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Study on EL emission region of polymer thin film in PPV LED

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Abstract

In this paper, the intensity ratios $I(\lambda_1 = 515\ \text{nm})/I(\lambda_2 = 550\ \text{nm})$ of both electroluminescence (EL) and photoluminescence (PL) spectra of poly(phenylene vinylene) (PPV) thin film in the same PPV light-emitting diode (LED) are measured in order to discuss the EL emission dominant region. In the EL spectrum, the ratio $I_1(\lambda_1)/I_1(\lambda_2)$ decreased from 1.35 to 1.25, when the bias voltage increased from 4 to 12 V. In the PL spectrum, the ratios $I_1(\lambda_1)/I_1(\lambda_2)$ and $I_2(\lambda_1)/I_2(\lambda_2)$ (here I_1 and I_2 denote the intensities emitting from the indium–tin oxide (ITO) glass side and the opposite side, respectively) approach 1.5 and 1.3, separately. Based on these results, it is deduced that the emission dominant region of EL of PPV thin film in a single-layer PPV LED is close to the top electrode and apart from that of PL. © 1997 Elsevier Science S.A.

Keywords: Poly(phenylene vinylene) and derivatives; Electroluminescence; Thin films

1. Introduction

Since a poly(phenylene vinylene) light-emitting diode (PPV LED) was fabricated by Burroughes et al. [1], many scientists have paid much attention to investigating the electroluminescence (EL) characteristic of PPV thin film [2–4]. It is well known that both EL and photoluminescence (PL) spectra of PPV have the same double-peak shape, and the wavelengths of the peaks are 515 nm (denoted λ_1) and 550 nm (denoted λ_2), respectively. This implies that the emission of both EL and PL of PPV comes from the same excited state [5]. Because there is obvious overlap between absorption and luminescence spectra of PPV in the region of λ_1 [6], the optical path of emitting light in PPV thin film will influence the intensity ratio $I(\lambda_1)/I(\lambda_2)$ based on the self-absorption effect. It should be more helpful to investigate the dependence of the intensity ratio $I(\lambda_1)/I(\lambda_2)$ on the bias voltage and the difference between the ratio magnitudes in EL and PL spectra in order to research the EL emission dominant region.

In this paper, the spectra of both EL and PL of PPV thin film in the same LED are measured and discussed, and the different emission dominant regions for EL and PL are suggested.

2. Experimental

2.1. The fabrication of PPV LED

The methanol solution of PPV precursor polymer in the form of a tetrahydrothiophenium polyelectrolyte is spin-coated onto indium–tin oxide (ITO) glass to form thin film. After thermal conversion ($T = 300$ °C in a vacuum of below 5 Pa for 3 h), the Al is thermally deposited on the surface of the PPV film as the top electrode. The thickness of PPV thin film is 80 nm.

2.2. The measurement of PL and EL spectra of PPV LED

For determination of PL and EL emission dominant regions, the emitting intensities of PL from the ITO glass side (denoted I_1) and that from the Al electrode side (uncovered position, denoted I_2) are measured when the exciting light ($\lambda = 450$ nm) irradiates directly onto the PPV film surface and the incident angle of exciting light changes from 0 to 90°. Meanwhile the emission intensities $I_1(\lambda_1)$ and $I_1(\lambda_2)$ in EL spectra are measured when the bias voltage changes from 4 to 12 V.

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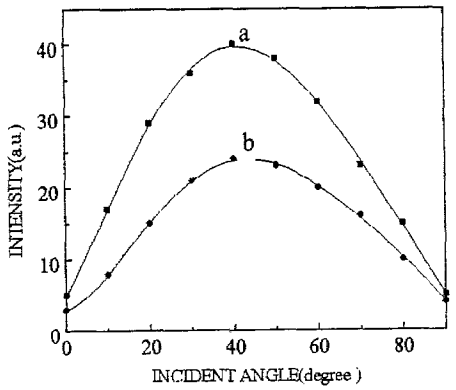

Fig. 1. I_1 curve (a) and I_2 curve (b) with different incident angles of exciting light in PL spectra.

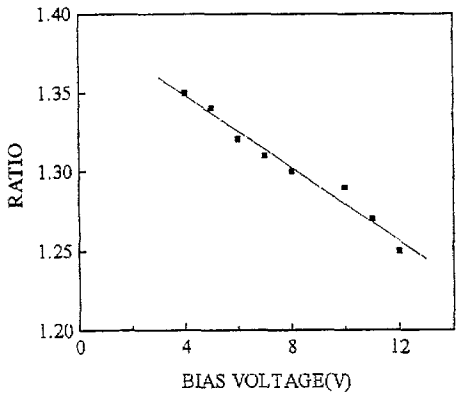

Fig. 2. Ratio of $I(\lambda_1)/I(\lambda_2)$ emitting from the ITO glass side with different bias voltages in EL spectra.

3. Discussion

Fig. 1 shows that the ratio I_1/I_2 in PL spectra is larger than 1.5 when the incident angle is between 20 and 70°. After considering that the indexes of reflection of both PPV and glass are less than two, the calculated values of reflectance on the boundaries of both PPV and glass should be less than 0.11 according to Fresnel's reflection formula. Therefore, it is reasonable to neglect the influence of reflection on I_1/I_2 in the following discussion. Therefore, if the luminescence ability of every region in PPV film were the same, the I_1 should not be larger than I_2 because of the self-absorption of film and the absorption of glass. Thus, the PL emission dominant region in PPV thin film should lie close to glass. This conclusion is consistent with our other measured results that the average ratio $I_1(\lambda_1)/I_1(\lambda_2) = 1.5$ and $I_2(\lambda_1)/I_2(\lambda_2) = 1.3$ since the two ratio magnitudes show that the PL optical path in PPV film observed from the glass side is shorter than that from the top-electrode side. These results can be attributed to the lower conversion extent of PPV in the region near the ITO glass side. It is well known that the PL intensity of PPV decreases with increasing conversion extent [6].

Fig. 2 shows that the ratio of $I(\lambda_1)/I(\lambda_2)$ in the EL spectrum observed from the glass side decreases from 1.35 to 1.25 when the bias voltage increases from 4 to 12 V. We first discuss the influence of the reflection of the Al electrode on the EL spectrum. When the dominant region of EL moves to the Al electrode, the decreasing value of the optical path of the reflected light in PPV film is the same as increasing the value of the optical path of the direct emitting light. Hence, the total result should be that the ratio $I(\lambda_1)/I(\lambda_2)$ decreases; and if the case is exactly opposite, the result is opposite too, because the self-absorption of PPV film to emitting light and the intensity of self-absorption to 515 nm light is larger than that to 550 nm light when the optical path is the same. On further referring to the discussion about the PL spectrum, we can deduce that the emission dominant region of EL lies on the region of PPV close to the Al electrode, and this region will move toward the Al electrode as the bias voltage increases. It is reasonable that the injected electron moves more slowly than the injected hole because PPV acts as a hole carrier semiconductor.

Therefore, the emission dominant region of EL is apart from that of PL in PPV thin film in a single-layer PPV LED. This conclusion is very helpful for the manufacture of highly efficient PPV LEDs.

Acknowledgements

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