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Electrical and Optical Properties of N, N`-Bis (Inaphthyl)-N,N`-Diphenyl-1,1`-Biphenyl-4,4`-Diamine as Hole Transport Layer in Organic Light Emitting Devices

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Abstract: Problem statement: The aim of this research was to study the electrical and optical properties of N, N`-bis(Inaphthyl)-N,N`-diphenyl-1,1`-biphenyl-4,4`-diamine (NPB) organic materials often used as hole transport layer in Organic Light-Emitting Devices (OLED). **Approach:** The NPB layer was prepared using the thermal evaporation method. From photoluminescence spectra, two peaks at 630 and 480 nm were observed with 55 nm NPB. The electrical conductivity was strongly influenced by the layer thickness. **Results:** The energy band gap of each NPB layer was successfully presented in the range of 2.4-2.9 eV. **Conclusion:** This study successfully showed the effect of different thickness of NPB in OLED.

Key words: Thermal evaporation, photoluminescence, energy band gap, electrical conductivity

INTRODUCTION

Various organic light emitting diode displays have been investigated in recent years. Despite their excellent performance, various techniques have been recently reported to further improve their efficiency. The basic structure of an OLED is shown in Fig. 1 and typically consists of three organic semiconductor layers sandwiched between two electrodes. The electron-injecting electrode consists of a low work function metal alloy, deposited by vacuum evaporation. Vacuum evaporation is widely to use for preparation OLEDs. OLEDs structure consists of two important layer which is hole tranposrt layer (HTL) and electron transport layer (ETL) connected by two electrodes. Indium Tin Oxide (ITO) as an anode on the bottom, hole-injecting, electrode (Paul *et al*., 1997). Upon recombination, energy is released as light, which is emitted from the light-transmissive anode and substrate.

Currently, there is great interest in the study of OLEDs containing small molecules as emitting layer. In addition to applications in OLEDs, these molecules have been found to be useful in applications such as optical devices, luminescence probes in biomedical assays, luminescence sensors for chemical species and fluorescent lighting (Kido and Okamoto, 2002; Silva and Pereira, 2006).

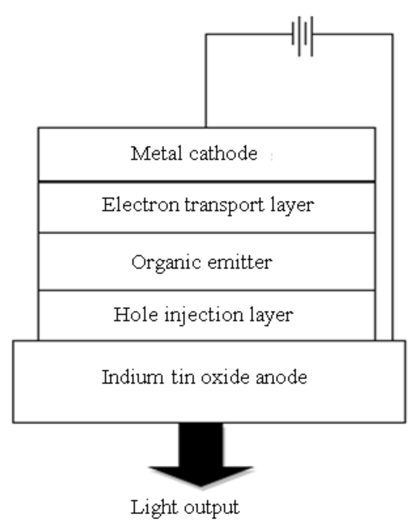

Fig. 1: The basic structure for organic light emitting devices

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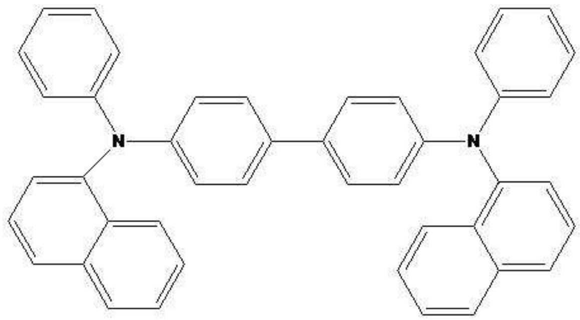

Fig. 2: Molecular structure of N,N`-bis(Inaphthyl)-N, N`-diphe.nyl-1,1`-biphenyl-4,4`-diamine

OLED development needs to include optimization of device structure, development of novel materials and improvement of manufacturing techniques and cost. Electrical doping of charge transport layers of organic light emitting diodes is one step towards this direction. One of the most widely used Hole Transport Layer (HTL) in OLED is N,N`-bis(Inaphthyl)-N,N`-diphenyl-1,1`-biphenyl-4,4`-diamine(NPB) (Fig. 2). This is because NPB can be manufactured readily and is thus abundantly available even though its Tg at 98°C is a trifle low which may affect its morphological stability at high operating temperatures (Hunga and Chen, 2002).

In the present study, different thickness NPB layer was prepared by vacuum evaporation method. The effect of thickness of NPB on the energy band gap, electric conductivity and photoluminescence of the NPB was investigated.

MATERIALS AND METHODS

Experimental: For the preparation of NPB organic layer, Indium Tin Oxide (ITO) was cut into square plates (0.02×0.020 m) glass and used as substrate. The ITO glasses were immersed in ultrasonic baths with acetone for 10 min. Then, the ITO glasses were rinsed in deionized water for 10 min and then blow dry with nitrogen gas. This procedure was used to remove organic contamination and particles from the ITO surface. Different thickness of organic layers were deposited on the ITO at a rate of 2.5 A/s from resistively heated tungsten boats at a base pressure of 1.0×10^{-5} Torr.

Current-voltage measurements were made with a Keithley source meter (model 2400). The thickness of the layers was measured by Tencor P-12 disk profile. The PL of the film was measured by a EL spectra USB 2000 FLG Spectrofluorometer.

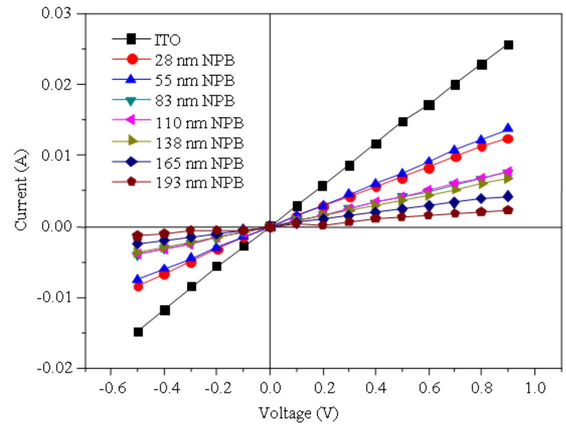

Fig. 3: Current-voltage curve for all different thickness of NPB

RESULTS

Figure 3 shows the current versus voltage curve of the seven NPB samples with different thickness. The electrical resistance (R) of a circuit component or device is defined as the ratio of the voltage applied (V) to the electric current (I) which flows through it. Observation of Fig. 3 shows that the resistance decrease as the thickness of the NPB layer increased.

The spectra of optical absorption measurements were made over the wavelength range of 360-800 nm. The variation in the absorbance with wavelength is shown in Fig. 4 for NPB with varying thickness. The spectra observed are similar. The expected variation of the absorption coefficient (α) with photon energy is given by:

$$(\alpha h\nu)^2 = C(h\nu - E_g) \quad (1)$$

Where:

c = A constant

E_g = The optical band gap

hν = Photon energy

The plot of $(\alpha h\nu)^2$ as a function of hν follows a straight line (fundamental absorption). Hence, in 2.4-2.9 eV range, the absorption spectrum can be described by Eq. 1. The energy axis intercept of the least-square fit to the linear part yields the optical band gap E_g.

The room-temperature absorption spectrum for different thickness of NPB is shown in Fig. 6. In order to further optimize device structure so as to achieve optimal PL performances, the thickness of NPB host layer was first changed

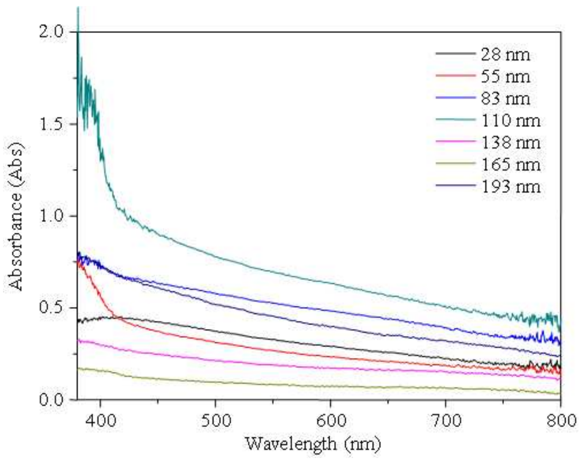

Fig.4: The absorbance versus wavelength for different thickness of NPB

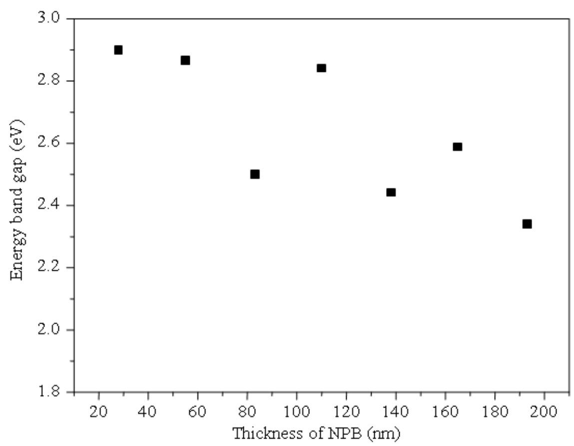

Fig. 5: Energy band gap for different thickness of NPB

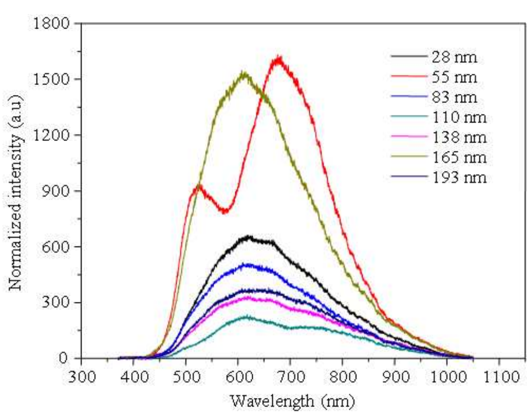

Fig. 6: The PL performance with the different thickness of NPB

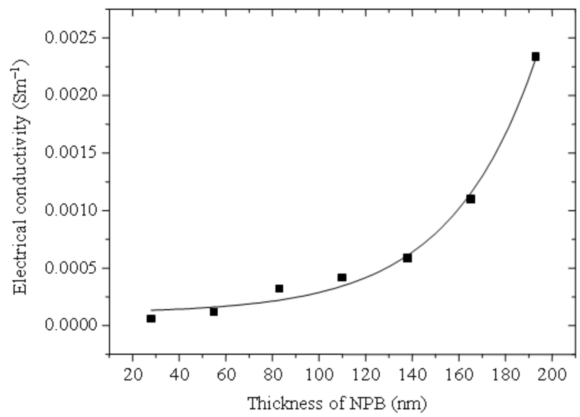

Fig. 7: Electrical conductivity for all different thickness of NPB

DISCUSSION

The electrical behavior of single layer OLEDs is known to have a strong linked to the NPB due to its mobility (Fig. 7). The electrical conduction is controlled by the energy states in the semiconductor bulk that usually arise from localized defects (Wolfgang *et al*., 2001).

From the result, the E_g decrease with the increase thickness of NPB (Fig. 5). These results can be easily correlated with the efficient hole transport inside the HTLs as the analysis of energy (Zhi-Feng *et al*., 2003). It is also can expected that the improvement is on account of a good balance between the injected electrons and holes in the OLED devices.

The thickness of the NPB host strongly affected the PL performances and as it was thinned to be 55 nm, the devices exhibited a peak efficiency and a better color coordinates, i.e., color saturation. It can be seen that the PL spectra of the 55 nm NPB have two peak located at 480 and 630 nm. This indicated that the 55 nm NPB has intermolecular interaction between ITO stronger than other thickness of NPB (Lingling *et al*., 2005; Avendano *et al*., 1999).

CONCLUSION

For the PL spectra, two new peaks at 630 and 480 nm were observed for 55nm NPB for the white light. The electrical conductivity was strongly dependence on the layer thickness. The E_g decrease with the increase thickness of NPB. Thus, a correlation between the E_g and electrical conductivity in NPB has been investigated.

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