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ENHANCED THE PERFORMANCES OF BLUE ORGANIC LIGHT EMITTING DIODE (OLED) BASED ON 4,4'-BIS(2,2'DIPHENYLVINYL)-1,1'-BIPHENYL (DPVBi).

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ABSTRACTS

Enhanced blue organic light emitting diode (OLED) has been observed from vacuum deposited of 4,4'-bis(2,2'diphenilvinyl)-1,1'-biphenyl (DPVBi) emitting material. The two-layer device structure consists of indium tine oxide (ITO)/PVK/DPVBi/Al has been studied. Here the indium tine oxide (ITO) used as anode, poly-9-vinylcarbozole (PVK) as hole transporting layer, 4,4'-bis(2,2'diphenilvinyl)-1,1'-biphenyl (DPVBi) as the blue emitting layer and Aluminum (Al) as the cathode. Optical properties of DPVBi thin film prepared from thermal evaporation technique were characterized using UV-VIS spectrophotometer. The performances of device were analyzed through current-voltage (IV) curve and the electroluminescent (EL) spectrum. The two-layer OLED device of ITO/PVK (98 nm)/DPVBi (56 nm)/Al (150nm) shows enhancement of blue light emission and better diodes behavior. The device shows blue emission at peak of 483 nm and the turn-on voltage are at 8.0 V.

INTRODUCTION

Organic light emitting diode (OLED) have attracted many interest due to it promising potential in development of full color display application. Since the discovery of organic electroluminescent material by Tang and Vanslyke in 1987 [1], it has been an active field of research in development variety of OLED color. OLED technology offers low cost manufacturing, mechanical flexibility, wide view angle and high brightness. Furthermore, these materials have low operating voltage and wide range of emission wavelength, which allowed one to realize full-color flat panel display. In other words, this technology will be quite well suited for advanced electronic display application in a few years ahead.

For full color display application, combination of red, green and blue (RGB) emitter is required [2]. These have attracted many researchers to study various types of emission characteristics, especially blue emission [2,3]. Oligomer from distyrylene derivatives (DSA) is one of the promising candidates for the blue light emitting source in organic light emitting diodes [4]. Realizations of single layer structure are very easy but their performances are very weak [5]. It was reported that by using oligomer as an emissive layer, a double-layer device with a carrier transporting layer of TPD can enhanced the blue emission [6]. Unfortunately the use of *N*,*N*'-diphenyl-

N,N'-(3-methyl)-1,1'biphenyl-4,4'-diamine (TPD) as hole transporting layer is consider unstable to environment.

In this paper, we have studied the performances of two-layer OLED device using 4,4'-bis(2,2'diphenylvinyl)-1,1'-biphenyl (DPVBi) as the emissive layer and the environmental stable material of poly-9-vinylcarbazole (PVK) as the hole transporting layer.

EXPERIMENTAL

The 4,4'-bis(2,2'diphenylvinyl)-1,1'-biphenyl (DPVBi) used as an emissive layer was purchased from American Dye Source Inc and used directly without further purification. The molecular weight of DPVBi is 510.69 g/mol with the melting point of 204.0–207.6 °C. The molecule structures of DPVBi are shown in Fig 1. Poly-9-vinylcarbazole (PVK) served as hole transporting layer with a weight–average molecular weight Mw of 1,100,000 was purchased from Aldrich Co. Inc.

For optical absorption characterization, the organic thin film was prepared on quartz crystal. While for device performance study, we fabricate a device consists of ITO/PVK/DPVBi/Al and ITO/DPVBi/Al as the comparison.

The indium-tine-oxide (ITO) coated glass as device substrates with a nominal surface resistance of 50 Ω/sq was purchased from Merck Balzers Corp. The ITO was etched and patterned to serve as anode. The substrate were cleaned in ultrasonic bath of acetone, 2-propanol and methanol, dried in a stream of nitrogen, and vacuum bake for about 20 minutes at 70 °C. The hole transport layer (HTL) of poly-9-vinylcarbazole (PVK) are deposited onto the substrate by spin coating technique. The PVK was prepared from 5.0 mg/ml 1,2-dichloroethane solution with typical spinning speed and time at 2000 rpm for 40 s, respectively.

The organic films of DPVBi were deposited by vacuum evaporation at 2.5 $x10^{-5}$ mbar using resistively heated tungsten boats. The deposition rates of DPVBi were controlled at 0.5-1 A°/sec. The thickness layer was control during deposition process using quartz vibrating system. The top electrodes of Aluminum were then deposited continuously after the DPVBi deposition without breaking the vacuum. The two-layer OLED device structure is shown in Figure 2.

The optical absorption spectra of the thin film were characterized using UV-VIS spectrophotometer. The electroluminescence (EL) device spectra were measured by HR2000 OceansOptic spectrometer and the current-voltage characteristics were measured by a Keithley 238 source measurement unit (SMU). All device measurement was carried out inside a glove box with the capability of controlling less 0.01 ppm of moisture and oxygen content.

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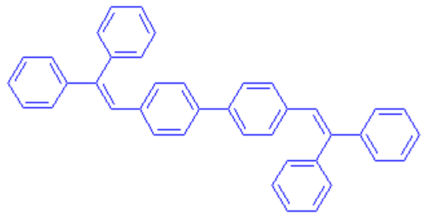

Figure 1: Molecular structure of DPVBi

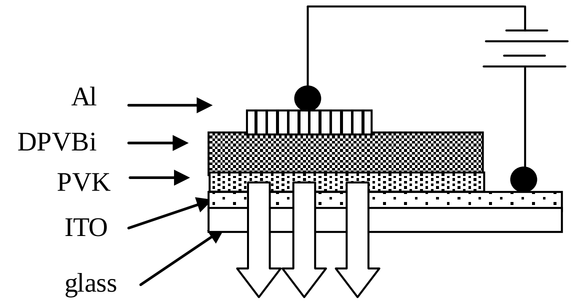

Figure 2: The double layer OLED device with ITO / PVK / DPVBi / Al structure.

RESULTS AND DISCUSSION

Single and double layer structure OLED based of DPVBi have been successfully fabricated. The thickness of the PVK and DPVBi layer that measured by ellipsometer and quartz crystal system were found to be 98.00 $\pm$ 0.01 nm and 56.00 $\pm$ 0.01 nm respectively.

The optical absorption spectrum of the PVK layer on quartz substrate showed that the PVK layer has two absorption peaks at 331 nm and 343 nm and the low absorption are in the 350 -700 nm region. Meanwhile the DPVBi layer has absorption peaks at 264 nm and 349 nm. Fig 3 shows the absorption spectrum of DPVBi thin film on quartz substrate. The films optical absorption spectra curves were used to determine the band gap of the organics, which is the energy gap between highest occupied molecular orbital (HOMO) and the lowest unoccupied molecular orbital (LUMO) of the material. The energy gap of the films can be calculated from the onset at the high wavelength end of the absorption edge [8] The calculated energy gap of PVK and DPVBi films was 3.47$\pm$ 0.01 eV and 3.10 $\pm$0.01 eV respectively. The value of the DPVBi energy gap predicted that the device can emits blue light. The light emits from DPVBi layer is secure and will not to be absorbed by the PVK since this PVK layer have higher energy gap compared to DPVBi layer.

Single layer device was fabricated in order to achieve blue color emission from DPVBi material. Unfortunately the current voltage (IV) curve and electroluminescence (EL) spectrum shows low intensity produced by single layer device. Figure 4 shows comparison of current-voltage curve of the two-layer and single layer device of ITO/PVK (98 nm)/DPVBi (56 nm)/Al (150 nm) and ITO/DPVBi (56 nm)/Al (150 nm). The current-voltage (IV) curve of device will determined the diodes behavior of the OLED device. The device with PVK layer showed a better rectifier diodes behavior compared to single layer device. The single layer device was increased its current linearly under the forward bias, but the double layer device shows diode rectifier characteristic under forward bias. It was indicated that by introducing a PVK layer, the devices improved it performance towards better diodes behavior.

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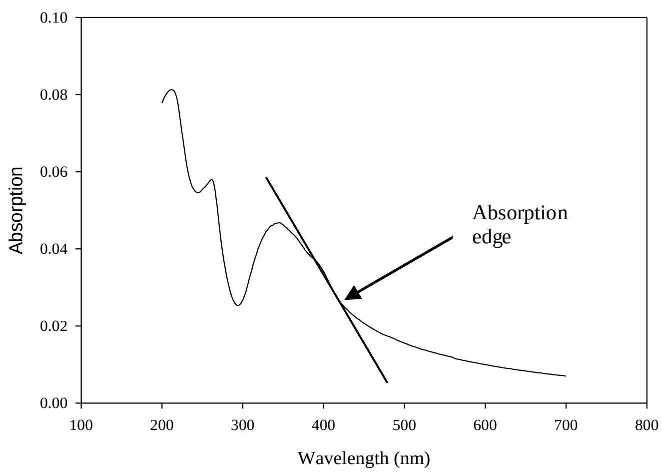

Figure 3: Absorption spectrum of DPVBi thin film on quartz substrate

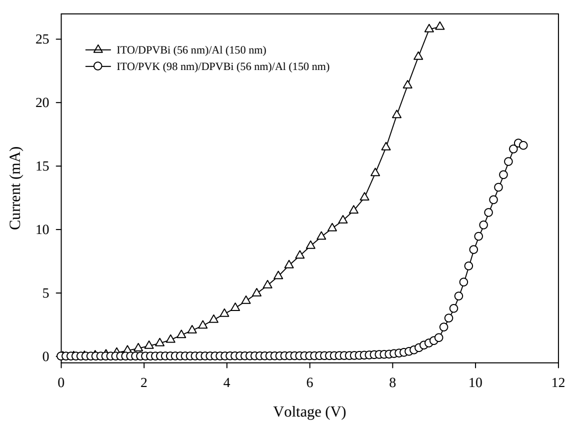

Figure 4: Current-Voltage (IV) curve for ITO/DPVBi (56 nm)/Al (150 nm) and ITO/PVK (98 nm)/DPVBi (56 nm)/Al (150 nm)

This can be explained base on the energy level related to transport and injection mechanism reported by Haskal and Parker in Fig. 5 [8,10]. Introducing PVK as a hole transport and electron blocking layer makes the electron is blocked frommoving from DPVBi into PVK [11]. Thus the electron confinement is expected to occur in the PVK/DPVBi structure [6]. This confinement will reduce dramatically by recombination of electron-hole whenever the forward bias reached the turn-on voltage at 8.0 V. While in the single layer device, the recombination is happened immediately with the increasing of applied voltage due to no electron-blocking layer that can confine the electron at interface. Thus, the single layer device will not show diode rectifier behavior in the current-voltage (IV) graph.

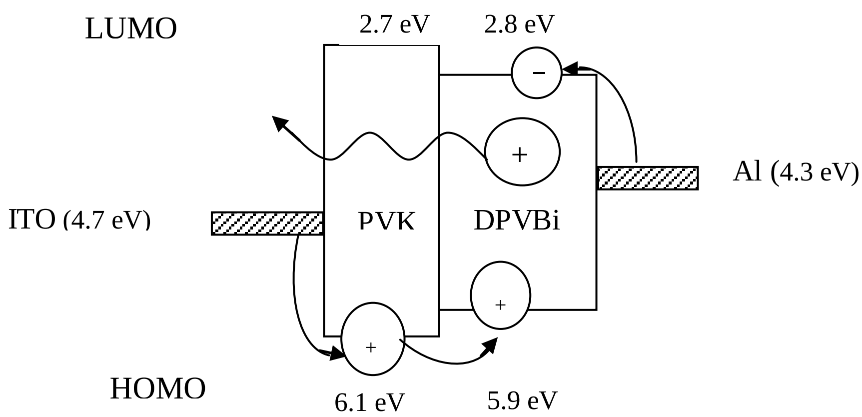

Figure 5: The energy level diagram of two-layer OLED fabricated. HOMO and LUMO data base on Haskal & Parker [8,10].

Further characterization shows same situation observed to the electroluminescence (EL) spectra. The emission of double layer DPVBi device shows higher intensity compared to single layer device (Figure 6). This observation can be explained from the charge confinement at interface layer and current-voltage rate. The confinement of the exciton at interface of PVK/DPVBi and the different current rate increased with forward bias at high field indicate a stronger magnitude of emission enhanced in two layer device compared to the single layer device [6]. As a result, the two layer structure devices are effective in enhancing the blue emission from DPVBi emitting layer.

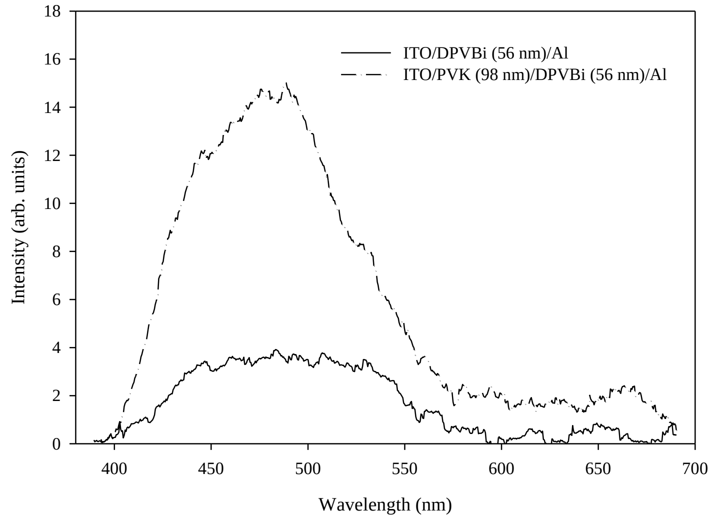

Figure 6: The emission spectrum of single and two-layer devices using DPVBi emitting layer. Both devices shows blue color at peak of 483 nm

From figure 6 also, we can see the peak wavelength are at 483 nm for both two-layer and single layer device, which is indicate the device emitted a blue color spectra. Since there is no electron transport or emitting layer such as Alq3 into which the recombination can extend, the emission were expected came from DPVBi layer [9].

CONCLUSION

In summary, device with two-layer structure of ITO/PVK/DPVBi/Al shows better OLED performances. The PVK in two-layer device gave better diodes behavior and able to enhanced blue light emission from DPVBi layer. The device shows blue emission at peak of 483 nm and the turn-on voltage are at 8.0V.

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REFFERENCES

[1] Tang, C. W., VanSlyke, S. A. 1987. Organic electroluminescent diodes. *J. Appl. Phys*. **51(12)**: 913-915.

[2] Jiang, X.Y., Zhang, Z.L., Zheng, X.Y., Wu, Y.Z., Xu, S.H. 2001. *Thin Solid Films***. 401**: 251-254

[3] Zhang, X.H., Wu, S.K., Gao, Z.Q., Lee, C.S., Lee, S.T., Kwong, H.L. 2000. **371**: 40-46

[4] Hosokawa, C., Higashi, H., Nakamura, H., Kusumoto, T. 1995. *Appl. Phys. Lett.* **67 (26)**: 3853-3855

[5] Troadec, D., Veriot, G., Moliton, A. 2002. *Synthetic. Metals*. **127**: 165-168

[6] Kajii, H., Tsukagawa, T., Okuno, H., Taneda, T., Yoshino, K., Ohmori, Y. 2001. *Thin Solid Films*. **393**: 388-392

[7] Lu, A., Jiang, Q., Zhu, W., Xie, M., Huo, Y., Chen, X., Wang, Z., Zou, D., Tsutsui, T. 2000. *Synthetic. Metals*. 111-112: 425-

[8] Parker, I.D., Pei, Q., Marrocco, M. 1994. *Appl. Phys. Lett*. **65 (10)**: 1272-1274

[9] Xie, W., Hou, J., Liu, S. 2003. *Semicond. Sci. Technol.* **18**: L42-L44.

[10] Haskal, E.I. 1997. *Synthetic. Metals*. **91**: 187-190

[11] Chung, D.H., Kim, S.K., Lee, J.Y., Hong, J.W., Cho, H.N., Kim, Y.S., Kim, T.W. 2003. *J. of Information Display*. **4(1)**: 29-44