LiF 음극 버퍼층을 사용한 폴리머의 효율 향상에 관한 임피던스 분석

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Impedance spectroscopy analysis of polymer light emitting diodes with the LiF buffer layer at the cathode/organic interface

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Abstract : Admittance Spectroscopic analysis was applied to study the effect of LiF buffer layer and to model the equivalent circuit for poly(2-methoxy-5-(2'-ethylhexyloxy)-1,4-phenylenevinylene) (MEH-PPV)-based polymer light emitting diodes (PLEDs) with the LiF cathode buffer layer. The single layer device with ITO/MEH-PPV/Al structure can be modeled as a simple parallel combination of resistor and capacitor. Insertion of a LiF layer at the Al/MEH-PPV interface shifts the highest occupied molecular orbital level and the vacuum level of the MEH-PPV layer as a result the barrier height for electron injection at the Al/MEH-PPV interface is reduced. The admittance spectroscopy measurement of the devices with the LiF cathode buffer layer shows reduction in contact resistance (R_C), parallel resistance (R_P) and increment in parallel capacitance (C_P).

Key Words : Admittance, MEH-PPV, LiF, equivalent circuit

1. Introduction

There is a considerable interest in the use of polymer as an emitter in multilayer structure of electroluminescent device [1-2]. In polymer light emitting diodes, both the electron and the hole should be injected efficiently for best device performance. It means thata small injection barrier height at the cathode/organic interface is required. Insertion of an insulating layer between the cathode and the organic layer leads to a significant improvement in the charge injection and electroluminescence output [3]. The enhancement is due to increased charge carrier density near the cathode/organic interface that results from enhanced electron tunneling, and removal of exciton-quenching gap states that are intrinsic to the cathode/organic interface [4-7]. Insertion of a LiF layer at the cathode/organic interface shifts the highest occupied molecular orbital level and the vacuum level of the organiclayer as a result the barrier height for electron injection at the cathode/organic interface is reduced [8].
Admittance Spectroscopy is one of the powerful tools to study the equivalent circuit models, the charge carrier dynamics, and dielectric properties of organic devices [9]. The single layer device with ITO/MEH-PPV/Al structure can be modeled as a simple parallel combination of resistor and capacitor [10].

In this work, we have applied the admittance spectroscopy analysis to find the effect of LiF cathode buffer layer and to model the equivalent circuit for ITO/MEH-PPV/LiF/Al device structure.

2. Experimental

The ITO-coated glass with a sheet resistance of 20 Ω/square was used for PLEDs. For the preparation of PLEDs, the ITO glass was cleaned sequentially in ultrasonic bath of trichloroethylene, acetone, and methanol. Finally, the ITO glass was sonicated in deionized water and then blown dry with N_2 gas. The LiF as the cathode bufferlayer was deposited to thickness of 0.5 nm by thermal evaporation. The emitting material layer(EML) used is of 0.6 wt% poly(2-methoxy-5-(2'-ethylhexyloxy)-1,4-phenylenevinylene) (MEH-PPV)solution in chlorobenzene. The 100-nm-thick MEH-PPV layers were prepared sequentially by spin coating on the substrate. For the removal of the residualsolvent, spin coated MEH-PPV films were baked in vacuum oven for 30 min. The cathode with 0.5-nm-thick LiF and 150-nm-thick Al weredeposited by thermal evaporation. The Admittance measurement was done by using LF 4192A Impedance analyzer. The amplitude test signal was 50 mV. The measurement frequency was in the range from 10 Hz to 10 MHz. A Keithley 2400 electrometer was used for measuring J-V characteristics as a voltage source and current measurement equipment.

3. Results and Discussion

The impedance was measured for the devices with and without LiF layer for a range of 10 Hz to 10 MHz for zero volt bias voltage to find the effect of LiF layer. Fig 1. shows the impedance vs. frequency plot and Fig 2. shows the cole-cole plot for the device with ITO/MEH-PPV/Al and

ITO/MEH-PPV/LiF/Al structure.

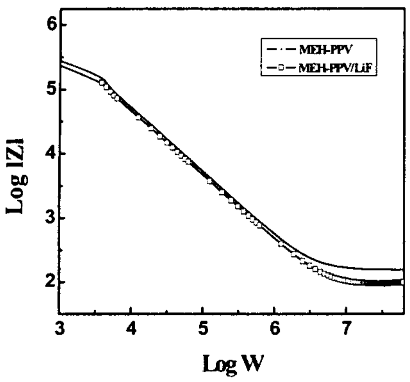

Figure 1. The impedance vs. frequency plot for the devices with and without LiF layer

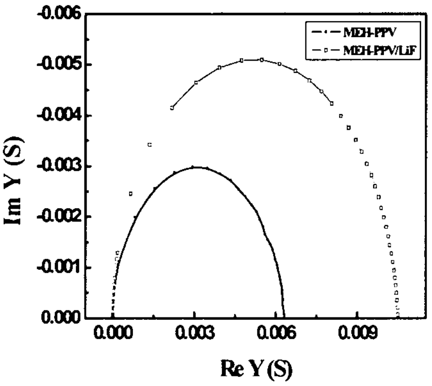

Figure 2. The cole-cole plot for the devices with and without LiF layer

The values of contact resistance (RC), parallel resistance (RP) and increment in parallel capacitance (CP) extracted from the cole-cole plot for the devices with and without LiF layer is summarized in Table-1.

Table 1. Comparison of values of Resistance and Capacitance for the device with and without LiF layer

	Without LiF layer	With LiF layer
$R_C(\Omega)$	154	93
$R_P(M\Omega)$	1.6	1.2
$C_P(nF)$	1.9	2.2

Insertion of a LiF layer at the Al/MEH-PPV interface shifts the highest occupied molecular orbital level and the vacuum level of the MEH-PPV layer, as a result, the barrier height for electron injection at the Al/MEH-PPV interface is reduced, which leads to reduction in the driving voltage of the device with LiF layer. The reduction of barrier height is attributed to the increment in CP and the reduction of driving voltage is attributed to the reduction of the RP of the devices with LiF layer which is well supported by our admittance measurement.

4. Conclusions

The device with the LiF cathode buffer layer at the Al/MEH-PPV interface can be expressed as a simple parallel combination of resistor and capacitor with a reduced value of resistance and increased value of capacitance than that of the device without the LiF cathode buffer layer. The lowering of the barrier height in PLEDs with thin LiF layer is attributed to the increment in device capacitance and the lowering of the driving voltage in PLEDs with a thin LiF layer.

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