight for mobile phone with My Chip Station Pro 2005.



(a) (b) (c)

Fig. 7. (a) Structure of mobile phone keypad backlight (b) Turn-off (c) Turn-on.

The structure of mobile phone keypad backlight and real images are shown in Fig. 7. In Fig. 7-(a), 1 is cathode(Al), 2 is EML, 3 is HIL and 4 is anode(ITO). Since the WPLED is driven by current, there was difference of luminance as distance from source.

4. Summary

We have synthesized the blue and yellow light emitting polymers. White light emitting polymer were made by blending two polymers with different ratio. We found that the optimized blending ratio was EMC5(blue):EMC10(yellow) = 98:2. The value of the maximum current efficiency and CIE coordinates at luminance of about 100 cd/m^2 are 1.4 cd/A and (0.27,0.36) respectively. We designed and fabricated the mobile phone keypad backlight.

The additional experiments with well-purified polymers are under investigation of better device performance such as higher luminance, higher efficiency and longer lifetime.

5. Acknowledgement

This research was financially supported by the Ministry of Commerce, Industry and Energy (MOCIE) and Korea Industrial Technology Foundation (KOITF) through the Human Resource Training Project for Regional Innovation.

6. References

1. J. H. Burroughes, D. D. C. Bradley, A. R. Brown, R. N. Marks, K. Mackay, R. H. Friend, P. L. Burns, and A. B. Holmes, *Nature*, 539 (1990)
2. H. A. A. Attar, A. P. Monkman, M. S. Bettington and M. R. Bryce, *Appl. Phys. Lett.* **86**, 121101 (2005).
3. Gong, X.; Ma, W.; Ostrowski, J. C.; Bazan, G. C.; Moses, D.; Heeger, A. J., *Adv. Mater.* **16**, 615 (2004).
4. Kawamura, Y.; Yanagida, S.; Forrest, S. R., *J. Appl.Phys.* **92**, 87 (2002).
5. Tasch, S., List E. J. W., Ekström, O., Graupner, W., Leising, G., Schlichting, P., Rohr, U., Geerts, Y., Scherf, U., Müllen, K., *Appl. Phys. Lett.* **71**, 2883 (1997).
6. Norio Miyaura and Akira Suzuki, *J. Chem. Soc., Chem. Commun.*, 866 (1979).