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*Three-component blend system based on polyfluorene derivative (**SK32**®), substituted polyacetlyene (**PTMSDPA**) and iridium complex (**red dopant**) were fabricated as a single emitting layer for white OLED. The two polymers and iridium complex were well mixed to provide transparent films. Its electro-optical properties were investigated in terms of emission color, brightness, and luminescence efficiency. The optimal weight ratio for white emission was 100 (**SK32**®): 5 (**PTMSDPA**): 0.5 (**red dopant**). The color coordination at this ratio was ($x = 0.33$, $y = 0.33$), completely matching to white color. The luminance was 831 cd/m^2 at 17 V, its current efficiency was estimated to 1.15 cd/A at 9 V and the maximum power efficiency reached 0.44 lm/W at 7 V.*

Keywords: electroluminescence; single emitting layer; white OLED

INTRODUCTION

Recently, white OLED have attracted much attention due to potential applications using as backlights and lighting. To achieve ideal white OLED, considerable efforts have been done. The main methods are as follows: (i) syntheses of new compounds which emit white light due to either excimer or exciplexes, (ii) development of a multilayer structure which can mix different color of each layer to emit white light, (iii) development of blend systems which utilize Förster type energy transfer between host and dopant [1–3]. Among them, the last one would be methodologically the most approachable because of facile fabrication and easy color tuning.

For RGB combination in such blend systems, basic properties of each component should be thoroughly studied beforehand. Polyfluorenes are one of the most promising materials which emit pure blue light. Their properties other than electrooptical properties have been also well described to date [4]. On the other hand, disubstituted aromatic acetylene polymers usually emit intense yellowish-green light. Also, this type of polymer has high quantum efficiency in photoluminescence and exhibits excellent thermal and mechanical properties [5–7]. It is also expected that the two polymers are miscible due to aromaticity-based intermolecular interaction. As a red emitting material with the lowest radiative energy among the RGB components, phosphorescent

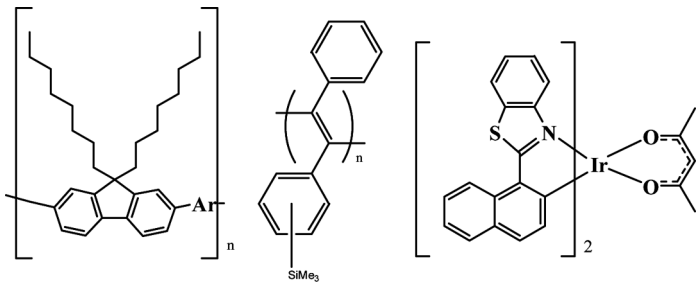
iridium complex can be one candidate as a color tuning dopant [6]. Thus, we focused on a mixture system of the three compounds for ideal RGB tuning in white OLED.

In this work, we successfully prepared a three-component, single emitting layer based on polyfluorene derivative, substituted polyacetlyene, and iridium complex. Eventually, it was found that the two polymers are well miscible and the optical band gap of the blend is easily controllable, and furthermore, suitable combination with small amount of red dopant leads to white OLED with appropriate brightness and luminescence efficiency.

EXPERIMENTAL

A polyfluorene derivative, **SK32**® was kindly donated from SK Group for blue-light emitting material. According to the previous papers, we synthesized disubstituted acetylene polymer, poly {1-phenyl-2-[p-(trimetylsilyl)phenyl]acetylene} (**PTMSDPA**) and **red dopant**, $(bsn)_2$-Ir(acac) [7–8]. Their chemical structures are shown in Scheme 1.

The Device structure is composed of ITO/PEDOT:PSS/**SK32**®**: PTMSDPA:red dopant**/LiF/Al. An indium-tin oxide (ITO) coated glass with a sheet resistance of 20 Ω/sq. which was commercially obtained was cut into 2.0 cm × 2.0 cm and carefully cleaned with DI-water, ethanol and organic solvents, and dried in an IR oven. The ITO electrode pattern was fabricated by photoetching technique. It was sequentially cleaned in an ultrasonic bath of acetone, methanol, and mixture of isopropyl alcohol and water (1:1 by volume). The poly (3,4-ethylenedioxythiophene)/poly (styrene sulfonic acid) (PEDOT: PSS) as a hole injection layer was spun onto the substrate from a water solution and then 100 nm thick PEDOT:PSS layer was baked



SCHEME 1 Chemical structures of **SK32**®, **PTMSDPA** and red dopant. Note that the structure of SK32 is expected one because this material is commercially available but the structure is unknown.

for 30 min at 150°C. Next, the 60 nm thick three-component blend film as emission layer was fabricated by spin-coating method which **SK32®**, **PTMSDPA**, and **red dopant** were dissolved in toluene at different weight ratio. Finally, the 1.0 nm-thick LiF film as an electron injection layer and 130 nm-thick Al film as a cathode were vapor-deposited under a pressure of 1×10^{-6} torr at rate of about 2 Å/s and 3 Å/s, respectively.

The spectra of UV-visible absorption were obtained by Shimadzu UV-2100, and the photoluminescence (PL) spectra excited by He-Cd laser at 325 nm were monitored by Optical Multichannel Analyzer (Laser Photonics, OMA system). The Electroluminescence (EL) spectra and Commission International De L'Eclairage (CIE) coordinates of these devices were measured by spectroradiometer (Photo Research, PR-650). The Current density-voltage characteristics were recorded by the computer controlled source-meter (Kiethley 2400). All measurements were carried out under ambient conditions at room temperature.

RESULTS AND DISCUSSION

The UV-visible absorption and PL spectra of **SK32®**, **PTMSDPA** and **red dopant** are presented in Figure 1. The spectral data are summarized in Table 1 in terms of maximum absorption wavelength ($\lambda_{max,UV}$), band gap energy calculated from the absorption edge ($\lambda_{edge,UV}$), maximum emission wavelength ($\lambda_{max,PL}$), and Stoke's shift [9–11]. As can be seen in Figure 1, $\lambda_{max,UV}$ values were measured to be 394 nm for **SK32®** and 430 nm for PTMSDPA. Two polymers, **SK32®** and PTMSDPA, exhibited their $\lambda_{max,PL}$ at 466 nm in blue emission and at 494 nm in yellowish green range, respectively. The red dopant showed $\lambda_{max,UV}$ at 478 nm and $\lambda_{max,PL}$ at 612 nm in the range of red emission.

In order to optimize a blend ratio of **SK32®** and **PTMSDPA**, several samples with different weight ratio were fabricated. The **SK32®** and **PTMSDPA** were found to be completely miscible at all ratio examined. Actually, no phase separation was seen under optical microscope (10×40 magnification) as well as by naked eye. This may be due to aromaticity-based intermolecular interaction between the two polymers at a molecular level.

Figure 2 shows the normalized EL spectra of **SK32®-PTMSDPA** blend at various weight ratios. The corresponding CIE coordinates are also shown in the same figure. With the increase of **PTMSDPA** concentration from 0.0 to 5.0 wt%, the initial maximum emission band at 452 nm shifted to longer wavelength to reach 488 nm (5.0 wt%) and the CIE coordinates varied from (0.15, 0.11) to (0.23, 0.33). Simultaneously,

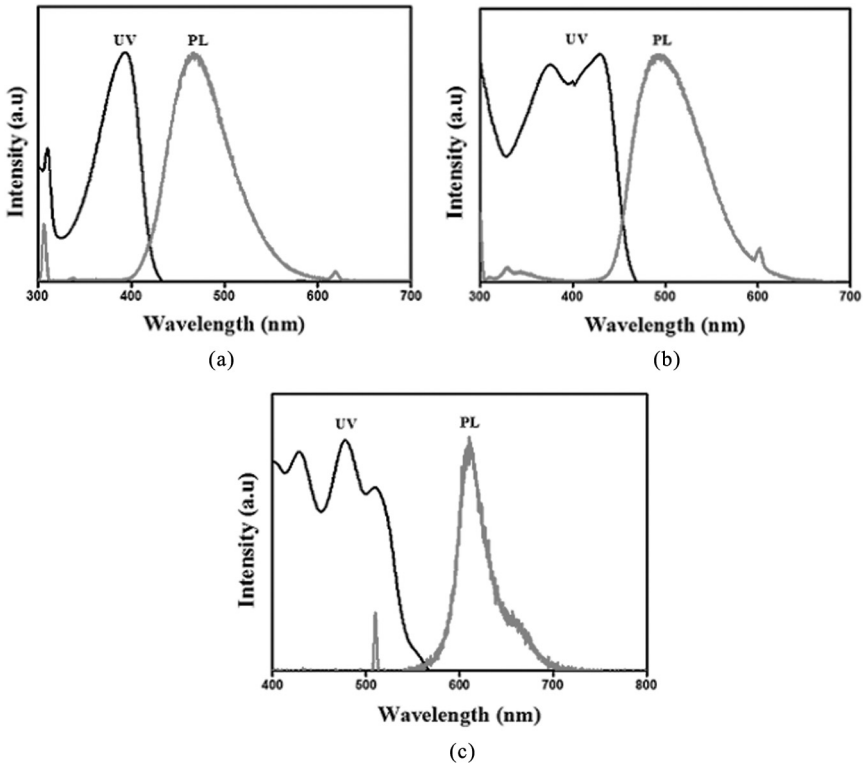


FIGURE 1 UV-vis absorption and PL spectra of (a) **SK32**®, (b) **PTMSDPA**, and (c) **red dopant** in dichloroethane. (See COLOR PLATE XIII)

the full width at half maximum significantly increased. The red-shift and the increase of full width at half maximum indicate an effective energy migration from **SK32**® to **PTMSDPA**.

The **SK32-PTMSDPA** blend with 100:5 weight ratio exhibited emission with a maximum at 488 nm, and its color coordination is ($x = 0.23$, $y = 0.33$). To further accurately tune the color for ideal

TABLE 1 Optical Properties of **SK32**®, **PTMSDPA** and **red dopant**

Materials	λ_{Max}, UV(nm/eV)	λ_{Edge}, UV(nm/eV)	λ_{Max}, PL(nm/eV)	Stoke's shift (nm)
SK32	394/3.15	419/2.96	466/2.66	72
PTMSDPA	430/2.88	453/2.74	494/2.51	64
Red dopant	478/2.59	564/2.20	612/2.03	134

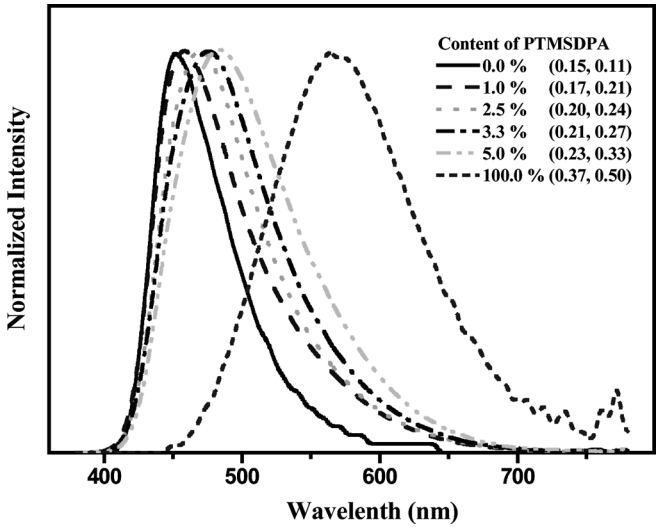


FIGURE 2 Normalized EL spectra of **SK32®-PTMSDPA** blend at various weight ratio.

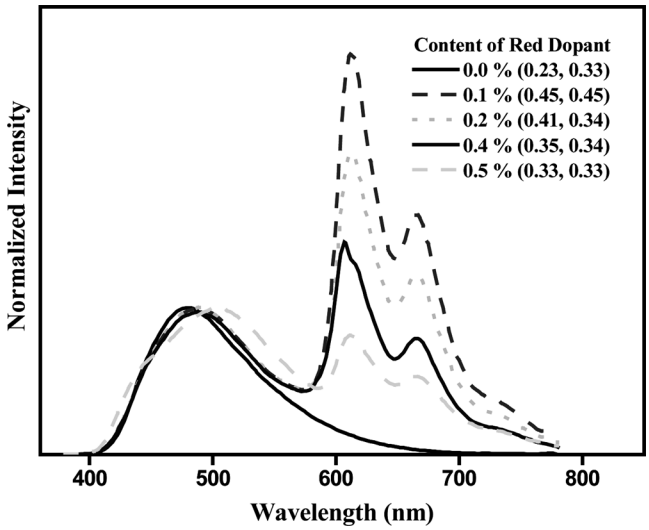


FIGURE 3 Variation of EL spectra of **SK32®-PTMSDPA** blend with 95:5 weight ratio upon addition of **red dopant**.

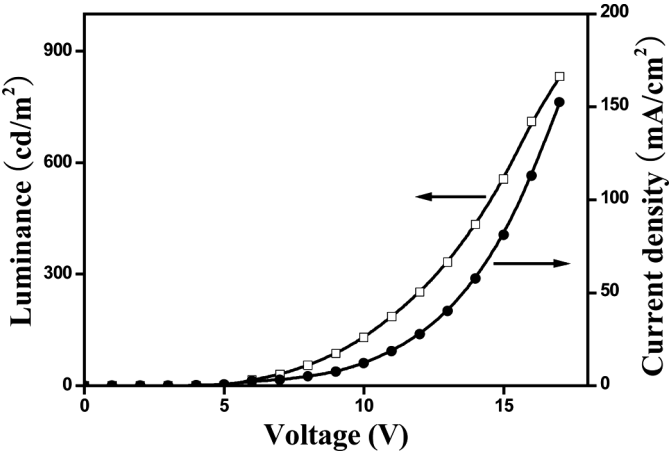


FIGURE 4 The current-brightness-voltage characteristics of white OLED.

white (x = 0.33, y = 0.33), **red dopant** was used as a phosphorescent red dopant. Figure 3 shows the variation of normalized EL spectra and the corresponding CIE coordinates of the OLED upon addition of **red dopant**. The intensity of EL maximum band ($\lambda_{max} = 488$ nm) of **SK32®-PTMSDPA** blend with 100:5 weight ratio gradually decreases with the increase of doping concentration of **red dopant**, while the

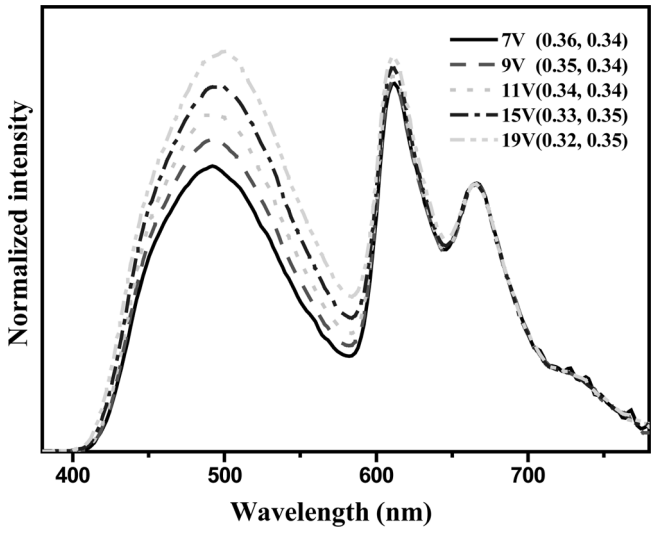


FIGURE 5 Normalized EL spectra of the white OLED with a driving voltage.

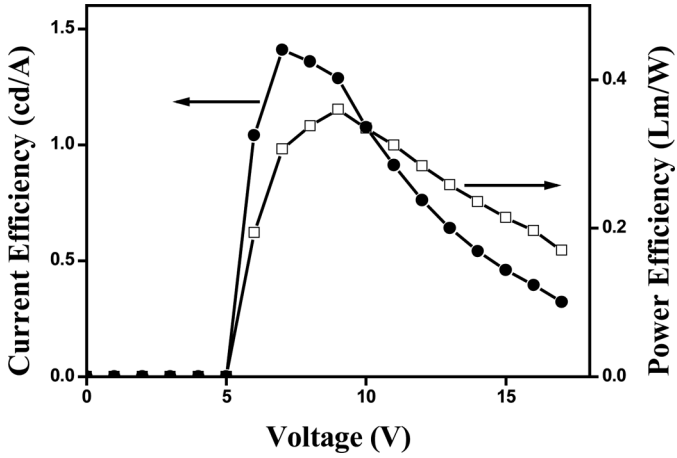


FIGURE 6 The variation of current and power efficiency with driving voltage for the white OLED.

red band ($\lambda_{max} = 608$, 664 nm) of **red dopant** significantly increases. Simultaneously, the initial CIE coordinates of (0.23, 0.33) with no **red dopant** shifted to (0.33, 0.33) after addition of 0.5 wt% **red dopant**. Eventually, white OLED was easily optimized by the three component, single emitting layer system.

Figure 4 shows the current-brightness-voltage characteristics of the white OLED fabricated. The turn-on voltage was about 4 V and the maximum luminance of 831 cd/m^2 was obtained at a driving voltage of 17 V. The CIE coordinates of the white OLED slightly changed from (0.36, 0.34) at 7 V to (0.32, 0.35) at 17 V as shown in Figure 5. Figure 6 shows the EL efficiency characteristics of the same device. The maximum current efficiency was 1.15 cd/A at 9 V and the maximum power efficiency reached 0.44 lm/W at 7 V.

CONCLUSIONS

White OLED device was fabricated using three-component blend of commercial polyfluorene (**SK32**®, blue), substituted aromatic polyacetylene (**PTMSDPA**, yellowish green), and iridium complex (**red dopant**, red) as a single emitting layer. The emission color tuning for white-light emitting was easily achieved by optimizing the mixing ratio of **SK32**®, **PTMSDPA** and **red dopant**. The maximum luminance, EL efficiency, and CIE coordinates reached 831 cd/m^2, 1.15 cd/A, and (0.33, 0.33), respectively. Further studies on the optimization of device structure and layer thickness are now in progress.

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