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White light emission from a polymer bilayer by incomplete cascade energy transfer

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Abstract

White light emission was obtained from a light-emitting diodes (LEDs) prepared from an immiscible polymer blend consisting of poly(9,9′-dihexylfluorene-2,7-divinylene-*m*-phenylenevinylene-*stat*-*p*-phenylenevinylene) (PDHFPPV) and poly(2-methoxy-5-(2′-ethy-hexyloxy)-1,4-phenylenevinylene) (MEH-PPV). An inefficient energy transfer between PDHFPPV and MEH-PPV was observed because the blends are partially miscible. More importantly, because the order of bandgap energy is PVK > PDHFPPV > MEH-PPV we observed pure and strong white emission from this PLEDs, which results from the efficient Förster-type energy transfer from PVK to PDHFPPV and the partial energy transfer from PDHFPPV to MEH-PPV. The ITO/(PVK/immiscible blend)/Li:Al devices showed more enhanced white-light output compared with that of the ITO/(immiscible blend)/Li:Al device.
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1. Introduction

The methods that have been proposed to produce white light-emitting diodes (LEDs) from polymers or organic small molecules can generally be classified into two categories. The first produces multi-layer devices composed of several different materials [1,2]. Kido et al. developed a device with three emitting layers, each layer emitting light in a different region of the visible spectrum to generate white light [3]. Xie et al. also reported white emission from organic multiple heterostructure [2]. The second methods to obtain white emission are that red emitting material is co-deposited with blue and/or green emitting materials [4]. In polymer blend system, Kido et al. reported composites of emitting dyes and poly(vinylcarbazole) emitted white emission [5]. In both small molecules doped polymer and polymer blend systems usually needs very low level (10^{-3}%) doping controls due to the effective Förster energy transfer. Therefore, in this study, we tried to an immiscible polymer blend composed of two polymer components for white emission. Energy transfer and

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light emitting characteristics of LEDs using PVK/immiscible polymer blend bilayer were described.

Generally, multilayer organic light-emitting devices consisting of charge-transporting and emitting layers exhibit higher performance than single-layer devices because in the multilayer devices more balanced charge carriers are confined within the emitting layers [6,7]. We have fabricated a polymer light-emitting diode (PLED) with a solution processed bilayer that emits white light. We observed pure and strong white emission from this PLEDs, which results from the efficient Förster-type energy transfer from PVK to blue-emitting polymer and the partial energy transfer from blue-emitting to red-emitting polymer.

2. Experimental

PVK (average M_w: 1,000,000) was purchased from Adrich Chem. Co. Poly(9,9′-dihexylfluorene-2,7-divinylene-*m*-phenylenevinylene-*stat*-*p*-phenylenevinylene) (PDHFPPV) (M_w: 32,000 and T_g: 125 °C), which acts as blue-emission was synthesized by employing the Heck reaction as reported elsewhere [8]. MEH-PPV (M_w: 120,000 and T_g: 65 °C), which acts as red-emission, purchased from H. W. Sands Co. and used without further purification.

EL devices with the PVK/immiscible blend bilayer structure were prepared as follows. PVK and (PDHFPPV + MEH-PPV) were dissolved in monochlorobenzene and trichloroethylene (TCE), respectively. The 60 nm-PVK solution was spin-cast onto an indium-tin-oxide (ITO) coated glass substrate followed by baking the polymer at 100 °C for 2 h. And then, the 40 nm-blend was spin-cast from the TCE solution on top of the PVK film. The Li:Al alloy cathode was vacuum-deposited onto the blend layer under a pressure of about 1×10^{-6} Torr to complete the device preparation. For comparison, single layer white EL device with the blend was prepared with the same method.

The electrical and luminescent characteristics of the devices were analyzed using a current/voltage source measurement unit (Keithley 236) and a brightness was obtained by using spectroradiometer (Minolta CS-1000). Photoluminescence (PL) and Electroluminescence (EL) spectra were measured using an ISS PC1 Photon Counting Spectrofluorometer.

3. Results and discussion

Fig. 1 shows the absorption and PL spectra of PVK, PDHFPPV, and MEH-PPV. It is evident that the bilayer film meets the necessary conditions for the Förster-type energy transfer. Thus we expect a cascade energy transfer from PVK to PDHFPPV and then to MEH-PPV in this bilayer system, as in the ternary blend systems.

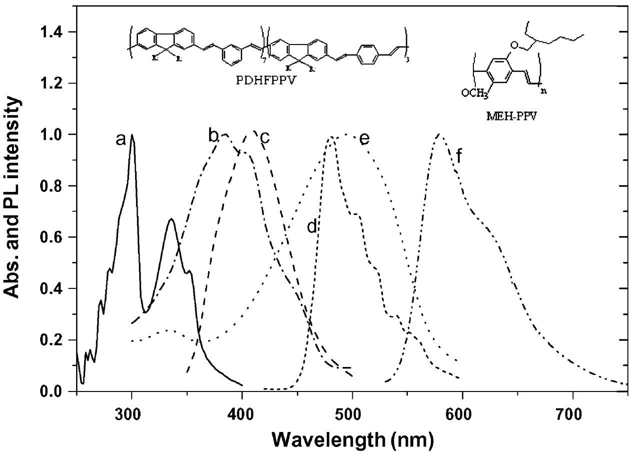

Fig. 1. Normalized absorption (Abs) and photoluminescence (PL) spectra of PVK, PDHFPPV and MEH-PPV. (a) Abs of PVK, (b) Abs of PDHFPPV, (c) PL of PVK, (d) PL of PDHFPPV, (e) Abs of MEH-PPV, and (f) PL of MEH-PPV.

From the PL output of the PVK/immiscible polymer blend (PDHFPPV:MEH-PPV) bilayer films excited at 340 nm, the PVK/PDHFPPV:MEH-PPV bilayer film exhibits pure white emission. In order to interpret this result, we measured PL excitation (PLE) spectra of the PVK/immiscible blend bilayer film. Fig. 2 shows the PLE spectra of the bilayer film, where the PL intensities at the emission wavelength of 475 nm and 580 nm, which correspond to the emission peak wavelengths of PDHFPPV and MEH-PPV, respectively were measured as a function of the excitation wavelength. The PLE spectrum measured at 475 nm demonstrates that the emission of PDHFPPV originates from not only the excitation energy transferred from PVK but also self-absorption of the PDHFPPV because PLE intensity maximums were observed at the absorption peak wavelengths of PVK (280 nm and 340 nm) and PDHFPPV (380 nm).

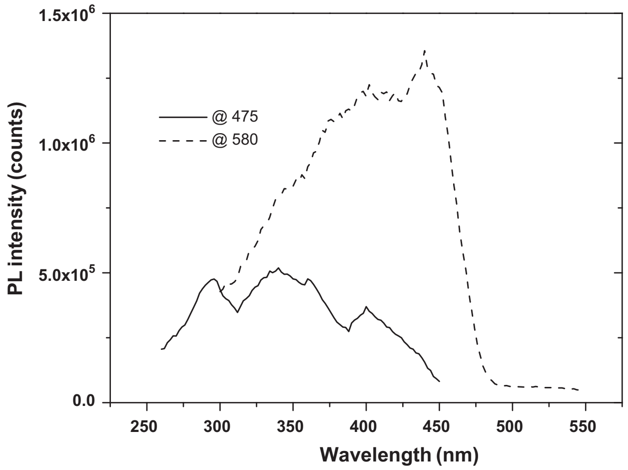

Fig. 2. The photoluminescence excitation spectra of the bilayer film.

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