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# Analyzing the influences of work function Anode on the Performance of OLED

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***Abstract:*** *In this work, we investigate the effect of increasing the work function of the anode on luminancepower and recombination rate. For this purpose, we choose a high-work function anode, and a low-work function anode. Then, we investigate their influences on luminance power and recombination rate. Therefore, two organic light-emitting diodes are designed by utilizing the indium tin oxide (ITO) anode and zinc oxide (ZnO) anode, and then we compare their performance. We utilize Langevin model and Poole-Frenkel model to analyze the OLEDs. The results indicate that increasing work function anode affects increasing luminance power, anode current and recombination rate.*
***Keywords:*** *OLED; work function anode; ITO; ZnO; work function*

## I. Introduction

By studying the different reports, we understand that there are various factors that influence on performance such as band gap, conductance, and work function. Transparent indium tin oxide (ITO) is commonly used as the anode in the organic electronic devices such as organic light-emitting diodes (OLEDs) and organic photovoltaic devices (OPVs) according to its high conductivity and excellent transmission of light [1–2]. However, ITO is toxic, expensive, and inflexible [3–4]. In addition, the graphene is suitable for the future portable electronics because it has high transparency in visible wavelength and better flexibility than the existing transparent conductive electrodes (TCEs) such as ITO, aluminum zinc oxide (AZO), and indium zinc oxide (IZO) [5]. Nowadays, the graphene has been widely used in optoelectronic devices including organic photovoltaic and OLEDs [6].

In spite of its great potential as TCEs, there are several problems to achieve high performance for good transparent conductors. First, the sheet resistance of the commercialized graphene is not enough to fabricate a high-performance device and the value is about 300 Ω [7]. Methods to overcome a high-sheet resistance caused by interval scattering in grain boundary are needed. Second, electrodes of organic electronic devices need qualified work function to achieve good carrier injection property [8]. However, the work function (4.5 eV) of graphene is not enough to apply for anodes of organic optoelectronics. Its work function is also too high to apply for a cathode [9–10].

In this work we have utilized three-layer device including of the MEH-PPV polymer film sandwiched between an ITO coated (or ZnO)and a metal. In addition, the polymer film is p-type doped with a uniform concentration of $1 \times 10^{16}\,cm^{-3}$.Increasing doping affects increasing the recombination rate of MEH-PPV. The work function of ITO is 4.7eV that hole-injection barrier of 0.2eV given the polymer highest occupied molecular orbital (HOMO) level of 4.9eV. The work function of cathode is 2.9eV (we have considered calcium as a cathode).

## II. Simulation

In this work, we have simulated two OLEDs (with SILVACO Atlas) with different work function anode.We used Poole-Frenkel and Langevin model for simulation of PLED. In Poole–Frenkel model, dependence of μ on the electric field (E) must be considered [12]. The zero-field mobility ($\mu_{E=0}$) and the parameter $E_0$ dictates how strongly μ is modified by the field:

$$\mu(E) = \mu_{E=0} \exp\left(\left(\frac{E}{E_0}\right)^{\frac{1}{2}}\right) \qquad (1)$$

Where $\mu_{E=0} = \mu_0 \exp\left(\frac{-\Delta}{K_B T}\right)$ with $\mu_0$ a constant and Δ the activation energy. In this case, current density is approximately [13]:

$$J_F \approx (9.8)\varepsilon\varepsilon_0 \left(\frac{V^2}{d^3}\right) \mu_{E=0} \exp\left(\left(\frac{e^3}{\pi\varepsilon\varepsilon_0 d}\right)^{\frac{1}{2}} \left(\frac{V^{\frac{1}{2}}}{K_B T}\right)\right) \qquad (2)$$

**2.1. The first OLED with a low-work function anode:**

This OLED has been fabricated by three layers that include ITO, MEH-PPV, and Ca/Al. ITO as an anode, MEH-PPV as an organic layer and an intermediate layer, and Ca/Al as the cathode. The thickness of the anode, cathode, and intermediate layer are 37.5nm, 40nm, and 40nm,respectively.The work function of the anode and cathode that have been utilized in this work are 4.7eVand 2.9eV, respectively. The structure of the OLED is shown in Figure1.

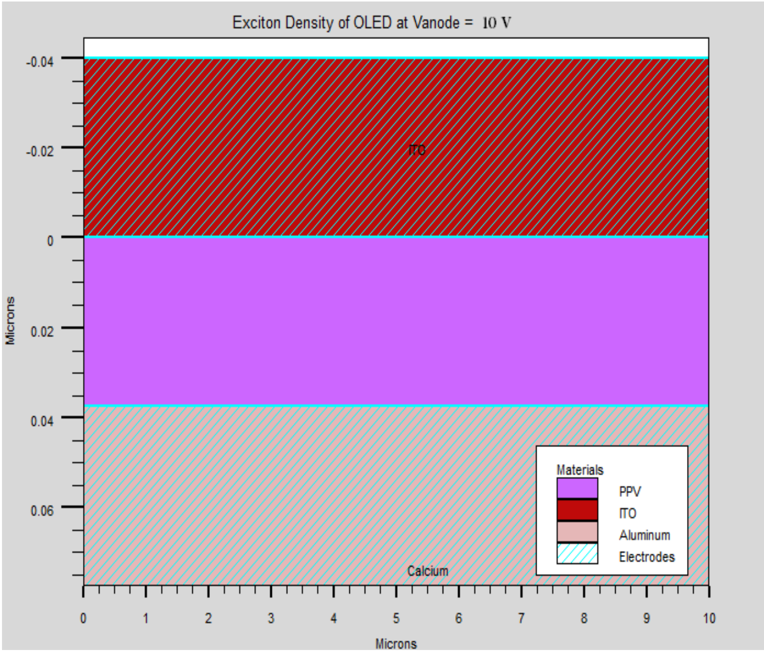
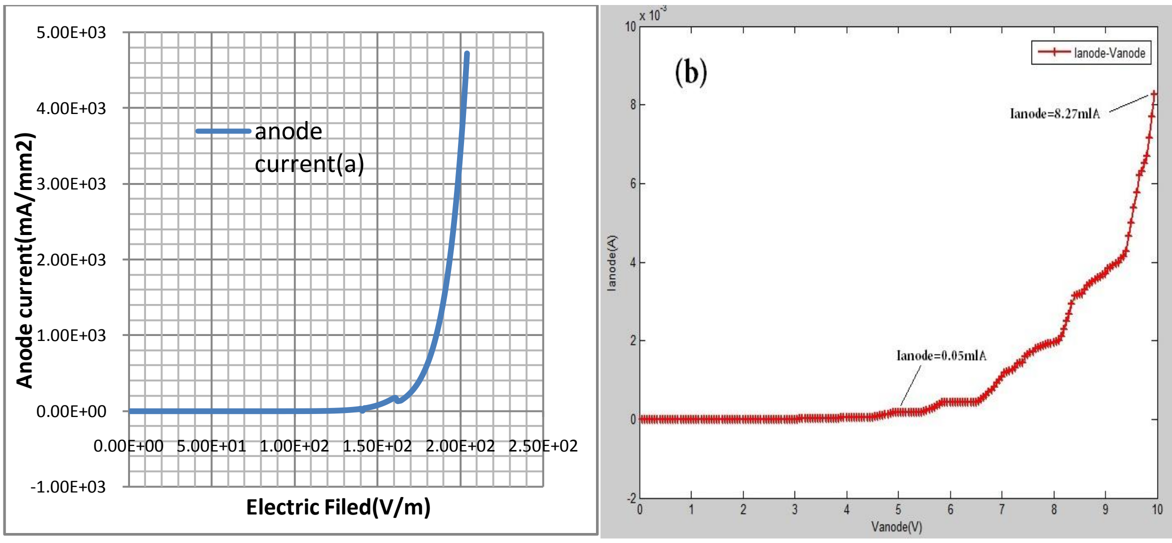



Figure.1.The structure of OLED.

Current density curves, luminance power curve, and recombination rate are shown in Figure 2.



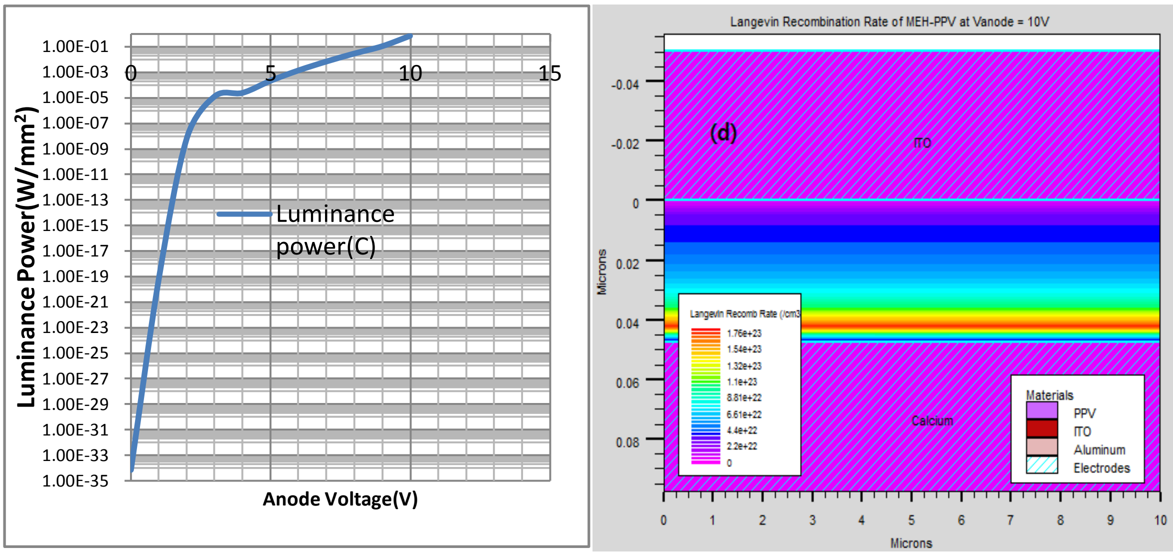
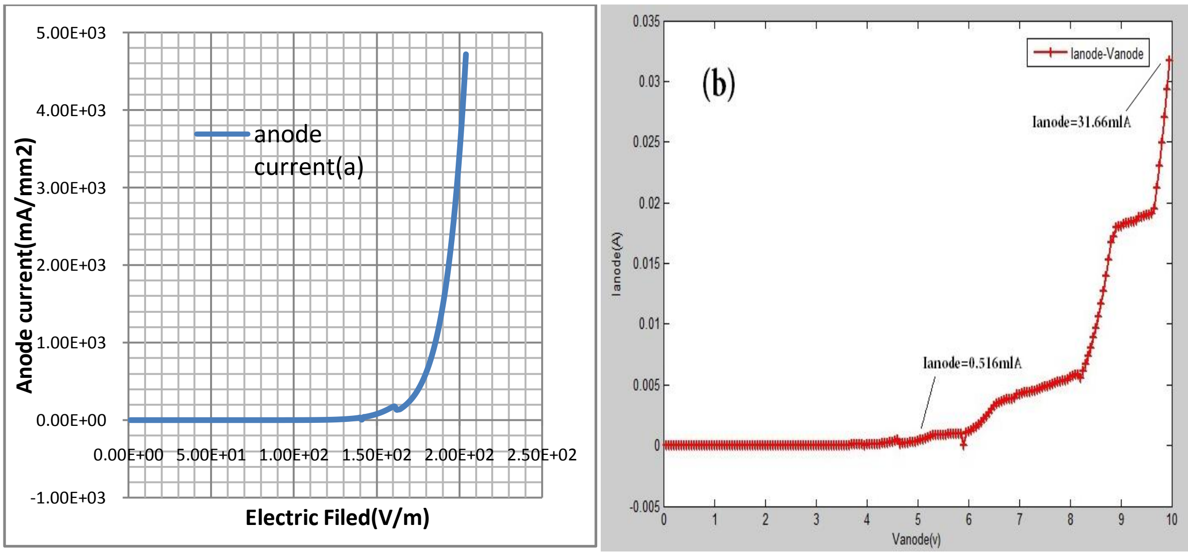



Fig.2.Theperformance of OLED with a low-work function anode(ITO anode) (a) Current Density-Electric Field curves; (b)Anode current–Anode voltage curves; (c)Luminance power–voltage curves; (d) Recombination Rate.

### 2.2. The second OLED with a high-work functionanode:

This OLED has been fabricated by three layers including of ZnO, MEH-PPV, and Ca/Al. ZnO as an anode, MEH-PPV as an organic layer and an intermediate layer, and Ca/Al as the cathode. The thickness of the anode and cathode and intermediate layer are 37.5nm, 40nm, and 40nm, respectively. The work function of the anode and cathode that have been utilized in this work are 5.2eVand 2.9eV, respectively.

Current density curves, luminance power curve, and recombination rate are illustrated in Figure3.



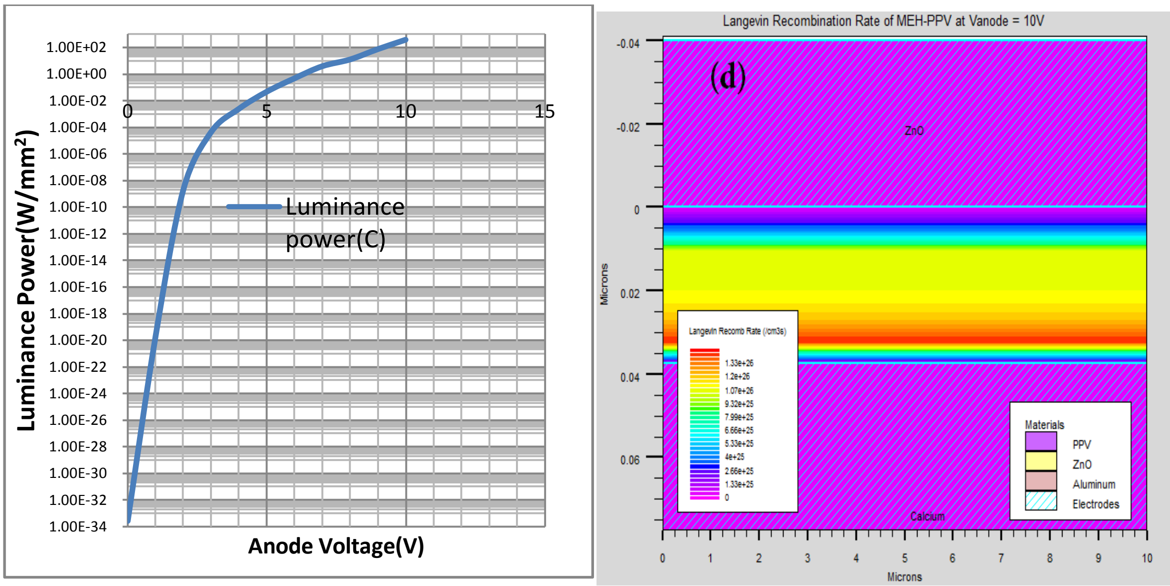



Fig.3.the performance of OLED with a high-work function anode(ZnO anode) (a) Current Density-Electric Field curves ;(b)Anode current–Anode voltage curves;(c)Luminance power–voltage curves ;(d) Recombination Rate.

## III. Results And Discussion

There are two categories of photo physical units: radiometric (physical properties) and photometric (as perceived by the eye). Radiometric units are, for example, the number of photons, photon energy, and radiant flux (optical power). A photometric quantity is the luminous intensity which represents the light intensity of a light source as perceived by the human eye. It is measured in candela (cd), a base unit in the SI system; according to [11].

A monochromatic light source emitting an optical power of (1/683) W at 555 nm into the solid angle of 1sr has a luminous intensity of 1cd. The "luminous flux," light power as observed by the eye, is measured in lumen (lm), and according to [11]. Monochromatic light source emitting an optical power of (1/683) W at 555 nm has a luminous flux of 1lm. This means that 1cd equals 1 lm/sr.

The luminance of a surface source (e.g. an OLED) is the ratio of the luminous intensity in a certain direction (under the angle $\theta$measured against the normal vector of the surface) divided by the projected surface area in that direction (A. cos$\theta$). Considering that $V_{bi}$ is equal to work function difference.According to Equation3, $V_{bi}$ is associated with work function difference. Increasing work function difference affects increasing luminance as a result of increased $V_{bi}$.

$$\Phi_{bi} = \Phi_a - \Phi_c = eV_{bi} \qquad (3)$$

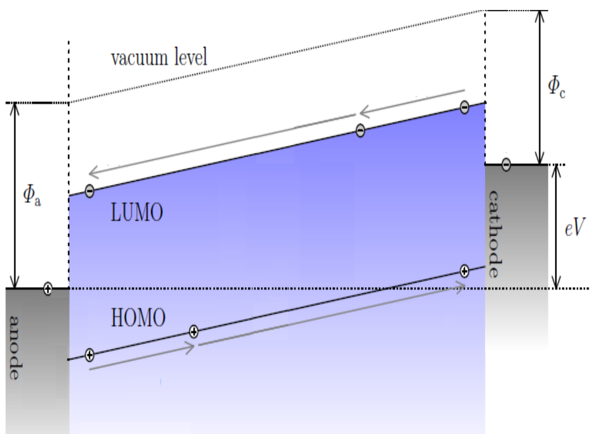



Figure.4.Simplified energy level diagram for an OLED consisting of only one organic layer

We can see in Figures 2(a) and 3(a), under the electric field at $1 \times 10^8$ v/m OLED starts to emit light. Also the increase electric field the increase current density and luminance power. In Figures 2(b) and 3(b) anode current is illustrated in terms of ITO anode and ZnO anode, respectively. In addition, we can see in Figures 2(b) and 3(b), anode current in voltage 5V are 0.05mlA and 0.516mlA, respectively. Also anode current in voltage 10V are 8.27mlA and 31.66mlA, respectively. Anode current has been compared in two-anode voltage. This comparison has been shown in Table 1.

Table1.Anode current in voltage 10V and 5V

| Anode | $V_{Anode}$(V) | $I_{Anode}$(mlA) |
|---|---|---|
| ITO Anode | 5 | 0.05 |
| ITO Anode | 5 | 0.516 |
| ZnO Anode | 10 | 8.27 |
| ZnO Anode | 10 | 31.66 |

In Figure 1(c), it is seen that the device "turns-on" at about 2 V. By comparing Figure 2(c) with 1(c), we see the luminance power is different in voltage of 2 volts. This is due to the difference in anode work function is obtained.We can see the recombination rate of the middle layers in Figures 2(d) and 1(d). In Figure 1(d), a recombination rate is approximately $6.61 \times 10^{22}$ cm$^{-3}$and in Figure 2(d) a recombination rate is approximately $1 \times 10^{26}$ cm$^{-3}$.This is due to the difference in anode work function that is obtained.

The comparison of device performances between ITO anode OLED and ZnO anode OLED is shown in Table 2.

Table2.The table shows anode current, luminance power and recombination rate in OLED with ITO anode and ZnO anode at the voltage of anode = 10V.

| Anode | $I_{Anode}$ (mlA) | Luminance Power(log(W/mm$^2$)) | Recombination Rate(1/cm$^3$) |
|---|---|---|---|
| ITO Anode | 8.27 | $1 \times 10^{-1}$ | $6.61 \times 10^{22}$ |
| ZnO Anode | 31.66 | $1 \times 10^{+2}$ | $1.11 \times 10^{26}$ |

## IV. Conclusion

The purpose of this work is to study the influence of increasing the anode work function on luminance power, recombination rate, and anode current. By investigating the simulations results mentioned above, it can be understood that increasing work function anode affects increasing luminance power and anode current. Furthermore, we have investigated the behavior of Zno anode (as a high-work function anode) and ITO anode (as a low-work function anode). The results indicate that increasing the anode work function affects increasing recombination rate in intermediate layer.

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