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THE EFFECT OF INTERFACE MODIFICATION BY PEDOT: PSS ON THE HOLE MOBILITY OF THE LEC DEVICE

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ABSTRACT

The purpose of the work is to understand how to effect the interface PEDOT: PSS on the hole mobility of the LEC device by Space Charge Limited Current (SCLC) approaches technique. PEDOT: PSS plays a significant role in organic electronics device as interface modification, particularly on Light-emitting electrochemical cells (LEC) due to fundamental structure of hole only device. This study analyses the hole mobility of the device based on current-voltage characteristic approach at room temperature. It has been observed that the PEDOT: PSS interface increases the hole mobility of the LEC device by a factor of 10^8.

KEYWORDS

Hole mobility, LEC, PEDOT: PSS, OLED, organometallic Iridium (III) Complex

1. INTRODUCTION

Light-emitting electrochemical cells (LECs) containing ionic compounds in the light-emitting layer have attracted interest in organic electronics in recent years due to their simple structure and easy flexible fabrication techniques [1, 2]. This simple structure of LEC devices compared to organic light-emitting diodes (OLEDs), LECs achieve the multi-tasking electron-hole transmission and their assembly in the light-emitting layer at the same time with a single active layer [3, 4]. Also, LECs are coated easily on transparent conducting films and then electrodes can be formed on this layer with Al, Ag or Au. Since holes are injected in a balance with the electric field applied to the electrodes, high brightness and efficiency can be achieved at low operating voltage for single-layer LEC devices. All these features are the reasons why LECs are studied a lot in the literature as an alternative light emitting diode. Metal complexes are mostly used as emissive materials in LEC devices. Ionic transition metal complexes (iTMCs) have been widely applied as a single layer in LEC devices [5-11]. The most prominent feature of iTMC materials is that they catalyse charge transfer reactions with their tunable oxidation and reduction properties. Ir(III) complex-based iTMC-LEC devices allow to create high electric fields in the device, thanks to their ability to work with air-resistant electrodes [12-14]. Hole injection at the oxide/organometallic interfaces, which form the basic structure of the LEC device and allow the light to be formed and emitted here, is a crucial parameter that affects the performance of the device [15-21]. The transparent conductive oxide, indium tin oxide (ITO), which forms the anode electrode of this interface in LEC, is a factor that limits the performance of the device because it is both rough and unsuitable for hole injection [22-24]. To overcome such problems, PEDOT: PSS is formed at the interface of the organometallic light-emitting layer with the ITO. Thus, the PEDOT: PSS interface provides an increase in hole injection in the LEC device, a decrease in the operating voltage, and an improvement of the light performance due to the transparency of

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PEDOT: PSS to visible light. [25-31]. Moreover, the high energy of the occupied electronic levels of the PEDOT moiety in the molecular chain of PEDOT: PSS compared to ITO results in a lower value of the barrier potential energy at the ITO/organometallic interface. [32-37].

In this work, the theoretical calculations of the hole mobility μ bases on the current-voltage values of the LEC device. The active layer of the LEC is commercial material Iridium(III) Complex (Ir[dF(CF3)ppy]2(dtbpy))PF6). This paper just focus on how to effect the PEDOT:PSS interface on calculation and comparing of the hole mobility of the LEC devices. The optical characteristic does not issue of this study.

2. MATERIAL AND METHODS

In order to fabricate a LEC device an ITO glass as anode and the bottom-up technique is used. The ITO transparent conductive films are cut as 1.5x1.5 cm. After cleaning procedure [37, 38] of ITO substrates, the PEDOT-PSS is coated with 3000 rpm for 45 seconds by Spin coater (model SPIN150). The PEDOT: PSS thin layer was annealed in a vacuum oven at 110 °C for 25 minutes. The Iridium (III) Complex is purchased from Sigma Aldrich to modify the LEC devices consist of just one active an emitter layer. The solutions of Ir(III) complexes (20 mg/mL in acetonitrile) were layered by spin coating and dried at 110 °C for 25 minutes in a vacuum oven to obtained a smooth film. Thermal evaporation system (NANOVAK Corporation) is used to evaporate the aluminum under 10^{-6} Torr vacuum (100nm). After all stages the LEC devices (ITO/Iridium (III)Complex/Al and ITO/**PEDOT:PSS**/Iridium(III)Complex/Al) are ready to characterize using a Keithley 2401 source. The Current-Voltage (I-V) data of the LEC diode is obtained by Keithley 2401 source under room temperature (Fig. 1). The hole mobility characterization of LEC diode can be calculated using the current-voltage curves. The hole mobility calculations [39] of LEC were made with the Space Charge Limited Current (SCLC) [40] approach considering the high potential differences. The SCLC curve trend can be given by the following equations; . $J = \frac{9}{8}\varepsilon\varepsilon_0\mu\frac{E^2}{L}$(1) and $\mu(E) = \mu_0 exp(\beta\sqrt{E})$ (Poole-Frenkel equation) (2). The equation (1) become, $J = \frac{9}{8}\varepsilon\varepsilon_0\frac{E^2}{L}\mu_0 exp(\beta\sqrt{E})$ (3). In eq. (1): J, current density; ε and ε_0, the dielectric constant and the permeability of empty space; E, the electric field; L, the organic layer thickness. In eq. (2): μ, the mobility; μ_0, the mobility in the zero electric field; β, the Poole-Frenkel coefficient. The concept of the mobility is the ability of charges to move. The J-V characteristics allow investigating that how the PEDOT: PSS interface effect the hole mobility of the diode by using the specified equations.

3. RESULT AND DISCUSSION

3.1. The hole mobility calculation

The forward bias current-voltage characteristics of the LEC structure at 300 K is showed in Fig. 1.

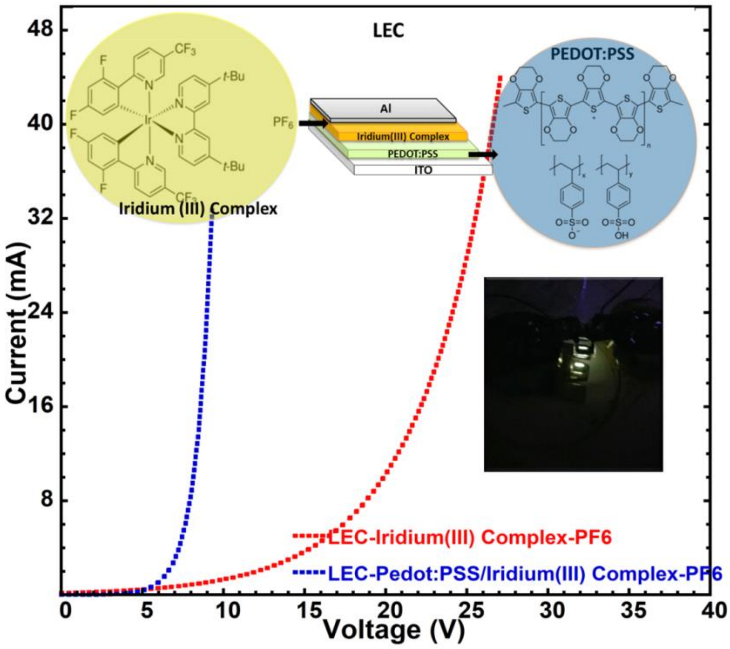


Figure 1. The forward bias current-voltage characteristics of the LEC structure and LEC devices are fabricated at Photoelectronics Lab (PEL), Toros University, LEC devices under measurement in glove box at 300 K°.

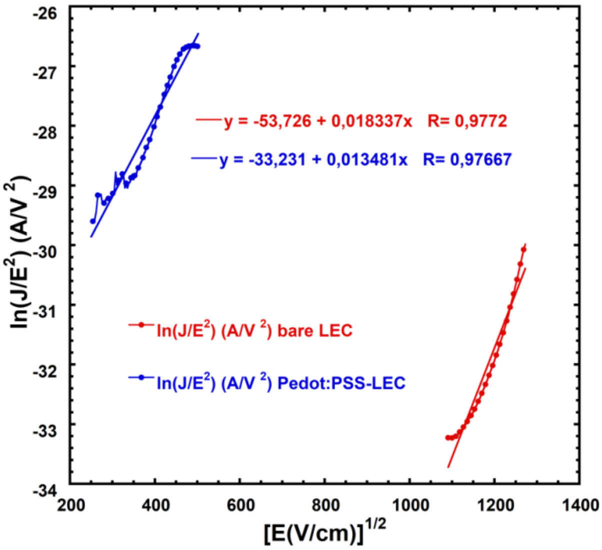
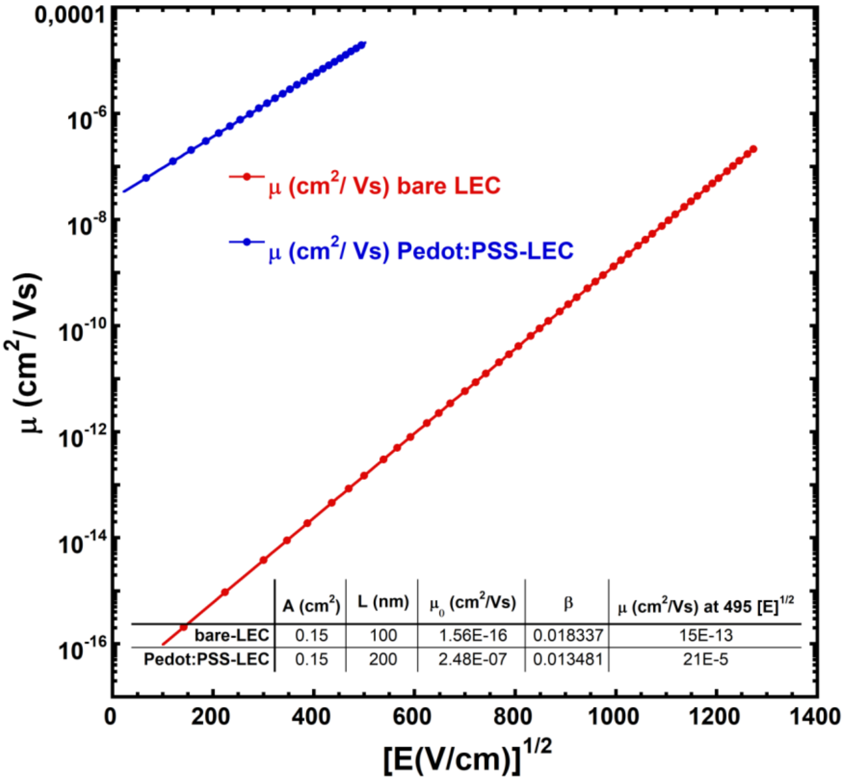


Figure 2. Plot of log J versus E1/2 of the ITO/PEDOT:PSS/Iridium(III)Complex/Al and ITO/Iridium(III)Complex/Al diode.



	A (cm^2)	L (nm)	μ_0 (cm^2/Vs)	β	μ (cm^2/Vs) at 495 $[E]^{1/2}$
bare-LEC	0.15	100	1.56E-16	0.018337	15E-13
Pedot:PSS-LEC	0.15	200	2.48E-07	0.013481	21E-5

Figure 3. Plot of mobility values μ versus $E^{1/2}$ of the ITO /PEDOT:PSS/Iridium (III) Complex/Al and ITO/Iridium (III) Complex/Al diodes.

By Fig. (2), Fig. (3) and equation (3), β, Poole-Frenkel coefficient and μ_0 are calculated. In addition, $\varepsilon = 3$ and $\varepsilon_0 = 8.85\times10^{-12}$ Farad/meter were taken for all calculations. By Equation (3), mobility values μ versus $E^{1/2}$ of the ITO/PEDOT: PSS/Iridium (III) Complex/Al and ITO/Iridium (III) Complex/Al diodes are plotted in order to get an idea how the mobility changes in diodes up to electric field. The mobility values of ITO /PEDOT:PSS/Iridium (III) Complex/Al diode are found as $21x10^{-5}$ cm2/Vs as the highest mobility value. The mobility of the ITO/PEDOT:PSS/Iridium(III)Complex/Al and ITO/Iridium(III)Complex/Al diode are 21×10^{-5} cm2/Vs and 15×10^{-13} cm^2/Vs respectively under 495 $(V/cm^2)^{1/2}$ electric field. The LEC devices fabricated in this work showed an ideal I–V behavior (Fig. 1). The hole mobility of the LEC device is calculated by SCLC approach technique. According to SCLC approach the mobility μ of ITO/PEDOT: PSS/Iridium(III)Complex-PF6/Al diode is found by factor $\sim10^8$ comparing the ITO/PEDOT:PSS/Iridium (III) Complex/Al diode and it is given the Table 1. The main reason for this is thought to be the high energy of the occupied electronic levels of PEDOT in PEDOT: PSS compared to ITO leads to a reduction of the barrier potential energy at the ITO/organometallic interface. The I-V characteristics of the LEC structures show that more holes tunnel from ITO to PEDOT molecular orbitals at the same time a decrease in the barrier height of the diode. In addition, considering the 100 nm and 200 nm film thicknesses of the LEC devices, it was observed that there was an inverse correlation between the hole mobility and the increasing distance, thanks to the extra energy levels created by PEDOT: PSS, despite the increase in the distance for tunneling the holes at the ITO/organometallic interface. This is one of the important parameters to be considered when manufacturing LEC devices.

4. CONCLUSIONS

In summary, the I–V characteristics of ITO/PEDOT:PSS/Iridium(III) Complex-PF6/Al junctions are studied. In this study, the SCLC method is used for calculating the hole mobility of the LEC device in order to understand how effect the PEDOT: PSS layer as interface on the hole mobility of the cell. The results show that PEDOT: PSS is enhance the hole mobility. According to the SCLC analysis results, the diode modified with PEDOT:PSS material possesses the best performance. The used PEDOT: PSS can be attributed to the change in barrier height values and the increase in hole injection.

CONFLICT OF INTEREST

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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