

## **ENHANCED PERFORMANCE OF ORGANIC LIGHT EMITTING DEVICES USING NANOCOMPOSITE SiO<sub>2</sub>:PHF AS AN EMITTING LAYER**

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### **ABSTRACT**

Polymer light-emitting diode with ITO/PHF/Al and ITO/SiO<sub>2</sub>:PHF/Al structure has been fabricated, where PHF is poly (4, 4'-diphenylene diphenylvinylene). ITO/PHF/Al has turn-on voltage at 23.0 V. The nanocomposites layer consisting of PHF and SiO<sub>2</sub> nanoparticles as an emitting layer in a single structured ITO/PHF/Al polymer light emitting diode. The nanocomposites SiO<sub>2</sub>: PHF solution was prepared by mixing 1.0 ml of PHF with 0.05 ml of SiO<sub>2</sub> colloidal solution. It was found that the spin-coated nanocomposites emitting layer has reduced the OLED turn-on voltage to 18.0 V. The calculated quantum efficiency for the ITO/SiO<sub>2</sub>:PHF/Al device is sixth time higher compared to the ITO/PHF/Al device. The investigated nanocomposites SiO<sub>2</sub>:PHF emitting layer shown to have a good adhesion and uniform surface with the anode and the cathode compare to the PHF emitting layer.

### **INTRODUCTION**

Organic light emitting diodes, OLEDs have recently gained a lot of interest in both academic and industrial fields owing to its potential applications for next generation flat panel color display [1-2]. OLEDs are thin film structures, in which organic materials are sandwiched between two electrodes. The hole and electron carriers move towards the oppositely and some of them can recombine radiatively to produce light. Generally, the injected hole is usually more mobile than the injected electron and these imbalance charges will contribute to the device inefficiency [3]. In the past two decades since single layer OLEDs were first reported by C. W. Tang et al [4], tremendous progress has been made in device fabrication and optimization such as using multi layer device structure with hole transport layer (HTL) [5] and electron transport layer (ETL) [6]. However the heterostructures build with different material such as polymer and inorganic films lead to a poor contact between the layers as the different of the layers crystalality. The poor contact in the bulk heterojunction between the inorganic nanostructure and conjugate polymer will increase the resistivity in the device that will increase the turn-on voltage, reduce the device lifetime and cause an imbalance for hole-electron recombination that will contribute to the device inefficiency. To overcome these problems many approaches such as using hole and electron injecting layer [7-8], ITO anode treatment [9] and device post annealing [10]. In recent years, there has

been increasing interest in combining the nanotechnology advances with organic devices. Uses of different organic-inorganic nanoparticles as nanocomposites in OLEDs have been reported recently to improve the OLEDs performance [11-12].

This paper reports the effect of using PHF-SiO<sub>2</sub> nanocomposites on the performance of the devices with a structure of Al/PHF/ITO where ITO Indium Tin Oxide coated on the glass substrate as an anode, PHF is poly (4,4'-diphenylene diphenylvinylene) as a blue emitting layer and Al is aluminum as cathode. The SiO<sub>2</sub> nanoparticles was used to form the nanocomposites emitting layer as it is one of the metal oxides that exhibit unique dielectric and chemical properties that can be utilized as a charge accelerator. It was found that the PHF-SiO<sub>2</sub> nanoparticles nanocomposites has reduce the turn-on voltage of the devices from 23.0 V to 18.0 V and increased the quantum efficiency of the device almost sixth time compare to the non-composite device.

## EXPERIMENTAL

The structure of the fabricated polymer light-emitting diode for the original device was ITO/PHF/Al while for the polymer-metal oxide device was ITO/nanocomposites SiO<sub>2</sub>: PHF/Al as shown in Figure 1.

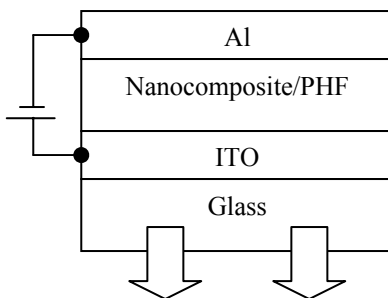


Figure 1: Structure of the OLEDs device

The nanocomposites emitting layer of PHF and SiO<sub>2</sub> nanoparticles were prepared through a direct mixing of PHF solution and SiO<sub>2</sub> nanoparticle solution. The nanoparticles SiO<sub>2</sub> solution were prepared by dissolving 0.014 gram of 50 nm nanoparticle commercial available SiO<sub>2</sub> powder in 4.0 ml of ethanol, EtOH. The solution then was stirred for 16 hours. Then 0.05 ml of the solution was dropped into 11 mg/ml of PHF in toluene. The SiO<sub>2</sub>: PHF solution was then deposited on the ITO coated glass substrate with a sheet resistance of 5  $\Omega/\text{m}^2$  using spin coating technique. The typical spinning speed and spinning time used were 3000 rpm and 40 s respectively. An aluminum layer as cathode was deposited onto the emitting layer through a mask by electron gun evaporation technique from a Molybdenum crucible at a chamber pressure of  $2.5 \times 10^{-5}$  mbar, yielding active areas of 0.71 cm<sup>2</sup>. The current-voltage of the device was measured using Keithley 238 source measure unit. The

electroluminescent spectra were measured by HR2000 Ocean Optic spectrometer at the room temperature. The devices heterostructure was studied using a Scanning Electron Microscopy, SEM at Inter-University Semiconductor Research Center (ISRC), Korea. The photoluminescence properties of the nanocomposites were measured using the Perkin Elmer LS 55 Luminescence Spectrometer.

## RESULTS AND DISCUSSION

Figure 2 shows the photoluminescence spectra of PHF and PHF-SiO<sub>2</sub> nanocomposites thin films. The shape and position of peaks for both films are almost similar, except that the intensity for nanocomposites film is higher. This indicates that the presence of transparent SiO<sub>2</sub> nanoparticles do not affected the optical properties of organic PHF polymer. However, the SiO<sub>2</sub> nanoparticles have increased the number of PHF molecules deposited in the film, since they provide more deposition surface area and this has contribute to photoluminescence increment.

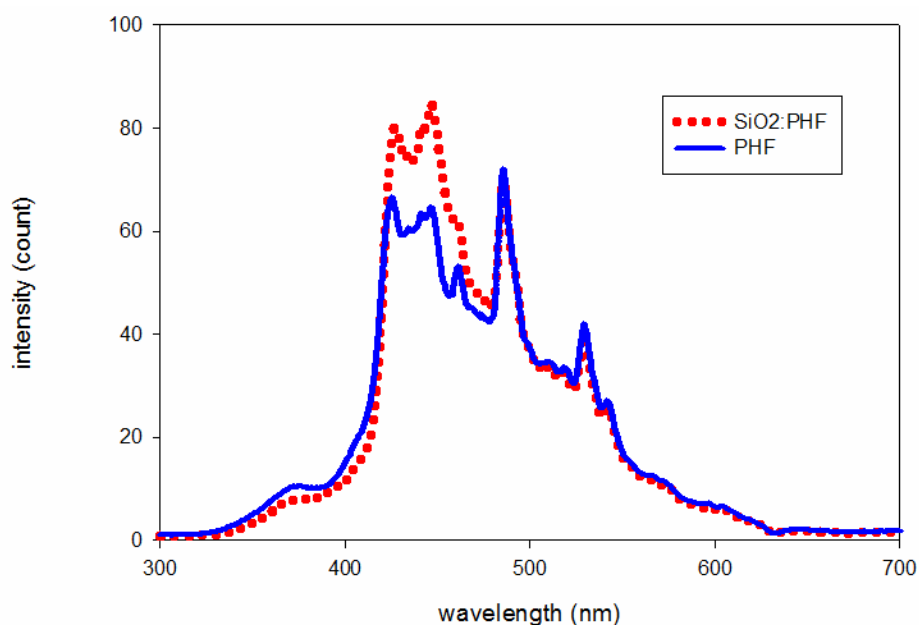


Figure 2: Photoluminescence spectra of the devices

Figure 3 shows the measured electroluminescence curves of the where the nanocomposites device has higher intensity. The measured electroluminescent showed us that the nanocomposites device had increased the electroluminescent spectra about fourth times compared to the PHF devices. The electroluminescent spectra also indicated that the presence of SiO<sub>2</sub> nanoparticles in the PHF do not give any significant change the emitted colour of the device.

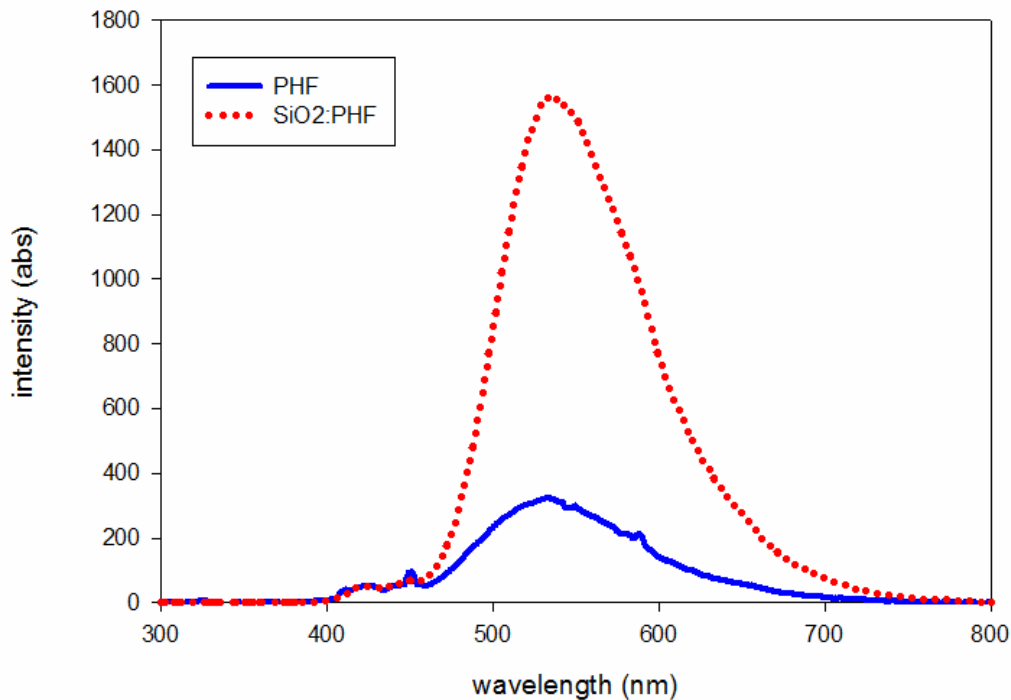


Figure 3: Electroluminescence spectra of the devices

The current-voltage characteristics of the fabricated devices in this study are shown in Figure 4. The turn-on voltage for the ITO/PHF/Al showed a turn-on voltage at 23.0 V while for the nanocomposites device showed a voltage reduction at only 18.0 V.

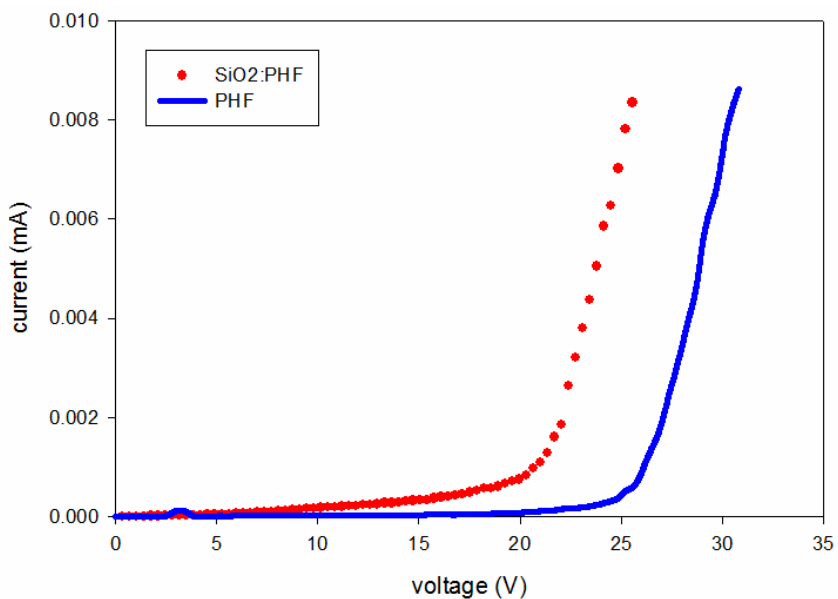


Figure 4: Current-Voltage (I-V) characteristic of the OLED devices

The quantum efficiency of the devices was obtained from the Ocean Optic HR2000 Spectrometer. The spectrometer gives out the incident flux value which will be divided into applied current to obtain the quantum efficiency. The quantum efficiency for the nanocomposites device has improved the quantum efficiency of the device from 0.2829 % to 1.2053 %.

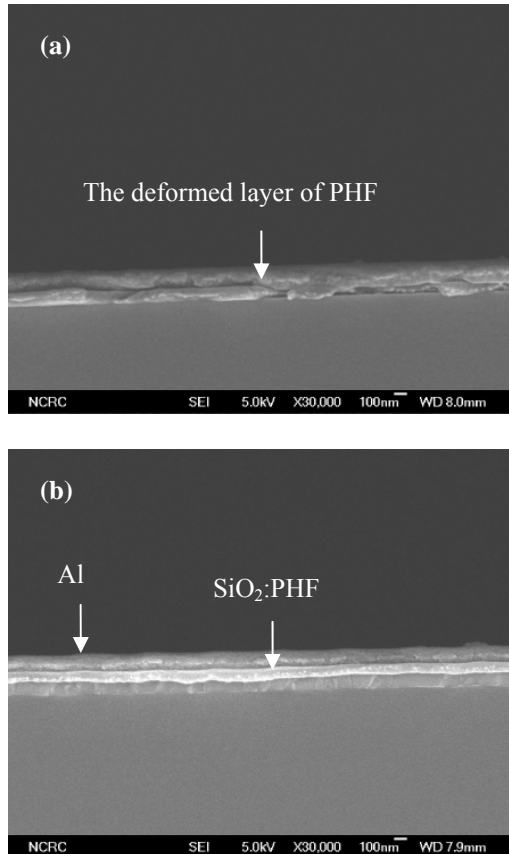


Figure 5: SEM image of (a) ITO/PEHF/Al (b) ITO/nanocomposites/Al

The SEM images show that the nanocomposite  $\text{SiO}_2$ :PHF sample has uniform formation of the emitting layer compared to the PHF sample.

We believe that the low turn-on voltage and high efficiency of the nanocomposite  $\text{SiO}_2$ :PHF device is due to the adhesion of  $\text{SiO}_2$  nanoparticles to the anode and the cathode as the smoother film will create an optimum heterojunction between the anode and cathode that contributes to optimum hole or electron injection, leading to low turn-on voltage and improved performance [11-12].

## CONCLUSION

The ITO/SiO<sub>2</sub>: PHF/Al and ITO/PHF/Al in the device structured of OLED devices have been successfully fabricated and characterized. It was found that the presence of nanoparticles will lower the turn-on voltage and improved the device performance.

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