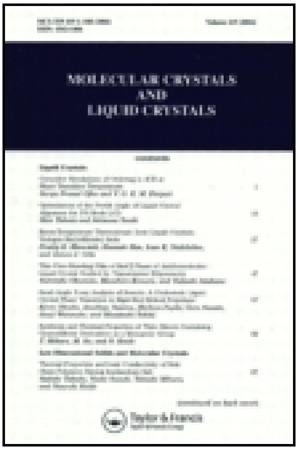

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Electrical Impedance Measurements of Organic Electroluminescent Devices Containing Blended Polymer Single-Layer

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Electrical Impedance Measurements of Organic Electroluminescent Devices Containing Blended Polymer Single-Layer

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We report electrical impedance measurements of organic electroluminescent (EL) devices consisting of ITO/blended emitting layer/LiF/Al. The measured impedance data have single semicircles, therefore, the equivalent circuit represented by a parallel combination of bulk resistance, R_b and capacitance, C_b, in series with a resistance, R_a. There is no interfacial capacitance, suggesting that LiF layer did not affect the charge injection of the organic EL device.

Keywords : organic electroluminescent device; polymer blend; impedance spectroscopy; energy transfer

INTRODUCTION

Organic EL devices have gathered attention due to their potential use in the large-area color display technology. Recently, π-conjugated polymers or polymers with conjugated pendant groups were mainly used as an emitting layer or a carrier transport layer. However, the quantum efficiency of polymer emitting materials was relatively smaller than that of organic compound. Therefore, various methods

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were employed to enhance the device efficiency such as applying a low work function metal electrode[1], doping with organic compound and introducing host-guest system.[2]

Impedance spectroscopy was known as a useful method for studying electrical properties of EL devices such as device structure and interfacial properties. Campbell *et al.*[3] and Kim *et al.*[4] reported results of the electrical impedance study on single and double-layer EL devices. However, the impedance properties of EL devices containing oxide or insulating layer introduced to enhance the quantum efficiency have not been reported so far.

In this paper, we fabricated single EL devices with poly(3-dodecylthiophene) (P3DoDT) and poly(N-vinylcarbazole) (PVK) polymer blends. To enhance the quantum efficiency of the devices, we used LiF layer between emitting layer and Al metal electrode. Also, we investigated the impedance properties of EL devices to understand the role of LiF layer when voltage is applied.

EXPERIMENTAL

P3DoDT was synthesized according to the method previously published.[5] PVK was obtained from TCI and used without further purification. Indium-tin-oxide (ITO) substrates were cleaned ultrasonically with detergent, deionized water, and isopropanol. After cleaning of the ITO substrate, we put a blended polymer film with 150nm thickness on it by spin coating. The molar ratios of P3DoDT to PVK were 1:0 (Type A), 2:1 (Type B), and 1:1 (Type C). On top of the polymer layer, 1.5 nm of LiF layer and 250 nm of Al layer were deposited at about 1×10^{-6} Torr. The emitting area was controlled to $5\times 5\mathrm{mm}^2$.

The voltage-current-luminance characteristics were measured using an optical power meter (Newport 1830-C) and a digital sourcemeter. Photoluminescence (PL) spectra and electroluminescence (EL) spectra were measured using a spectrograph (CP200), a double spectrometer (SPEX 1403) and a PMT (R943-02), respectively. Excitation light at 325 nm from a He-Cd laser used for the PL measurement. The electrical impedance measurements were made using an impedance spectrum analyzer (IM6). A 50 mV amplitude alternating current (ac)

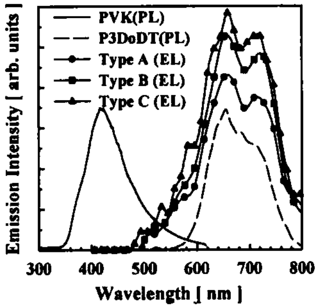


FIGURE 1 PL spectra of PVK and P3DoDT and EL spectra of ITO/blended emitting layer/LiF/Al devices.

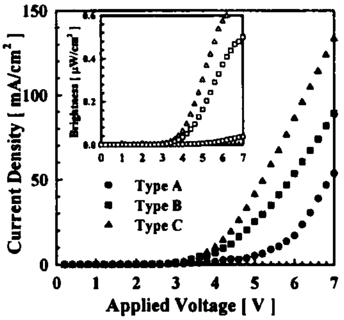


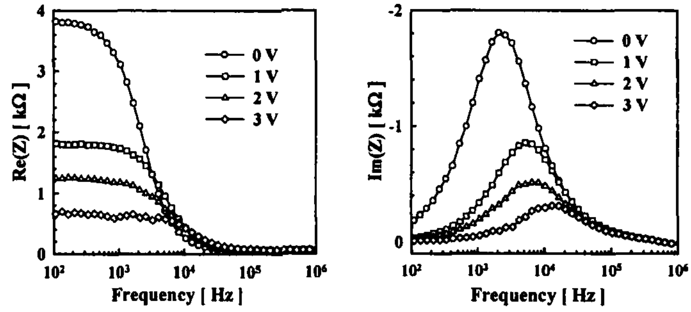
FIGURE 2 Voltage-current-luminance characteristics of ITO/blended emitting layer/LiF/Al devices.

signal superimposed on a direct current (dc) bias was used to measure the device impedance as a function of frequency ranging from 100 Hz to 2 MHz and also as a function of dc bias.

RESULT AND DISCUSSION

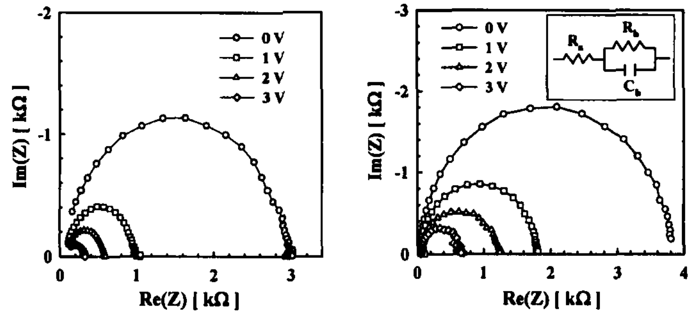
Figure 1 shows PL spectra of PVK and P3DoDT films and EL spectra of the A, B and C type devices. The EL spectra showed the maximum peak at around 650 nm caused mainly by P3DoDT, whereas the PVK emission in blue region was not observed. This implies that the energy transfer from PVK to P3DoDT cases the enhancement of orange-red emission originating from P3DoDT. A similar result between MEH-PPV and DSiPV was reported by Lee *et al.*[6]

Figure 2 shows typical voltage-current-luminance characteristics of ITO/blended emitting layer/LiF/Al EL devices. The current density increases and luminance is enhanced when the applied voltage is increased. Moreover, the luminance intensity increased upon PVK added, and that of the devices with a blend ratio of PVK to P3DoDT equal to 1:1 was enhanced by a factor of 33 compared with that of 1:0 devices at the 6 V. This result also demonstrates that the energy transfer from PVK to P3DoDT occurred in the blend emitting layer.



(a) (b)

FIGURE 3 Frequency dependence of real part (a) and imaginary part (b) of the impedance of an EL device with Type C at various applied voltages.



(a) (b)

FIGURE 4 Impedance Cole-Cole plots of EL devices with (a) Type A and (b) Type C.

The real part, Re(Z), and imaginary part, Im(Z), of the impedance of an EL device with Type C as a function of frequency are shown in Figure 3. At low frequencies (< 6×10^3 Hz), the Re(Z) is almost independent of frequency. Adjoining this plateau, the Re(Z) values strongly decreased. With increasing frequency, the Im(Z) value, (see Figure 3(b)), initially increases and moves through a maximum, subsequently decreased, and reaches a minimum at high frequencies. The positions of the maximum Im(Z) shift to a higher frequencies with increasing the applied voltage. Figure 4 shows the impedance Cole-Cole plots of the EL devices. In both cases, the Re(Z) and Im(Z) values initially decrease with increasing voltage. However, in the device with Type C, the diameters of Cole-Cole semicircles were less strongly decreased than those of device with Type A. These phenomena point to the fact that the PVK host polymer affects the bulk impedance of the EL device.

The impedance plots of both devices have single semicircles, which may be represented by a parallel combination of bulk resistance, R_b and capacitance, C_b, in series with a resistance, R_a.[4] (see the inset of Figure 4(b)). According to this equivalent circuit analysis, there is no interfacial capacitance or it is at least negligibly small. This means that the inserted LiF layer between the blended emitting layer and the Al electrode was not acted as an interfacial capacitance. One possible suggestion for the explanation of this result is that the LiF dissociates during thermal deposition and alloys onto the Al electrode at the interface. Shaheen *et al.*[7] reported the mechanism of the alloy formation between LiF and Al metal by X-ray photoemission (XPS) experiment. Therefore, the LiF layer inserted for the enhancement of device efficiency did not affect the charge injection to the EL device during operation.

CONCLUSION

We have investigated impedance properties of organic EL devices consisting of ITO/blended emitting layer/LiF/Al. The following results were obtained: 1) The energy transfer occurred in the blended emitting layer from PVK to P3DoDT enhancing the luminance efficiency of the devices. 2) The measured impedance data have a single semicircle implying no interfacial capacitance. Consequently, the equivalent circuit is represented by a parallel combination of bulk resistance, R_b, and capacitance, C_b, in series with a resistance, R_a. It also suggests that the LiF layer did not affect the charge injection of the organic EL device.

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