Large area lighting applications with organic dye embedded flexible film

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ABSTRACT

A flexible large area lighting devices have been demonstrated by PDMS films. The (polydimethylsiloxane) PDMS films doped with organic/inorganic materials. The PDMS film is favorable due to its heat stability, good transparency, and flexibility. This study aimed to combine both organic and inorganic materials for flexible large area lighting applications. The architecture consists of blue LEDs coupled to a leaky waveguide that is covered with the PDMS film. The white light was generated with the poly (9, 9-dioctylfluorene-co-benzothiadiazole)F8BT blended into the PDMS slurry. Organic wavelength conversion materials were chosen owing to their ability to decompose in nature. The more conventional inorganic phosphors such as YAG are difficult to decompose and may present environmental issues which can bring concerns in many lighting applications.

These flexible PDMS films had thicknesses of 100μm, 440μm, and 980μm. The resulting white light devices had color temperatures of 8944K, 4863K, and 4429K, respectively. In this study, we have also compared the performance of the organic versus conventional YAG phosphor embedded films.

Keywords: flexible surface white light, decompose in nature

1. INTRODUCTION

In recent, light emitting diodes (LEDs) have become increasingly important due to its small size, fast response times, long lifetime as well as high luminous efficiency. [1] In most cases of the solid state lighting, the fabrication of the white light emitting diodes (LEDs) combines III-V nitride compound semiconductors as the blue chip with the color converted material: the YAG ($Y_3Al_5O_{12}$: Ce) phosphor. [2] There are many application of the LED such as display, lighting, communication, and biomedical engineering. In order to fabricate the large area lighting devices, the approach of pulse spray YAG phosphor was proposed and demonstrated before for the purposed of the large area phosphor covered. [3] Although the use of the purse spray can manufacture the large area phosphor onto the Lambertian-like lighting blue chip to form the white LED, but it is just a point light source after all, and the lighting area is still insufficient. In order to generate the large area or flexible lighting, organic light-emitting devices can be considered.

Organic light-emitting devices (OLEDs) is becoming widely popular recently, and there has been considerable amount of research and development for the improvement of efficiency of organic light-emitting devices (OLEDs) because of their potential applications in general illumination, flat panel displays, automotive and outdoor lighting. Many approaches have been developed to generate the white light emission of OLED by the partial energy transfer, such as host materials that are doped with fluorescence/phosphorescence dyes. [4] Several researchers have developed the mixing of the various colors lighting from the host molecules with the organic excimer / exciplex emissions to yield white light emission. [5.6]The fluorescence/phosphorescence dyes is considered as the environmental-friendly protection material which can decomposed by living organisms, such as microorganisms in the nature. However, due to the poor heat resistance, moisture and oxidation, the short lifetime, low heat and humidity tolerance and relatively low luminous intensity have been haunting the practical usage of the organic material in solid state lighting

This study is to resolve the influence of the heat for the dye by a light guide device and combine the organic dye and inorganic semiconductor material lighting to form the large-area lighting devices. The use of the light guide can not only to keep the organic dye away from the heat source (lighting source) but also to generate the large area lighting device in standard production method. The dye in this study is poly[(9,9-di-*n*-octylfluorenyl-2,7-diyl)-*alt*-(benzo[2,1,3]thiadiazol-4,8-diyl)] (F8BT) and it's molecular structure as shown in Figure 1. The photoluminescence and PL excitation spectra of

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the F8BT dye as shown in Figure 2. In this image, the excited wavelength at 363~365nm and the emission band peaking around 531nm.

Figure 1. The molecular structure of the poly[(9,9-di-*n*-octylfluorenyl-2,7-diyl)-*alt*-(benzo[2,1,3]thiadiazol-4,8-diyl)] (F8BT).

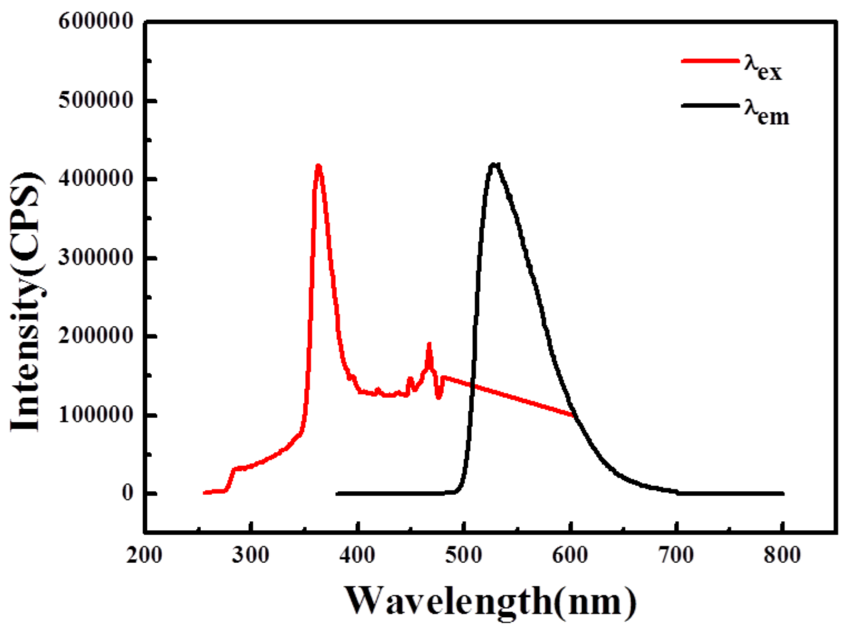

Figure 2. The photoluminescence and PL spectra of the F8Bt dye.

2. EXPERIMENT SETUP

Figure 3(a) shows the schematic of the flexible poly [(9,9-di-*n*-octylfluorenyl-2,7-diyl)-*alt*-(benzo[2,1,3]thiadiazol-4,8-diyl)] (F8BT) film, Fig. 3(b) shows that the dye film and Fig. 3(c) shows a large-area white light source made by a phosphor-doped PDMS film with the light guide and the blue LED bars. Two different setups were considered in this study: the first one is the direct pumping of the flexible PDMS film by white light bar and the second one is the blue-LED pumped light guide covered with PDMS film. The film can be regular phosphors or F8BT as we introduced previously. The material used in the second version of the devices include the light guide with this experiment included the size 10 × 10 cm_2 of the light guide and 3030 blue chip package and put these 18 blue chip packages (current rating of 120 mA and a dominant wavelength of 470 nm) to generate a blue light bar. The PDMS film fabrication procedure is described as below: First, prepare 8.5×10^{-3}wt% F8BT dye solution and 5wt% YAG phosphor ($Y_3Al_5O_{12}$:Ce^{3+}) with the particle size of 10 μm is blended with the silicone to form the dye and phosphor suspension slurries. Second, these suspension slurries are dropped and spin coated at 500 rpm for 30 s on the glass substrate, and then baked it in an oven at about 80 ^{o}C. Third, these dye and phosphor PDMS films are peeled off from the glass substrate then putting the films on the light guides. Finally, prepare 18 dye and yellow phosphor white light LEDs respectively to produce the dye and phosphor light bar. Figure 4(a) illustrates the cross-sectional of the F8BT dye by scanning electron microscopic (SEM) image, which shows the dimension of the F8BT dye particles to be around 2.6~7μm. The SEM cross-sectional image of the yellow phosphor blended PDMS film as shown in Fig. 4(b) and the phosphor particles to be around 16~20μm. The dyes which dissolve more completely in the PDMS film can demonstrate a more uniform material cross-section when compared to the phosphor PDMS film in which the granular feature can be observed due to the insolubility of the phosphor particles to the host film.

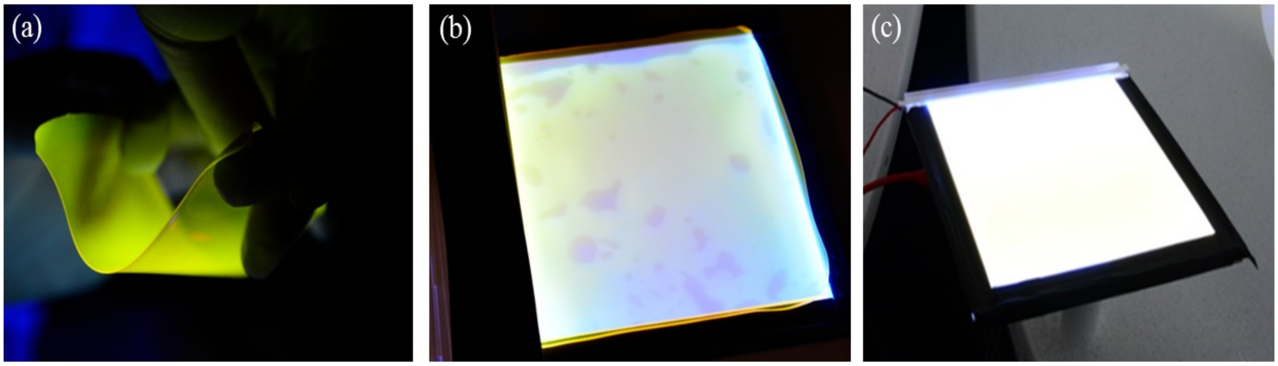

Figure 3.(a) the schematic of the flexible F8BT dye PDMS film, (b) put the dye PDMS film and (c) the yellow phosphor film on the light guide to form the face white lighting device.

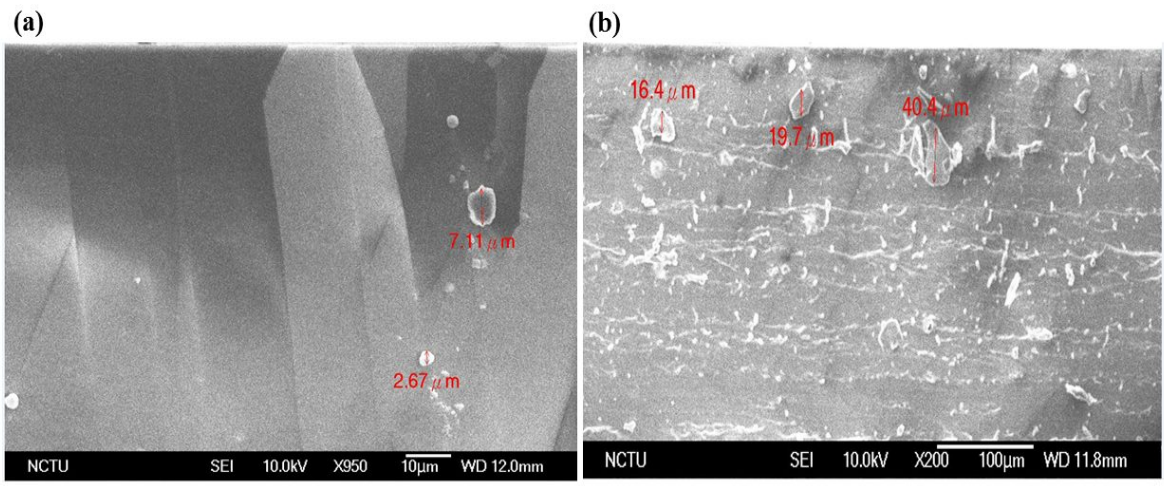

Figure 4. The SEM cross-sectional images of (a) the F8BT dye and (b) the yellow phosphor blended PDMS film.

3. RESULTS AND DISCUSSIONS

3.1 Phosphor film LED device

The emission spectral are all measured at 120 mA and shown in Figure 5. The plain reference sample with only standard phosphor film exhibits the correlated color temperature (CCT) of 5591K. The other samples are with different weights of phosphors, that the 3wt%, 5wt% and 8wt% phosphor film are with the CCT of 8014K, 5371K, and 5205K, respectively. The sample with the phosphor film put upon the light guide is have superior performances against to the phosphor with the white light bar one. The luminous flux of the 5wt% phosphor film is recorded with the 10% enhancement more than the phosphor with white light bar.

Another important parameter is the uniformity of the film under the large-area condition. In Fig. 6(a), it shows that the schematic diagram of the large area LED device with the light guide and installed in a frame and the PDMS film covers on the top of the light guide. Typical uniformity test consists of multiple-point measurement such as the 5, 9, and 13 point luminous flux measurements, and in this study the 9 point uniformity measurement was adapted as shown in Fig. 5(b). Table 1 shows the result for the direct white light bar pumped phosphor PDMS film and the blue-LED pumped light guide sample. As the result, the illumination uniformity of the white bar and the phosphor PDMS film devices is about 69% and 39% (min brightness/max brightness of the data by 9 point measured), respectively.

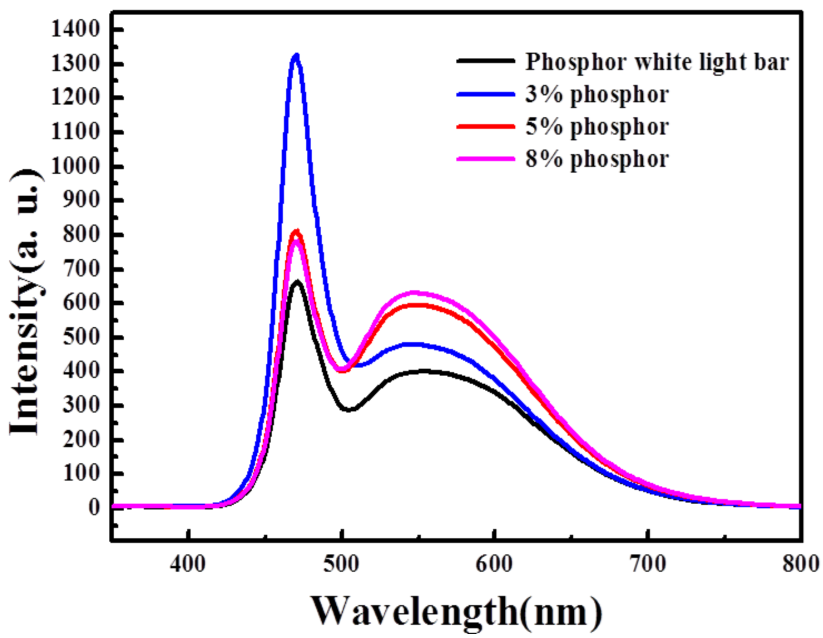

Figure 5. The emission spectral for the combination with light bar, phosphor film covered and light guide of the device.

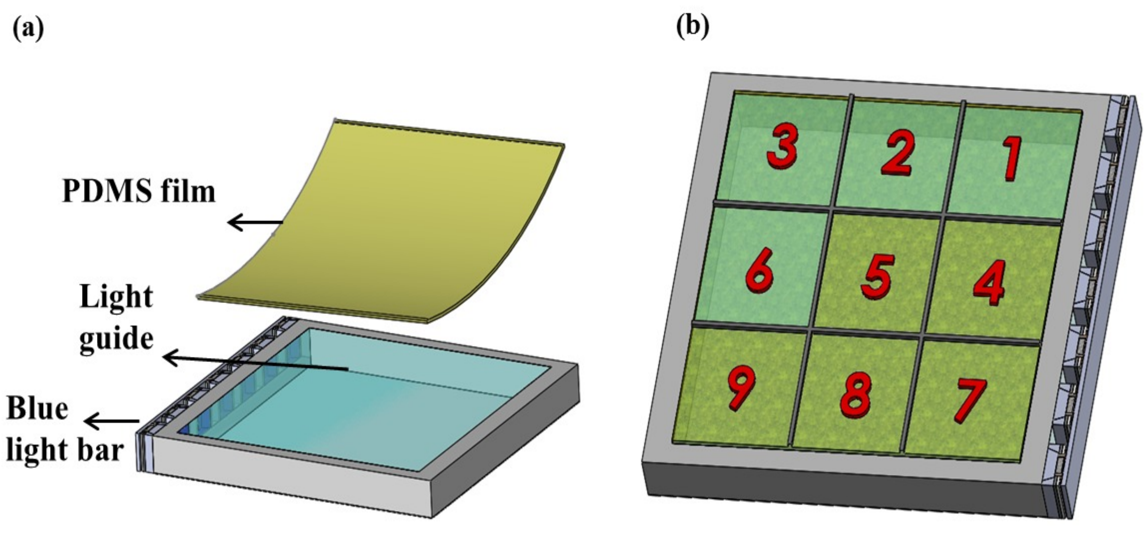

Figure 6. (a) The schematic diagram of the large area LED device. (b) The illumination uniformity experiment to investigate

Table 1. The luminous result between the white light bar and phosphor film covered device of the 9 point uniformity measurement.

Luminous(lm)	1	2	3	4	5	6	7	8	9
Direct White light bar pumping	538.1	336.6	465.4	419.5	358.9	447.4	523.2	386.9	416.7
Phosphor film on the light guide	937.8	567.4	609.8	1058.2	421.3	648.6	868.8	412.4	485.1

3.2 Dye film LED device

The devices is manufactured by the F8BT dye embedded PDMS film have the same two versions of setups as the phosphor ones in the previous section. In Figure 6, it shows that the emission spectrum for the F8BT dye implementing on the large-area white light sources at the current 120mA. The ideal weight percentage for the PDMS film is 8.5×10^{-3}wt% F7BT blended into the PDMS slurry because the other weight percentage of the dye can't solidify and form the film perfectly. As the reason, it exhibits 8.5×10^{-3}wt% of the F8BT dye to form white light bar that is taken beside the light guide as the reference sample with the correlated color temperature (CCT) of 6289K in this illustration. The other samples are also the 8.5×10^{-3}wt% of F8BT dye embedded PDMS film and separately provides the thickness of 1, 1.5, and 2 times layers. The 1, 1.5, and 2 dye layers make the samples with the CCT of 8944K, 5063K, and 4430K, respectively. As the result, the covered of the dye PDMS film is also with the better illumination than the dye white light bar due to the dye film has 20% luminous flux enhancement than the dye white light bar in the 8.5×10^{-3}wt% concentration of the dye PDMS layer.

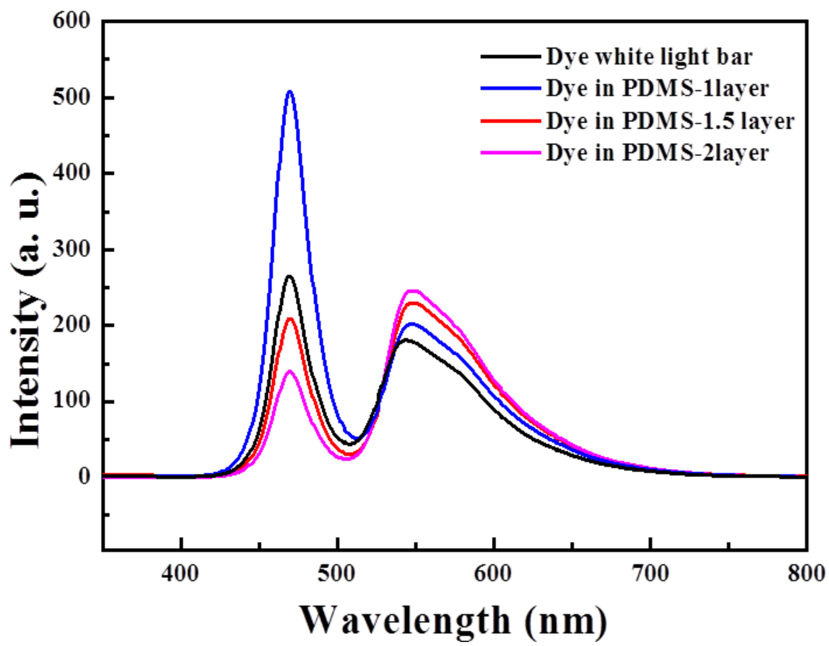

Figure 7. The emission spectral for the combination with light bar, dye film covered and light guide of the device.

In order to carry out the uniformity arrangements of the F8BT dye production large area LED device, the 9 point uniformity measurement is also used. The result of the flexible dye PDMS film emitted by blue light bar and the white light bar are as shown in Table 2. According to the table, the illumination uniformity of the white bar and the dye PDMS film devices is about 69% and 55%, respectively.

Table 2. The result between the white light bar and dye film covered device of the 9 point uniformity measurement.

Luminous(lm)	1	2	3	4	5	6	7	8	9
Direct White light bar pumping	58.1	51.3	53.2	54.7	51.4	50.3	54.2	49.8	50.1
Dye film on the light guide	275.1	192	221.9	333.2	183	221.5	280.1	192.9	206.9

4. CONCLUSION

Although the luminous flux of the dye embedded PDMS film is worse than the phosphor embedded PDMS film, the combination of the dye PDMS layer and the blue chip light bar is still a good conception to integrate the organic emitter and inorganic light source, and the light guide can not only put the emitter away the light source or heat source, but also to develop the large area lighting device. The PDMS film combined with the light guide and the blue-LED bar is a better choice than direct pumping by the white light bar. When the dye or the phosphor is dispensing in the package, the light would be absorbed and scattered by the package flame or the blue chip. In summary, it is very usefully to manufacture the large area LED device is by the employ of the light guide and dye PDMS film.

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