White Light-Emitting Diodes Using Conjugated Polymer Blends

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Abstract

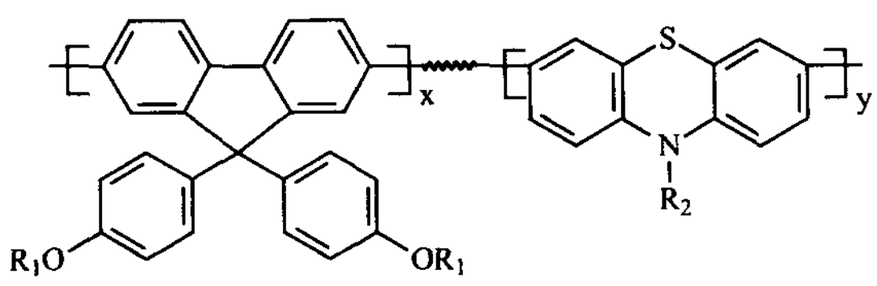
We report the characterization of white light emitting devices fabricated using conjugated polymer blends. Blue emissive poly[9,9-bis(4'-n-octyloxyphenyl)fluorene-2,7-diyl-*co*-10-(2'-ethylhexyl)phenothiazine-3,7-diyl] [poly(BOPF-*co*-PTZ)] and red emissive poly(2-(2'-ethylhexyloxy)-5-methoxy-1,4-phenylenevinylene) (MEH-PPV) were employed in the blends. The inefficient energy transfer between these blue and red light emitting polymers (previously deduced from the PL spectra of the blend films) enables the production of white light emission through control of the blend ratio. The PL and EL emission spectra of the blend systems were found to vary with the blend ratio. The EL devices were fabricated in the ITO/PEDOT/blend/LiF/Al configuration and white light emission was obtained for one of the tested blend ratios.

1. Introduction

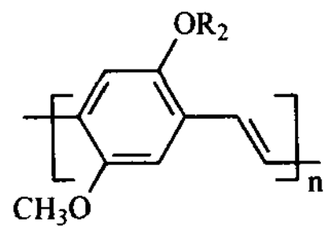
Conjugated polymers have attracted much research interest in science and technology in the past few decades as electro-active materials for diverse applications that include transistors, photovoltaic devices, nonlinear optical devices, and polymer light-emitting diodes (PLEDs). White light emitting diodes using organic molecules and polymers have attracted significant research interest due to their applications in full color displays combined with a color filter, in backlights for liquid crystal displays, and in meeting various other lighting requirements. White light emission requires the mixing of two complementary colors or three primary colors. Various methods and challenges for generating white light have been reported. The doping method has been widely used to obtain white light. In small molecule devices, a red light emitting material is co-deposited with blue and/or green light emitting materials[1-3]. Kido *et al.* have reported that solution-processed polymer devices using composites of blue (B), green (G), and red (R) emitting dyes and poly(vinylcarbazole) emit white light[4]. In both vacuum-deposited small molecule devices and solution-processed polymer devices, control of the energy transfer between the red, green, and blue dyes is essential, and usually requires the introduction of very low levels of doping controls [5,6].

In this study, we fabricated white light emitting diodes using polymer blends composed of two emission components. A highly efficient blue light emitting PF copolymer and a well known red light emitting PPV derivative, poly[2-(2'-ethylhexyloxy)-5-methoxy-1,4-phenylenevinylene] (MEH-PPV), were used in the blends. The synthetic routes of the polymers used in the blend system are shown in Schemes 1 and 2.

Scheme 1



Poly(BOPF-co-PTZ) (R_1 = n-octyl, R_2 = 2-ethylhexyl)



MEH-PPV (R_2 = 2-ethylhexyl)

2. Experimental

The absorption spectra were measured using a Hitachi spectrophotometer model U-3501 and the steady-state photoluminescence spectra were recorded on a Spex FL3-11. The ionization potentials of the polymer films were measured with a low-energy photo-electron spectroscope (Riken-Keiki AC-2). The polymer films were prepared by spin casting blend solutions containing 1% of the polymers by weight in chlorobenzene. Uniform and pinhole-free films with a thickness around 80 nm were easily obtained from the polymer solution. For the double layer device, a modified water dispersion of PEDOT [poly(3,4-ethylenedioxy-thiophene)] doped with poly(styrene sulfonate) (PSS) (Bayer AG, Germany) was used as the hole-injection/transport layer. To improve the electron injection, we deposited a thin LiF layer (~0.5 nm) onto the polymer film, and then deposited the aluminum electrode (~100 nm) using the thermal evaporator at a pressure of 10^{-6} torr. The device performance was studied by measuring its current-voltage-EL (I-V-L) characteristics, electroluminescence (EL) spectra and CIE coordinates. The I-V-L characteristics were measured with a Keithley 236 source-measure unit and a Keithley 2000 multimeter equipped with a PMT through an ARC 275 monochromator. The external quantum efficiency (QE) of the EL, defined as the ratio of the emitted photons to the injected charges, was calculated from the EL intensity measured with the calibrated Si photodiode. All processes and measurements described above were carried out in air at room temperature.

3. Results and discussion

Figure 1 shows the UV-visible absorption spectrum of each polymer used in the polymer blends. Poly(84BOPF-*co*-16PTZ) and MEH-PPV exhibit absorption maxima at 371 and 512 nm respectively. Optical band gaps were obtained from the absorption edges of each polymer. The blue light emitting poly(84BOPF-*co*-16PTZ) has a wider band gap (2.82 eV) than MEH-PPV (2.10 eV). To determine the HOMO levels of the polymers, their ionization potentials were measured using photoemission spectroscopy.

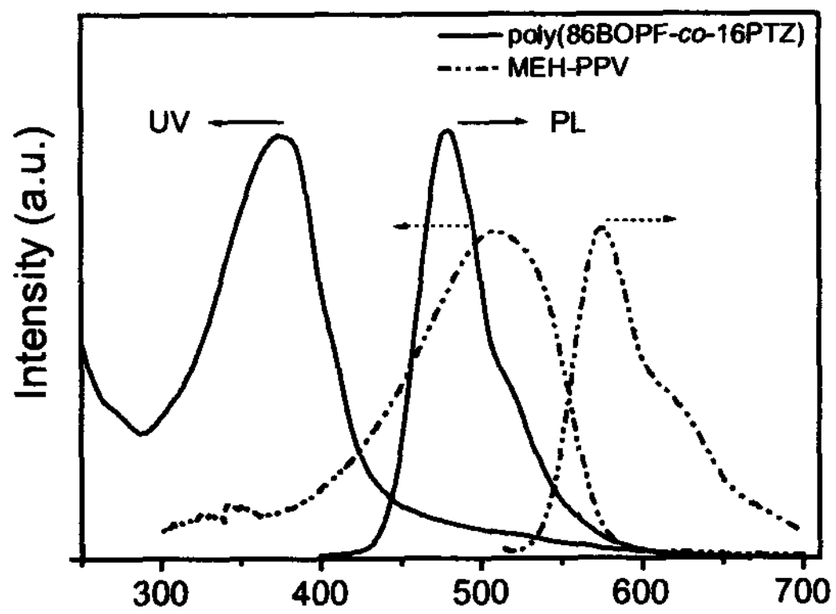


Figure 1. UV-visible absorption and PL emission spectra of the individual polymer films.

The measured ionization potentials of poly(84BOPF-*co*-PTZ) and MEH-PPV were 5.40 and 4.90 eV respectively. The LUMO levels of the poly(84BOPF-*co*-16PTZ) and MEH-PPV thin films were estimated to be 2.58 and 2.80 eV respectively. Poly(84BOPF-*co*-16PTZ) and MEH-PPV thin films exhibit PL maxima at 482 nm (greenish blue) and 575 nm (orange red) respectively, as shown in Figure 1.

Several polymer blend systems with different blend ratios were prepared from these two polymers. We prepared several blend systems containing 0.5 to 3.0% red emitting MEH-PPV in the blue emitting PF copolymer host.

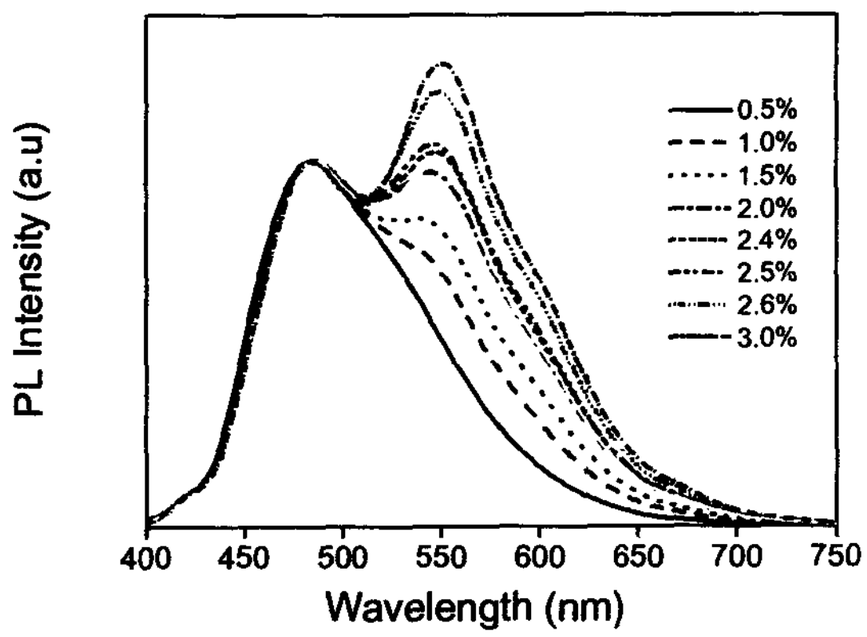


Figure 2. PL emission spectra of the thin films of the polymer blends with different blend ratios.

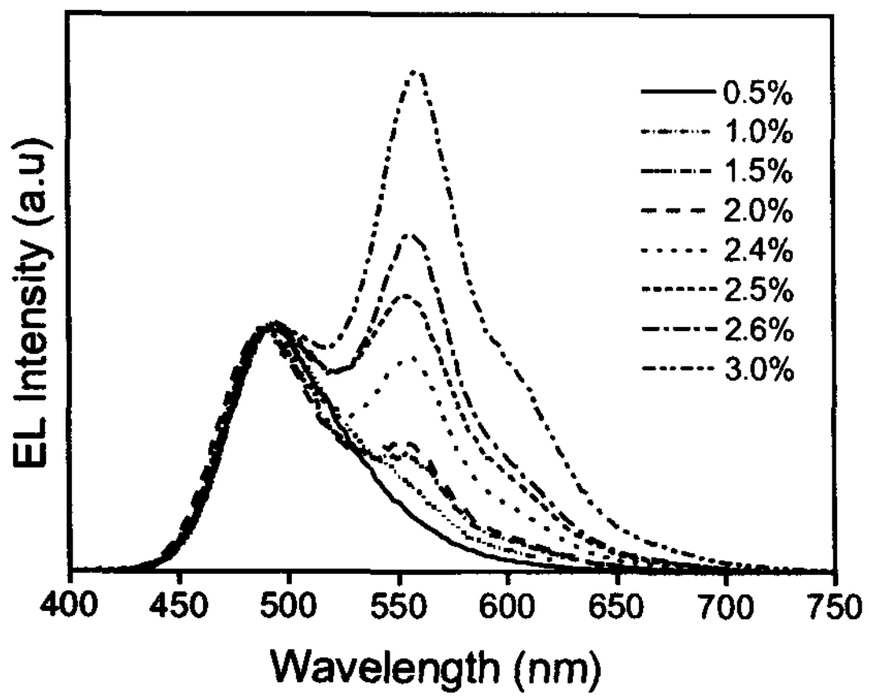


Figure 3. EL spectra of the devices with ITO/PEDOT/blend/LiF/Al configurations using polymer blends with different blend ratios.

Their absorption spectra are almost the same as that of the host PF derivative; only weak absorption due to MEH-PPV was observed, suggesting that most of the absorption was due to the PF copolymer.

Figure 2 shows the PL spectra of the polymer blends. As the ratio of MEH-PPV increases, the intensity of the emission band near 560 nm increases. In the polymer blend containing 2.5% MEH-PPV, the intensities of the two emission bands at 490 and 560 nm are comparable. Considering that the spectral overlaps of poly(BOPF-*co*-PTZ) and MEH-PPV are large enough to produce Förster energy transfer between the polymers, this inefficient energy transfer is likely to be due to a phase separation of the polymer blends, which should be investigated further. In fact, this inefficient energy transfer enables the production of white light emission through control of the blend ratio.

EL devices were fabricated in the ITO/PEDOT/blend/LiF/Al configuration. Figure 3 shows the EL spectra of the EL devices fabricated using the polymer blend systems. As in the PL spectra, as the MEH-PPV ratio in the blend system increases the intensity of the emission band at 560 nm increases. The two emission bands in the EL spectra of the EL device using a polymer blend containing 2.5% MEH-PPV are of comparable intensity, and this device exhibits an efficient white light emission.

Among all the EL devices tested in this experiment, the device using the 2.5% MEH-PPV blend system exhibited the CIE coordinates (0.32,0.49) closest to the standard CIE coordinates for white light emission (0.33, 0.33).

4. Conclusion

Blends of light emitting polymers were prepared in order to produce white light emission. EL devices using polymer blends of poly(84BOPF-*co*-16PTZ) and MEH-PPV were found to exhibit current- and voltage- independent stable white light emission. A polymer blend contained 2.5% MEH-PPV was found to exhibit an EL spectrum that is closer to the standard white than those of the devices using other blend ratios.

5. Acknowledgements. We gratefully acknowledge funding from the Advanced Backbone IT technology development project supported by the Ministry of Information & Communication of the Republic of Korea.

6. References

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