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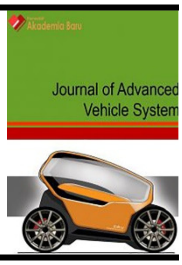

Electrical characterization and fabrication of OLED

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ABSTRACT

One of the most motivating areas of scientific research in printed electronics is Organic Light-Emitting Diode (OLED). They are engaging for use in next generation display and lighting technologies. In display applications, OLEDs have a broad range of emission colour and high power efficiencies in pliable substrates. In lighting applications, OLEDs appealing features such as broadband emission and inexpensive manufacturing process. The aim of this paper is to characterize and fabricate a double layer OLED. The emitting layer of the device is Poly [2-methoxy-5-(2-ethylhexyloxy)-1, 4-phenylenevinylene] (MEH: PPV). The electrical characterization of the double layer OLED is performed using ATLAS tool. The thicknesses of the two layers are swept to show their effect on the OLED electrical characterization. In addition, two different devices with different thicknesses are fabricated using wet process. The electrical characteristics of the fabricated devices are measured and compared with the simulated one.

Keywords:
OLED, MEH:PPV, Printed Electronics

1. Introduction

Recently Printed Electronics (PE) demonstrates a great interest in large area electronic systems. It could be counted as an emulator to the silicon based technology in some applications due to its elasticity, cheapness, lightweight and environmentally friendly [1]. It permits fabricating electronic systems on a flexible and low-cost substrate such as plastic, textile or paper [2, 3]. The expense of these systems is significantly much lower than the conventional silicon base electronics [4]. Nowadays, OLED has drawn the attention in PE for lighting and displaying applications. The first study of electroluminescence in organic materials was in 1950s by Bernanose then by Pope in 1963 and Helfrich in 1965. In 1990 the first OLED was presented by Burroughs which was based on polymer materials which called Polymer LED (PLED) [5].

The aim of this paper is to simulate and fabricate a double layer OLED. The electrical characteristics of proposed devices are simulated using Atlas tools from Silvaco.

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The paper is organized as following; section I introduces the general structure of OLED. Section II explains OLED principle of operation. Section III shows the proposed devices. Section IV is the simulation result. Section V Shows experimental results and section VI is the conclusion.

2. Principle of operation

To enhance the performance of OLED it has several structures. It can be a single layer, double or multi layers [6]. This paper focuses on the double layer OLED. It consists of two organic layers confined between two electrodes cathode and anode as shown in Fig. 1.

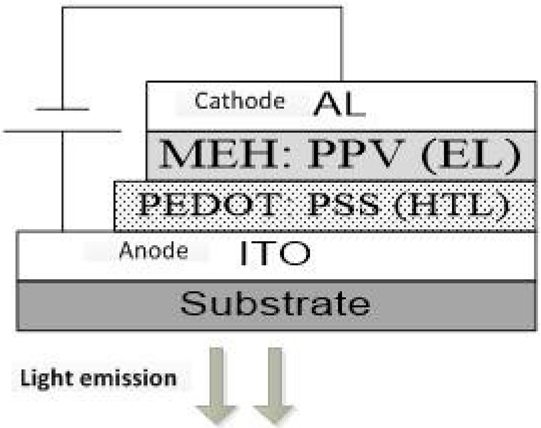


Fig. 1. Double layers OLEDs

The first organic layer is Hole Transport Layer (HTL) and the second one is Emissive Layer (EL). The HTL transports only holes from the anode layer to the EL and blocks the electron from escaping out of the EL. The free electrons transport from the anode layer toward EL. The recombination of the hole–electron pair happens at the interface between the two layers, which inspire electroluminescence [7].

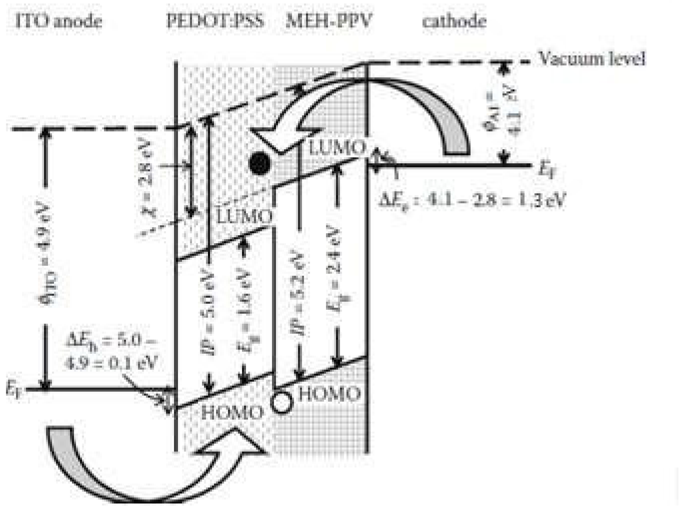


Fig. 2. Energy level diagram of double layer OLED

When applying a forward bias, the anode has more positive electrical potential than the cathode. Hence, free electrons can pass the electron energy barrier ΔEe which is the difference between cathode work function ϕc and EL affinity χ as shown in Fig. 2. In addition, holes move from the anode into the HOMO of the HTL passing the hole energy barrier ΔEh. This barrier is the difference between Ionization Potential (IP) of HTL and the anode work function ϕA. The recombination leading light emission occurs at the hetero-junction between the two organic materials which provides an excited state. This state, called exciton, depends on the total spin quantum numbers. It could be singlet or triplet exciton. The probability of triplet exciton is 75% while singlet is 25% [8, 9].

3. Device models

The model used in organic materials bases on the one-dimensional time-independent drift-diffusion transport model. It demonstrates the charge carrier transport inside the organic semiconductor. This model contains the continuity equation and the charge carrier mobility for electrons and holes [10, 11]. The Poole–Frenkel-like mobility model is the field-dependent mobility model used for a high electric filed. In that case, the mobility depends on the applied electric field as indicated by [12].

$$\mu_n(E) = \mu_{n0} exp\sqrt{\frac{E}{E_0}} \quad (1)$$

$$\mu_p(E) = \mu_{p0} exp\sqrt{\frac{E}{E_0}} \quad (2)$$

where E is the magnitude of the electric field, μ_{n0} and μ_{p0} are the zero field mobility's of electron and hole respectively, and E_0 is material parameter. The recombination rate of free electrons and holes is described by Langevin's theory [12]. The Langevin recombination rate is

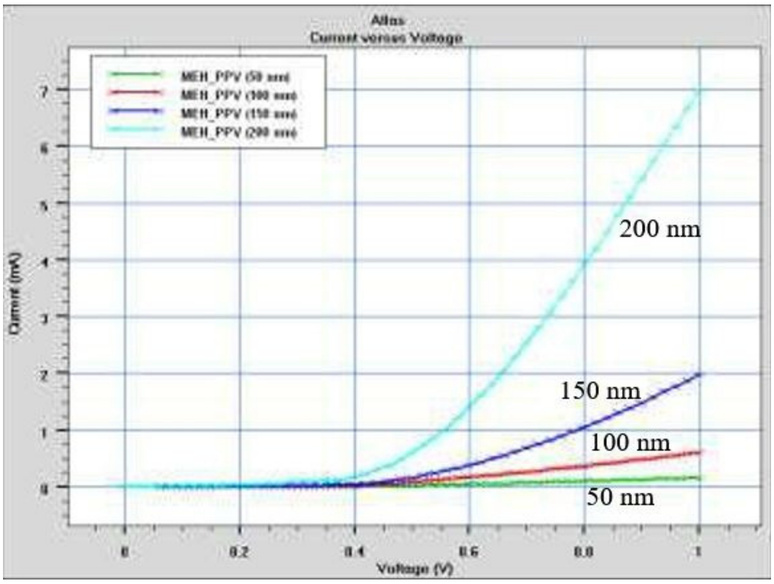
$$R_L = \frac{q}{\varepsilon}(\mu_n + \mu_p)np \quad (3)$$

where, ε is the permittivity of the organic material, q is the electron charge and n and p are the densities of free electrons and holes respectively.

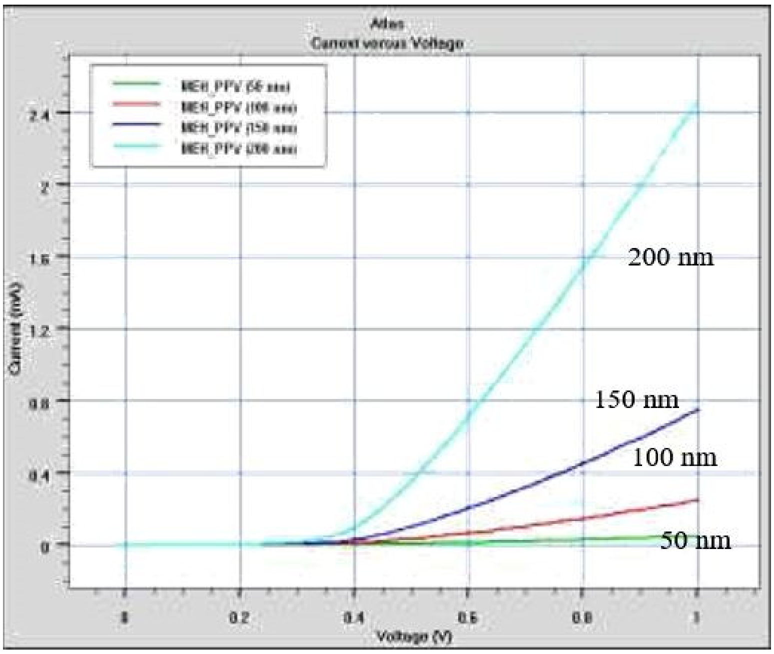
4. Proposed design and simulation results

A double layers OLED is designed and characterized using ATLAS tool from Silvaco. As shown in Fig. 1 it is typically consisting of glass substrate coated with ITO as an anode, PEDOT:PSS as (HTL), MEH:PPV as (EL) and Al as cathode.

In this structure the hole energy barrier ΔEh is 5.0 - 4.9 = 0.1eV. It is relatively low due to the high value of IP of PEDOT:PSS. The electron energy barrier ΔEe is 4.1 – 2.8 =1.3eV which is relatively high. The effect of thicknesses variation for both EL and HTL on the device electrical characteristic are examined. The PEDOT:PSS thicknesses are chosen to be 50 nm and 100 nm which are the same thicknesses obtained from fabrication. At each thickness of PEDOT:PSS, the MEH-PPV thickness varies from 50 nm to 200 nm. The I-V characteristics of all devices are shown in Fig. 3. The results show that the current increases as the thickness of PEDOT:PSS decreases and the MEH:PPV thickness increases. This is because when PEDOT:PSS layer thickness increases more holes are injected into the EL. On the other hand, the concentration of electrons injected from anode is less than holes due to the high electron energy ΔEe. Accordingly, the concentrations of holes and electrons are unbalance which reduces the current.



(a)



(b)

Fig. 3. I-V Characteristics of (ITO/ PEDOT: PSS/ MEH-PPV/AL) with PEDOT:PSS thicknesses a) 50nm, b) 100nm

In addition the turn on voltage is slightly decreased with increasing the thickness of MEH:PPV.

5. Experimental details

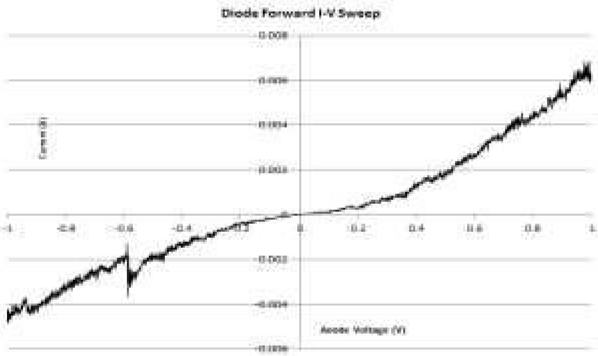
Two different devices with different thicknesses of MEH:PPV (EL) are fabricated. For both devices the thickness of PEDOT:PSS is the same. The fabrication technique is based on solution (wet) process. *MEH:PVV Preparation:* The MEH:PPV material is from Sigma Aldrich with CAS # 536512. Its average molecular weight is 150,000-250,000. It is dissolved in toluene solvent with concentration of 15mg/ml. The solution is then left on the magnetic stirrer for 48 hours to grantee that the MEH:PVV is completely dissolved.

Device Fabrication: The two substrates are ITO coated glass from Sigma Aldrish. The area of each substrate is 2.5 X 2 cm2 with thickness 1.1 mm. The surface resistivity is 70-100 Ω/sq. The substrates are cleaned by acetone, de-ionized water (DI-water) then Isopropanol (IPA) for 20 min each in ultrasonic bath at 50oC. The samples then dried with Nitrogen flow. The samples are then baked for 10 min at 50oC. For both samples the PEDOT:PSS material (CAS # 739316 from Sigma Aldrish) is then spin coated at 500 rpm for 10 sec to guarantee the solvent is completely evaporated. Then both samples are packed on hot plate for 10 min at100^{o}C. The thickness of the film is 50nm which is measured by DektakXT surface profiler. For the first sample the MEH_PPV is spun coated with 500 rpm for 10 sec then 1000 rpm for 30 sec to get a homogenous film. The sample is then packed at 100^{o}C for 10 sec. The thickness of the resulting MEH:PPV layer is 200nm. To get a difference thickness the second sample is spun coated with 500 rpm for 10 sec then 2000 rpm for 30 sec. The measured MEH:PPV thickness at this speed is 150 nm. For metallization, 100 nm AL cathode is deposited on the top of the MEH:PPV layer of both devices using a sputtering tool. The I-V characterizations for both devices are measured using Keithily 4200. The voltage is wept from -1 to 1V. The fabricated OLEDs show I-V characterization curves similar to the conventional diode. Fig.4 a. shows the I-V curve for the first OLED with 50 nm, 200 nm PEDOT:PSS and MEH:PPV layers thicknesses respectively. The measured result shows that the forward current is 6mA at 1V forward bias. The turn on voltage is 0.2V. The I-V curve of the second OLED with 50 nm, 150nm PEDOT:PSS and MEH:PPV layers thicknesses respectively is shown in Fig.4 b. The measured current is 1.5mA when applying a 1V forward bias and the turn voltage is 0.25V.

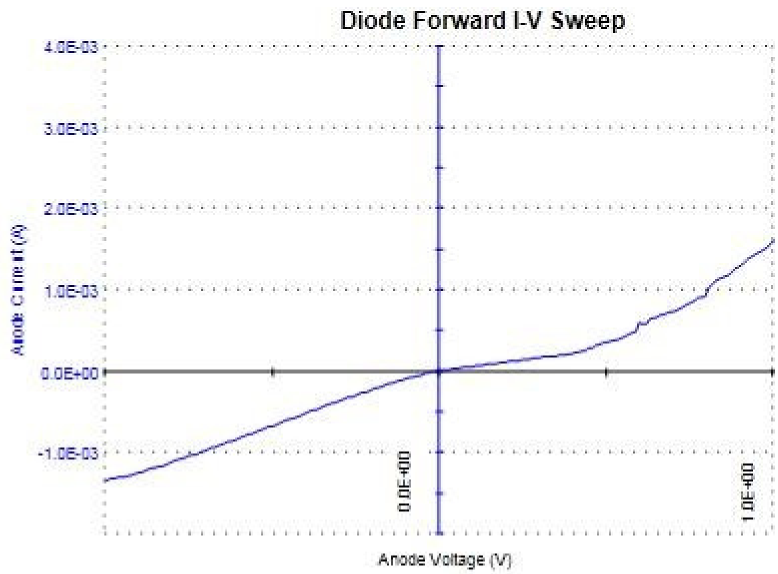
6. Conclusion

This paper introduces the effect of thicknesses variation of the two polymer layers on electrical properties of two layers OLED. In addition, it shows the similarity between the simulation and measured results. The electrical properties of the OLEDs are simulated using ATLAS tool.

The fabrication technique is based on wet process. The structure of the OLEDs is ITO/PEDOT:PSS/MEH:PPV/Al. The OLED with lower PEDOT:PSS thickness and higher MEH:PVV thickness shows a better electrical performance for both simulation and measured results. The hole energy barrier in the constructed OLED is less than the electron energy barrier. Hence more holes are injected toward the EL than electron injected from anode. Therefore the current is reduced with decreasing the MEH:PPV layer thickness. The simulated forward current for OLED with 50nm PEDOT:PSS thickness and 200nm is 7 mA while the measured value is 6mA for same applied forward potential. In addition, when the MEH:PPV thickness is reduced to 150nm with same PEDOT:PSS thickness the simulated current value is reduced to 2mA while the measured value is 1.5mA.



(a)



(b)

Fig. 4. Measured I-V characteristics of (ITO/ PEDOT: PSS/ MEH-PPV/AL) with PEDOT:PSS thicknesses 50nm and MEH:PPV thicknesses **a**. 200 nm (1000 rom), **b**. 150 nm (2000 rpm)

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References
[1] Suganuma, Katsuaki. *Introduction to printed electronics*. Vol. 74. Springer Science & Business Media, 2014.
[2] Organic Light Emitting Diodes. Taylor & Francis Group, CRC Press, 2012.
[3] Ohishi, Tomoji, Hiroaki Kawada, Tsutomu Yoshida, and Takeshi Ohwada. "Development of a High-Performance Flexible Substrate for Flexible Electronics: Joining TAC Films and an Ultra-Thin Glass by Using TEOS-DAC Synthesized by the Sol-Gel Method." (2015).
[4] Chang, J.B., de la FuenteVornbrock, A., Huang, D.C., Jagannathan, L., Liao, F., Mattis, B., Molesa, S., Redinger, D.R., Soltman, D., Volkman, S.K. "Printed electronics for low cost electronics system" *Technology Status and Application Development Subramanian*, Qintao Zhang Solid-State Circuits Conference, ESSCIRC 34th European, 2008.
[5] Kunić, Srećko, and Zoran Šego. "OLED technology and displays." In *ELMAR, 2012 Proceedings*, pp. 31-35. IEEE, 2012.
[6] Kalyani, N. Thejo, and S. J. Dhoble. "Organic light emitting diodes: Energy saving lighting technology—A review." *Renewable and Sustainable Energy Reviews* 16, no. 5 (2012): 2696-2723.
[7] Ma, Wanli, Parameswar K. Iyer, Xiong Gong, Bin Liu, Daniel Moses, Guillermo C. Bazan, and Alan J. Heeger. "Water/Methanol-Soluble Conjugated Copolymer as an Electron-Transport Layer in Polymer Light-Emitting Diodes." *Advanced Materials* 17, no. 3 (2005): 274-277.
[8] Simon Rankel, Dragan Mihailović, "OLEDs Organic Light Emitting Diodes." Department of Physics, University of Ljubljana Faculty of Mathematics and Physics, Ljubljana, 2004.
[9] Zhang, Yifan. "Excited State Interactions and Management in Organic Light Emitting Diodes." PhD diss., University of Michigan, 2014.
[10] Retrieved in 2016 from: www.silvaco.com/content/kbase/otft_oled.pdf
[11] Chan, J., A. D. Rakic, Y. T. Yeow, and A. B. Djurisic. "Electrical and optical simulation of Tris (8-hydroxyquinoline) Aluminium-Based Microcavity Organic Light Emitting Diode (MOLED)." In *Optoelectronic and Microelectronic Materials and Devices, 2004 Conference on*, pp. 53-56. IEEE, 2004.
[12] Siemund, H., F. Bröcker, and H. Göbel. "Enhancing the electron injection in polymer light-emitting diodes using a sodium stearate/aluminum bilayer cathode." *Organic Electronics* 14, no. 1 (2013): 335-343.