

## White Organic Electroluminescence Base on a new Aluminum Complex

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**ABSTRACT:** A bright blue emission material, tris{2-(benzimidazol-2-yl) pyridinato} Aluminum (**AIBIP**) used for white-light of organic light emitting devices has been synthesized. The decomposition temperature was observed at 400 °C and no melting transition ( $T_m$ ) was observed up to 400°C. For three-layer LED devices with the configuration of ITO/NPB/**AIBIP** /Alq3/MgAg, the white light emission covering the whole visible region from 400 to 700 nm with the maximum brightness of 75 cd/m<sup>2</sup> and current density of 330 mA/cm<sup>2</sup> was observed. [Journal of American Science 2009: 5(1), 83-87] (ISSN: 1545-1003)

**Keywords:** Electroluminescence; white light; device

### 1. INTRODUCTION

White organic light emitting diodes have attracted much attention, because their potential applications in the backlights of laptop computers and portable panel light sources. In the literatures, several strategies including multi-layer devices have been developed to realize highly efficient white organic electroluminescence [1-5]. Luminescent chelate complexes have been shown to be particularly useful in electroluminescent (EL) displays because of their relatively high stability and volatility. The most well-known example of such chelate compounds is Alq<sub>3</sub>, not only a good emitter but also a highly efficient electron-transporting material, where q is the 8-hydroxyquinolinato ligand [6, 7]. Via the modification of the ligand of metal chelate compound, the emission color of a metal chelate compound may be tuned. Other properties, such as thermal stability and carrier mobility, may also be improved upon. In the present work, we report the synthesis and electroluminescent (EL) property of tris{2-(benzimidazol-2-yl) pyridinato} Aluminum (**AIBIP**). The **AIBIP** containing N,N-bidentate ligand instead of N,O-bidentate

one such as 8-hydroxyquinoline. Therefore, the thermal stability, an important character for the practical application in the electronic fields, of this metal complex is investigated by thermogravimetric analysis (TGA) and differential scanning calorimetry (DSC). The organic emitting device using **AIBIP** as emitting layer has been fabricated to study the electroluminescent property of this metal complex.

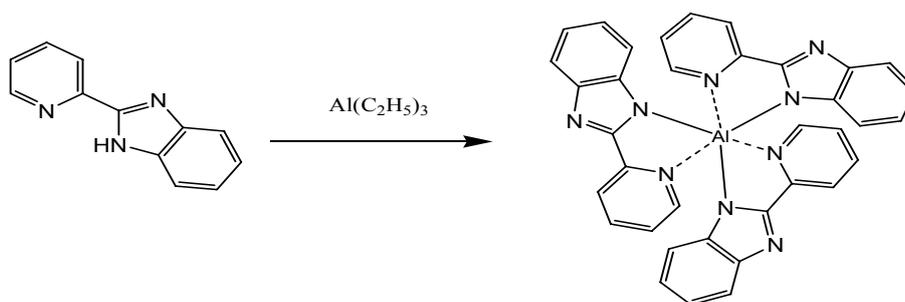
### 2. EXPERIMENTAL METHOD

The synthesis of the title compound was accomplished by following processes, as shown in Scheme 1. The triethylaluminum solution (25% w/w in hexane 1.86ml,  $2.82 \times 10^{-3}$  mole) was slowly added to 100 ml of THF solution containing 2-(2-pyridyl)benzimidazole (1.75g,  $9.0 \times 10^{-3}$  mole) at 0°C under N<sub>2</sub>. After the resulting mixture was stirred at room temperature for 6 hours, 5 ml isopropyl alcohol was added to quench the reaction. The solvents were removed under vacuum condition at  $5 \times 10^{-3}$  Torr, and the residual solid was sublimed to purify the final product. Light green of **AIBIP** was obtained in 85% yield. The formula of this compound has been determined by <sup>1</sup>H NMR and

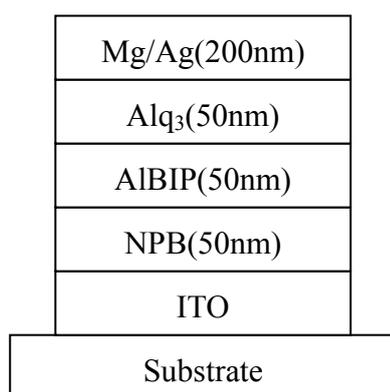
elemental analysis. The organic light emitting device, Fig. 1, using **AIBIP** as the emitting and electron-transporting layer were fabricated on the transparent conductive indium-tin oxide (ITO) glass substrate. The organic layers and the cathode were sequentially deposited by conventional vacuum vapor deposition in the same chamber without breaking the vacuum under  $3 \times 10^{-6}$  Torr. The cathode composed of magnesium silver alloy (Mg:Ag = 10:1) were deposited onto the top layer of organic materials by co-evaporation of Mg and Ag from different source. Before the deposition, all of the organic materials were purified by the train sublimation method. In the present work, the *N,N'*-bis-(1-naphthyl)-*N,N'*-diphenyl-1,1'-biphenyl-4,4'-diamine (NPB) was used as the

hole-transport material (HTM), and tris (8-quinolinolato) aluminum ( $\text{Alq}_3$ ) was employed as the electron-transporting material (ETM). The EL spectrum and the Commission Internationale de l'Eclairage (CIE) co-ordinates were measured by Pro-650 Spectroscanner (step size is 1.0 nm and bandpass is 4nm), the current-voltage (I-V) characteristic was measured by Keithley 2400 Source meter.

Thermogravimetric analysis (TGA) was performed on a Perkin-Elmer thermogravimeter (Pyris 1) under a dry nitrogen gas flow at the heating rate of 20°C/min. Glass transition temperature ( $T_g$ ) and melting point ( $T_m$ ) of materials were determined by differential scanning calorimetry of the Perkin-Elmer differential scanning calorimeter (DSC-7).



**Scheme 1.** Synthesis process for the **AIBIP** complex.



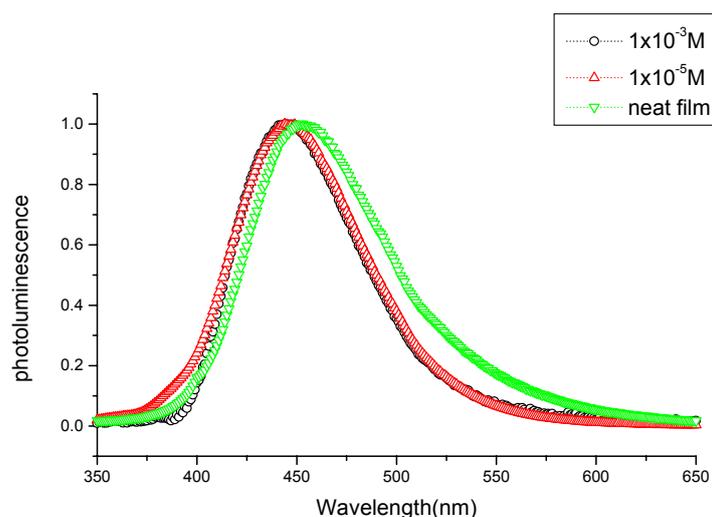
**Fig 1:** The organic light emitting device (OLED).

### 3. RESULTS AND DISCUSSION

The TGA of **AIBIP** that possesses a maximum rate of weight loss occurring at 400 °C and no weight loss was observed at the temperature lower than 350 °C. Above 600 °C, there is about 14 wt % of residue composed of aluminum ash. This aluminum complex is reasonably stable upon exposure to air and exhibited a high thermal stability in nitrogen. The melting temperature ( $T_m$ ) of **AIBIP** was not observed up to 400 °C with DSC curve. The DSC and TGA results indicate that the **AIBIP** possesses a high thermal stability, which may serve as an advantage for the fabrication of organic light emitting device because the use of the materials with high thermal stability as the active emissive layer or carrier transporting layer may provide the device with greater longevity [11, 12].

The Photoluminescent (PL) spectra of the **AIBIP** solutions and neat film, excited with 350 nm laser line, were illustrated in Figure 2. At low concentration,  $1 \times 10^{-5}$  M in DMF, only one emission band is observed with maximum at 450 nm, corresponding to the relaxation of **AIBIP** from the excited state of a single molecule into ground state. There is red shift emission band that a maximum at 460 nm is

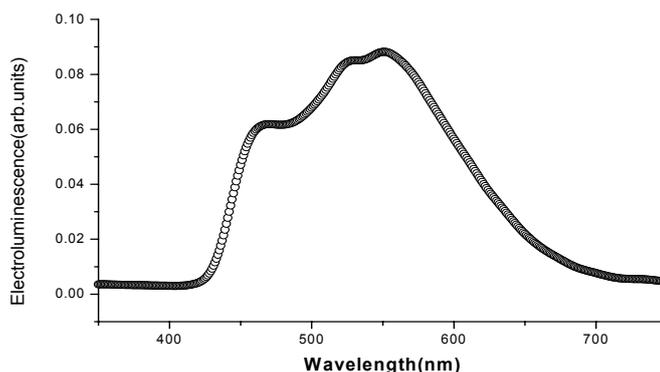
observed in the spectrum of the **AIBIP** neat film. To investigate the electroluminescent properties of **AIBIP** typical three-layer device with the configuration of ITO/NPB/**AIBIP**/Alq3/MgAg was fabricated by using NPB as the hole-transporting layer and **AIBIP** as the emitter and Alq3 is electron-transporting layer. The EL spectrum of organic light emitting device at the bias voltage of 10 V, Fig. 3, shows the broader emission bands ranging from 400 to 700 nm were observed, indicating that the three-layer LED device emitted white light covering the whole visible light region. The band around 465 nm in EL spectrum can be attributed to emission of **AIBIP**, because its emission position is almost identical with that in PL spectrum of **AIBIP**. The emission band at 525 is Alq3 emission position and 565nm can be attributed to the exciplex emission originated from the interface between NPB and **AIBIP**. The emission is almost fixed in the white region in the CIE coordinate of  $x = 0.32$   $y = 0.37$ . For the small molecular organic materials, to develop the double layer of device with white emission is very important because this kind of material is very seldom prepared so far, and it is very important for the fabrication of display panels.



**Fig 2:** Photoluminescent spectra of the **AIBIP** in solutions and neat film

The change of the spectral wavelength may be achieved also by general conception of search and design of modified materials for wide band emission consists in substitution of the backside groups by electron acceptors like halogens etc. and different kind of donors [13,

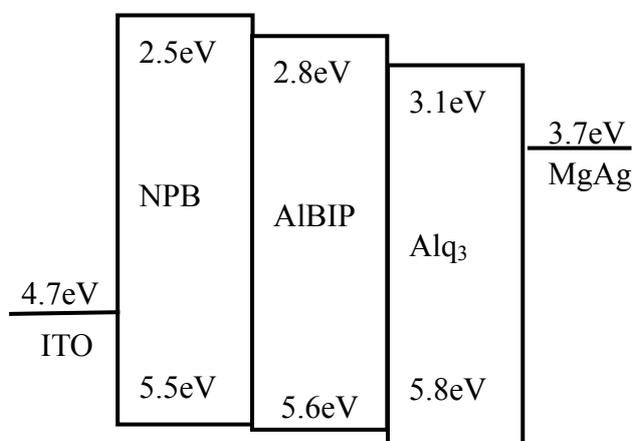
14]. At the same time important role here may play electron-vibration interactions determining the spectral broadening of the emission lines. So the future strategy of the materials design may be in this way also.



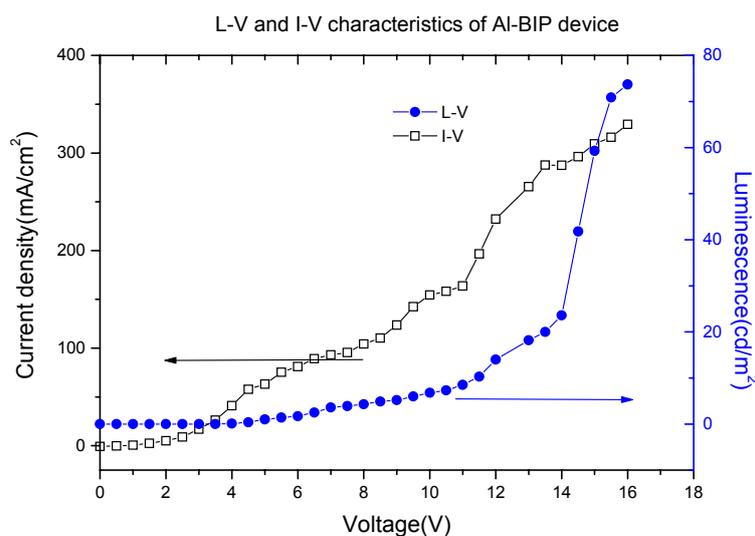
**Fig 3:** EL spectrum of OLED fabricated in this work.

Figure 4 shows the energy level diagram of the HOMO and LUMO of the different organic materials and the work function of cathode and anode. By using cyclic voltammetry (CV) method obtaining LUMO energy of **AIBIP** is 2.8eV and the optical band gap estimated from the absorption onset, we can determine the HOMO energy at 5.6eV. In Comparison with the energy level of **AIBIP** and NPB, **AIBIP** has much higher hole injection barrier than that of NPB. As a matter of fact, it is impossible for the hole injection from ITO into **AIBIP** without the assistance of NPB or some HTLs. This

diagram pointed out Alq<sub>3</sub> has lower electron injection barrier than that of **AIBIP**. Therefore, the electron injection from the MgAg into **AIBIP** will be enhanced and confines the recombination zone at the interface between NPB and **AIBIP**. Fig.5 shows the current-voltage and luminance-voltage characteristics of this device having a low turn on voltage of about 4.0V for current and luminance. This device shows a brightness of 75 cdm<sup>-2</sup> at the driving voltage of 16V with current density of 330 mA/cm<sup>2</sup>, decaying to 30 cdm<sup>-2</sup> in 120 hours.



**Fig 4:** Energy level diagram of OLED materials, ITO, and Mg-Ag alloy



**Fig 5:** Current-voltage and luminance- voltage characteristics of OLED fabricated in this work.

#### 4. CONCLUSION

A novel bright blue emission material, tris{2-(benzimidazol-2-yl)pyridinato} Aluminum (**AIBIP**), was successfully prepared by the reaction of 2-(2-pyridyl)benzimidazole and triethylaluminum. Because of its high thermal stability and excellent electrical characteristics, **AIBIP** and its related compound suggest a possible application for the use of white-light of the organic light emitting devices.

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