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PHOTORESPONSES OF A POLYMER-BLEND DEVICE

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Abstract We report the results of the photoconductivity measurements of the polymer-based diode formed with polymer blend of poly[2-methoxy,5-(2'-ethyl-hexoxy)-1,4-phenylene vinylene] (MEH-PPV) and poly[1,3-propanedioxy-1,4-phenylene-1,2-ethenyllene-(2,5-bis(trimethylsilyl)-1,4-phenylene)-1,2-ethenylene-1,4-phenylene] (called B-polymer). The local peak around 2.87 eV in the spectral response of photocurrent indicates the possibility of the excitation from the HOMO level of MEH-PPV to the LUMO level of B-polymer. From these results, we can conclude that the photocurrent and electroluminescence are originated from the rectified microjunction formation in the polymer blend, not from the energy transfer mechanism.

INTRODUCTION

Recently, electroluminescent devices based on blends of electron- or hole-transporting molecules with luminescent polymers, have gained a lot of interest, with their high quantum efficiencies.[1-4] We had studied a new polymer blend of MEH-PPV and B-polymer as an active material in light-emitting diode, photodiode and photovoltaic cell.[5] In LED mode, the device emits orange-color light which is correspondent with the energy gap of MEH-PPV and its quantum efficiency was drastically enhanced as the

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ratio of B-polymer was increased.[6] Interestingly, no light emission corresponding to the energy gap of B-polymer is observed. This is somewhat puzzling because the sample is a blended polymer of MEH-PPV and B-polymer.[5]

In this paper, we present new results of the photoconductive properties in our electroluminescent device made of the polymer blend of MEH-PPV and B-polymer. It was shown that mixtures of polymers tend to phase segregate due to the low entropy of mixing. The investigation of the phase segregation was confirmed by the measurements with transmission electron microscopy (TEM) and scanning transmission electron microscopy (STEM) for the mixture of MEH-PPV and CN-PPV.[7] Assuming that our polymer blend forms a similar phase segregation, we had proposed a micro heterojunction model with appropriate band offsets at the interface which could explain the observed one peak signal in EL spectra.[5] However, the energy transfer through B-polymer can also be possible in this blended polymer. That is, the B-polymer transfers energy to the MEH-PPV where the EL occurs. In this case, there is no need to form a rectifying microheterojunction at the boundary of the phase segregation between the two polymers. However, the EL peak intensity of the polymer blend enhances the pristine MEH-PPV, which is not consistent with the energy transfer picture through B-polymer because the amount of MEH-PPV becomes smaller in the polymer blend. To clarify this issue more directly, the steady-state photoconductivity of the polymer-blend device was investigated as a function of incident beam energy at room temperature. The results show an additional peak at 2.87 eV which could be originated from the charge transfer between HOMO level of MEH-PPV and LUMO level of B-polymer indicating the microheterojunction formation at the interface of phase segregation in the polymer blend.

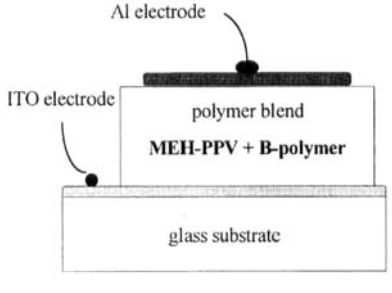

FIGURE 1. Schematic Diagram of Polymer-Blend Diode Structure

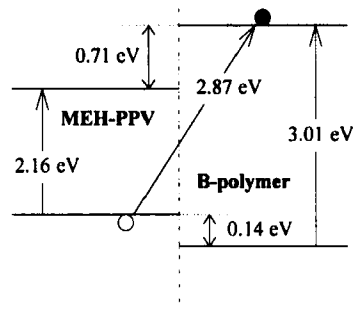

FIGURE 2. Microheterojunction at the Interface of MEH-PPV and B-polymer

EXPERIMENTAL

The devices were prepared with the polymer blend layer sandwiched between electrodes with different work functions, Aluminum and ITO as used in 'general' polymer LEDs (FIGURE 1). For the measurements of the photoconductive property, a 300 W tungsten-halogen lamp dispersed by a single-grating monochromator, was employed as a light source. In the case of steady-state photoconductivity, Keithley 487 picoammeter/voltage source was used. The intrinsic dark conductivity of the polymer blend was $10^{-12} \sim 10^{-9}$ S/cm. We normalized out the spectral response of the measurement by replacing the probe head used to obtain the photoconductivity data with a calibrated silicon photodiode. In the modulated photoconductivity experiment, standard photo-modulation technique was employed, *i.e.* the excitation light was chopped with mechanical chopper, and the resulting modulated signal was processed through EG&G 5208 Two Phase Lock-In Analyzer tuned to the chopping frequency. All the diode fabrication and the measurement were carried out at room temperature under the ambient condition.

RESULTS AND DISCUSSIONS

FIGURE 2 shows the microheterojunction at the interface of MEH-PPV and B-polymer which we propose as a model for the LED and photodiode made of polymer blend. The magnitudes of two bandgaps and the interchain excitation are estimated from the photoconductivity measurement result shown in FIGURE 3. FIGURE 3 shows the photoexcited current spectrum of our polymer blend device as a function of the energy of the illuminated light. This spectral response is fitted with three Lorentzians peaks centered at 2.16 eV, 2.87 eV and 3.01 eV. The main peaks at 2.16 eV and 3.01 eV are correspondent with the energy-gaps of the two polymers, MEH-PPV and B-polymer respectively. The small peak centered at 2.87 eV is particularly interesting because it suggests an excitation from the HOMO level of MEH-PPV to the LUMO level of B-polymer at the microheterojunction interface of the polymer blend. If the band offset between the HOMO level of two polymers is 0.14 eV, the band offset between the LUMO levels becomes 0.71 eV. As a result, the charge excitation energy from the HOMO of MEH-PPV to the LUMO of B-polymer is estimated to be 2.87 eV which is consistent with the observed 2.87 eV peak in FIGURE 3. In our previous paper, the band offset was estimated to be 0.12 eV using the Foweler-Nordheim plot of the dark current I-V characteristics of our polymer blend.[5] This band offset value is close to the above assumed value of 0.14 eV between HOMO levels of the two polymers.

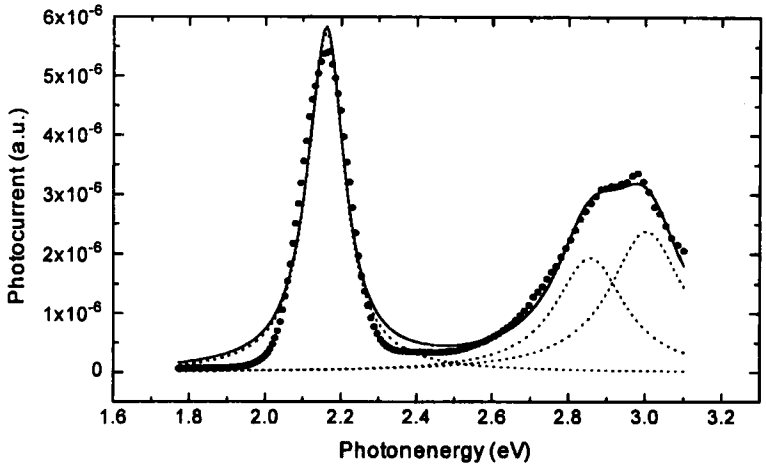

FIGURE 3. Photocurrent spectrum fitted with three Lorentzian peaks , Dot (•) : photocurrent, dotted straight line : three Lorentzian peaks, solid straight line : fitted line

Therefore, the observed 2.87 eV peak seems to indicate the charge excitation from the HOMO of MEH-PPV to the LUMO of B-polymer, which can be a direct proof of the microheterojunction formation in this polymer blend.

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