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Optical properties for N,N'-bis (Inaphyhly)-N,N'-diphenyl-1,1'-biphenyl-4,4'-diamine and tris (8-hydroxyquinolinato) aluminum in organic light emitting devices

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ABSTRACT

The optical properties of N,N'-bis (Inaphthyl)-N,N'-diphenyl-1,1'-biphenyl-4,4'-diamine (NPB) and tris (8-hydroxyquinolinato) aluminum (Alq_3) organic materials used as hole transport and electron transport layers in organic light-emitting devices (OLED) have been investigated. The NPB and Alq_3 layers were prepared using thermal evaporation method. The results show that the energy band gap of Alq_3 is thickness independence while the energy band gap of NPB decreases with the increasing of sample thickness. For the case of photoluminescence the Alq_3 with thickness of 84 nm shows the highest relative intensity peak at 510 nm.

Keywords: Energy Band Gap; N,N'-Bis (Inaphthyl) -N,N'-Diphenyl-1,1'-Biphenyl-4,4'-Diamine Tris (8 Hydroxyquinolinato) Aluminum; Organic Light Emitting Diode; Photoluminescence

1. INTRODUCTION

Various organic light emitting devices displays have been investigated in recent years. Many techniques like anode [1] and cathode [2] modifications, inserting hole blocking layer [3], control the thermal evaporation rate [4] and doping system have been recently reported to further improve display efficiency due to their excellent performances. Currently, there is great interest in the study of OLEDs containing small molecules as emitting layer. Such molecules have been found to be useful in OLED applications such as optical devices, luminescence probes in biomedical assays, luminescence sensors for chemical species and fluorescent lighting [5,6]. Advantages of organic LEDs over inorganic ones are their high emission efficiency in the visible spectrum, easy to process, robustness and almost infinite possibility for modification. They also have low operating voltage, low power consumption and wide viewing angle. However, there are still several problems which must be solved especially for transferring research results to commercial application of OLED devices in display technology. Short OLED lifetime, low carrier mobility and high interface barriers must be improved by optimizing the material parameters and fabrication steps.

As present, the basic structure of an OLED is shown in **Figure 1** and typically consists of three organic semiconductor layers (hole injection layer, organic emitter and electron transport layer) sandwiched between two electrodes. The electron-injecting electrode consists of a

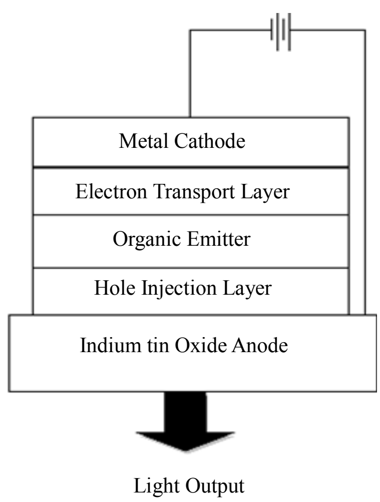

Figure 1. The basic structure for organic light emitting device.

low work function metal alloy, typically Mg-Ag or Li-Al, deposited by vacuum evaporation. The bottom, hole-injecting, electrode is typically a thin-film of the transparent semiconductor indium tin oxide (ITO) [7]. Upon recombination, energy is released as light, which is emitted from the light-transmissive anode and substrate. N'-bis (Inaphthyl)-N,N'-diphenyl-1,1'-biphenyl-4,4'-diamine (NPB) was chosen as hole injection layer because it can be easily manufactured and is abundantly available in powder form. However, tris (8-hydroxyquinolinato) aluminum (Alq_3) is used as an ETL because Alq_3 is thermally and morphologically stable therefore can be easily evaporated into thin films form. Easily synthesized and purified, molecularly shaped to avoid exciplex formation (e.g. with N,N'-bis (Inaphthyl)-N,N'-diphenyl-1,1'-biphenyl-4,4'-diamine at the interface), and produce green fluorescent light become another reason to be a good host emitter [8].

2. EXPERIMENTAL

For the preparation of Alq_3 and NPB organic layers, the indium tin oxide (ITO) glasses substrate was cut into square plates (2 cm × 2 cm). The ITO glasses were immersed in ultrasonic baths with acetone for 10 minutes. Then, the ITO glasses were rinsing in deionised water for 10 min and then blow dried with nitrogen gas. This procedure was applied to remove organic contamination and particles from the ITO surface. Thermal evaporation technique using resistively heated tantalum boats in vacuum, at a base pressure of 1.0×10^{-5} Torr was used to prepare thin film sample. Different thickness of organic layers was deposited on the ITO at a rate of 2.5 A/s at room temperature. The thicknesses of the layers were measured by Tencor P-12 Disk Profile. The PL spectra of the devices were measured by a EL spectra USB 2000 FLG Spectrofluorometer. The spectra of optical absorption measurements were made over the wavelength range of 360 nm-800 nm to obtain the energy band gap.

3. RESULTS AND DISCUSSION

3.1. Energy Band Gap

The spectra of optical absorption measurements were made over the wavelength range of 360 nm-800 nm. The variation in the absorbance with wavelength is shown in **Figures 2** and **3** for Alq_3 and NPB with varying thickness.

The optical absorption spectra of both samples, Alq_3 and NPB are similar thus the optical band gap was calculated using a well known equation as

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

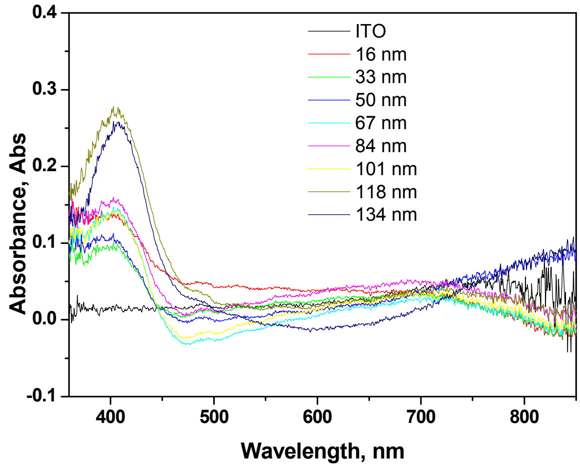

Figure 2. The optical absorption of Alq_3 at various thickness.

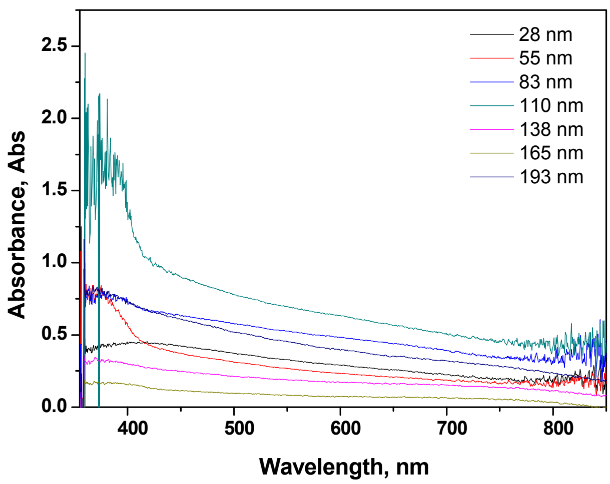

Figure 3. The optical absorption of NPB measured at different thicknesses.

where c is a constant, E_g is the optical band gap, $h\nu$ is photon energy. The energy band gap was obtained by plotting $(\alpha h\nu)^2$ as a function of photon energy, $h\nu$.

The result shows that the energy band gap for the Alq_3, is tend to be independent on the layer thickness as shown in **Figure 4**. However for NPB layers the energy band gap decreases with the increasing NPB thickness as displayed in **Figure 5**. This result can be easily correlated with the efficient hole transport in hole injection layer as discussed by Zhang Zhi-Feng *et al*. This phenomenon is due to a good balance between the injected electrons and holes in the OLED structure [9].

3.2. Photoluminescence

The photoluminescence spectra of Alq_3 were successfully measured using Ocean Optics spectrofluorometer operated at 390 nm. **Figure 6** shows the normalized photoluminescence intensity for samples at various thick-

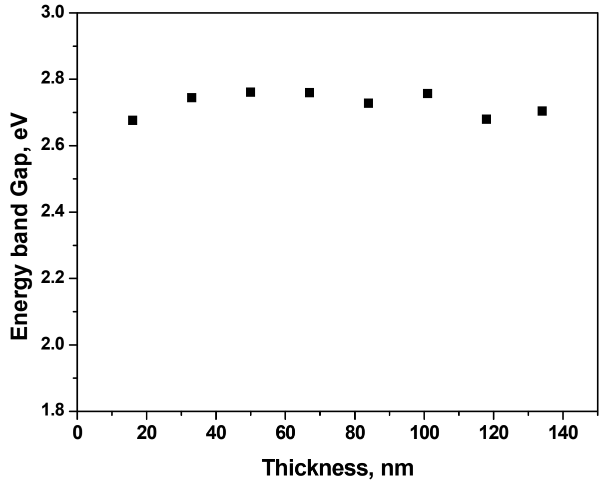

Figure 4. Energy band gap for different thickness of Alq_3.

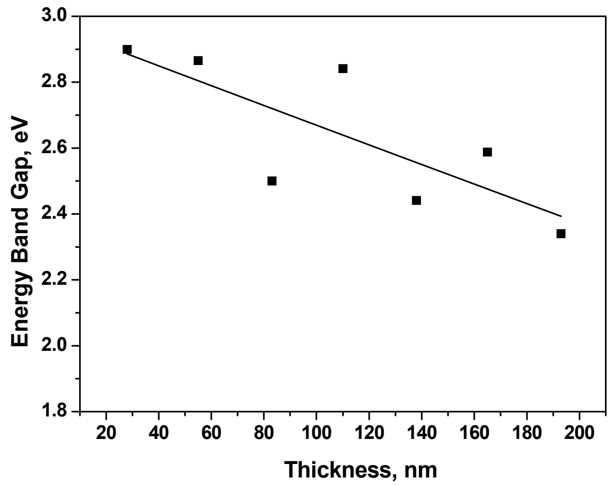

Figure 5. Energy band gap for different thickness of NPB.

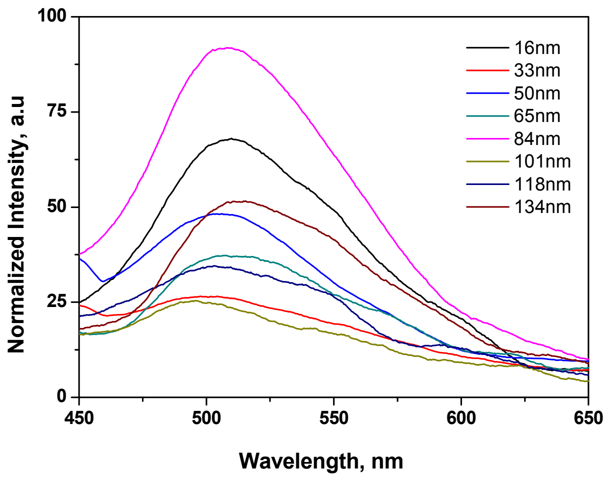

Figure 6. The PL performance with the different thickness of Alq_3.

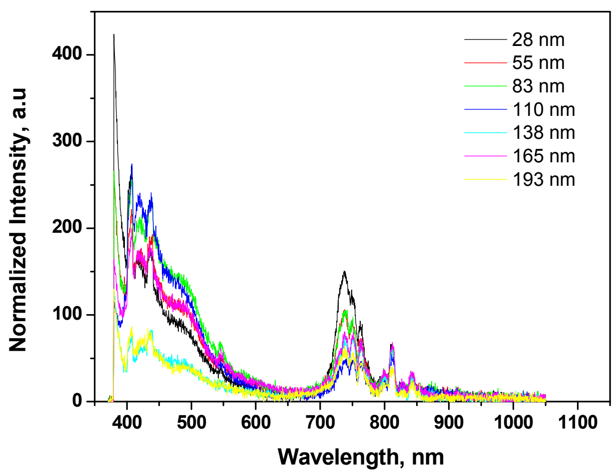

Figure 7. The PL performance with the different thickness of NPB.

nesses. It can be observed that Alq_3 with 84 nm thickness gives the highest relative intensity at emission wavelength of 510 nm. In the case of NPB layer there is no any photoluminescence phenomenon occurred as displayed by **Figure 7**. The spectra in **Figure 7** are the optical reflectance of the excitation source. However NPB layer with a thickness 110 nm gives the highest relative reflectance intensity at the peak of excitation source, *i.e.* 390 nm and 750 nm respectively.

4. CONCLUSIONS

The energy band gap of Alq_3 and NPB layers for OLED structure have successfully been measured. The NPB layer shows a thickness dependence of energy band gap while the energy band gap for Alq_3 is tend to be independence on the sample thickness ranging from 16 nm to 134 nm. As electron transport layer in OLED structure, the photoluminescence spectrum of Alq_3 was observed at 510 nm with the optimum thickness of 84 nm.

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