15-2: Efficient organic light-emitting diodes with Teflon buffer layer

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Abstract

In this report, high-performance organic light-emitting diodes (OLEDs) with polytetrafluoroethylene (Teflon) buffer layer are demonstrated. Compared with conventional buffer layer, copper phthalocaynine (CuPc), Teflon film shows lower absorption in the wavelength from 200nm to 800nm. The OLEDs with Teflon and CuPc buffer layer were fabricated under same conditions, and the device performances were compared. The results indicate that when the thickness of Teflon is 1.5nm, the performance of OLEDs is greatly enhanced with an efficiency of 9.0cd/A at the current density of 100mA/cm², while the device with an optimized 30-nm-thick CuPc buffer layer only shows an efficiency of 6.4cd/A at the same current density.

1. Introduction

Organic light emitting diodes (OLEDs) have gained great interest due to their potential application as future flat panel display [1]. Up to now, many efforts have been made to improve the efficiency and the lifetime of the devices [2,3]. It was recognized that the external quantum efficiency of OLEDs depends on the carrier injection efficiency and the carrier recombination efficiency. However, enhanced carrier injection and transport to the emission region do not ensure the improved device luminous efficiency, and the balance of holes and electrons is required for obtaining high performance devices [4].

In order to further improve the device performance, a double hole-transporting layer structure has been introduced and was found to perform well [5]. It has also been demonstrated that inserting an organic conducting layer such as poly-3,4-Ethylenedioxythiophene (PEDOT) [6-8] or an insulating layer such as Al2O3 [9] and poly(methylmethacrylate) (PMMA)[10,11] at the interface between the electrode and the organic layer helps to increase the device efficiency.

Van Slyke et al. [12] demonstrated a highly stable organic device using a copper phthalocaynine (CuPc) buffer layer between the ITO anode and a hole-transporting layer of N, N'-bis-(1-naphthyl)-N, N'-diphenyl-1, 1' biphenyl 4, 4' -diamine (NPB). The insertion of a CuPc layer can improve the efficiency and the lifetime of OLEDs, but it generally results in a substantial increase in drive voltage. Recently, L. S. Hung et al. [13] managed to use plasma polymerization at low frequencies to deposit a CHF_3 buffer layer on ITO. Their devices showed superior operational stability, but the influence of CHF_3 buffer layer on the device efficiency was not reported. Besides, the fabrication process of CHF_3 was also complicated. In this work, with simple vapor deposition, Teflon film was prepared as the buffer layer, and the effect of Teflon on the device efficiency and stability has also been investigated compared with the OLEDs with CuPc buffer layer material.

Table 1 Double-layer green-emitting OLEDs structures with Teflon or CuPc buffer layer

OLED	Teflon Thickness (nm)	CuPc Thickness (nm)	OLED structure
A	0.5	-	ITO/Teflon/NPB(50nm)/Alq_3:DMQA 1%(50nm)/LiF/Al
B	1.0	-	ITO/Teflon/NPB(50nm)/Alq_3:DMQA 1% (50nm)/LiF/Al
C	1.5	-	ITO/Teflon/NPB(50nm)/Alq_3:DMQA 1% (50nm)/LiF/Al
D	-	30.0	ITO/CuPc /NPB(50nm)/Alq_3:DMQA 1% (50nm)/LiF/Al

2. Experiments

As shown in Table 1, a series of double-layer OLEDs were fabricated. Teflon of different thickness or optimized 30-nm-thick CuPc were employed as buffer layer. NPB was used as hole transfer layer (HTL), and a doped emitter layer was used with 8-hydroxyquinoline aluminum (Alq_3) as the host and N,N-dimethylquinacridone (DMQA) as the emissive dopant. Lithium fluoride (LiF, 0.7 nm) and Aluminum (Al, 200 nm) were deposited on the substrate as cathode. Prior to the deposition, the substrate was cleaned, and the organic and metal layers for the OLEDs were deposited by high vacuum (~10^{-4} Pa for Teflon and 10^{-5} Pa for others) thermal evaporation. The emission area was defined by using a shadow mask to be $0.5\times0.5cm^2$. All organic small molecular materials used for OLEDs were purified by thermal gradient sublimation before use. Device characteristics were recorded using a Keithley 4200 source measure unit for the current/voltage characteristics, and the light output from the device were measured using a calibrated photodiode. The absorption spectra of Teflon and CuPc films on quartz glass substrate were collected with UV2100S. All the measurements were carried out at room temperature.

3. Results and discussions

Compared with OLEDs with CuPc buffer layer, the OLEDs with Teflon buffer layer achieved higher brightness. (Fig.1) And what's more, the luminance of OLEDs with Teflon buffer layer increased with the thickness of Teflon varying from 0.5 nm to 1.5 nm. For example, at the voltage of 15V, luminance of OLED with

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1.5 nm Teflon buffer layer was over 50000 cd/m^2, in contrast, the brightness was only 28000 cd/m^2 for the OLED with CuPc buffer. Besides, different from the CuPc devices, the Teflon buffered OLEDs with different Teflon thickness showed almost the same turn-on voltage, which was appreciably smaller than that of the OLEDs with CuPc buffer layer.

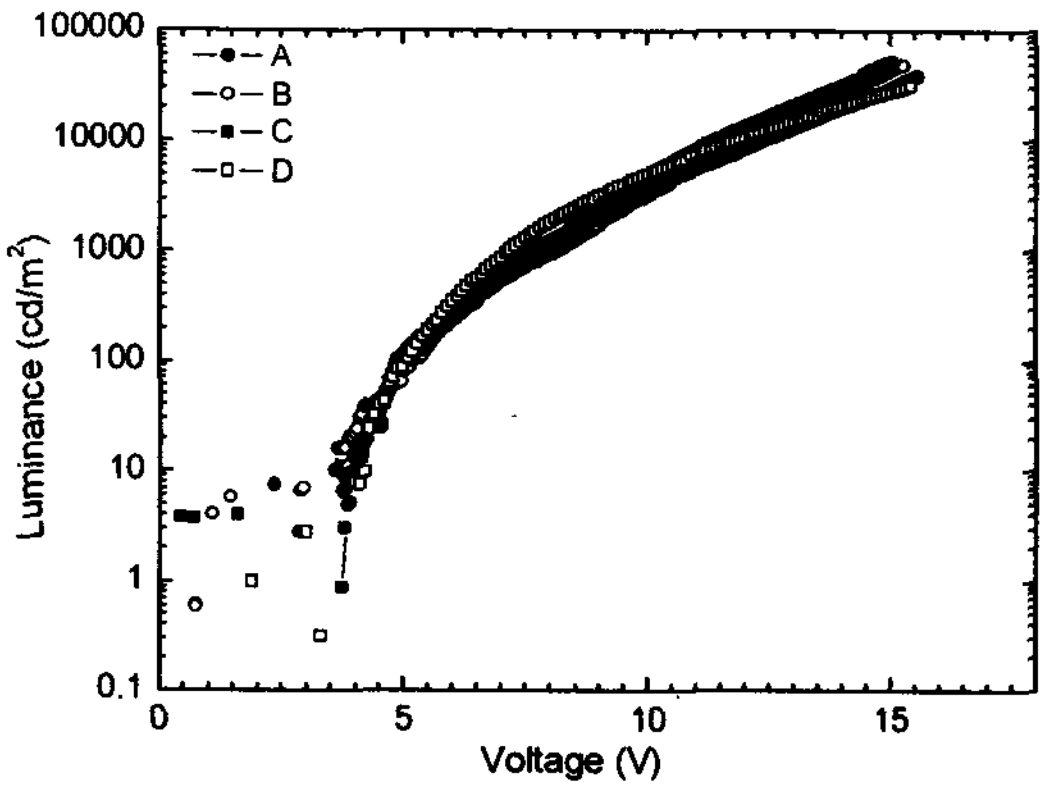

Figure 1 Luminance-voltage characteristics of the devices with the Teflon films of various thickness and the conventional device with CuPc buffer layer, the thickness of Teflon buffer layer in the three OLEDs A, B and C is 0.5nm, 1.0nm and 1.5nm, respectively. In the conventional device D, the thickness of CuPc buffer layer is optimized as 30 nm

On the other hand, experimental data from efficiency-current density characteristics of the Teflon and CuPc devices (Fig. 2) also indicated that Teflon buffer layer was useful for increasing the efficiency. When the thickness of Teflon was 1.5 nm, the performance of Teflon buffered OLEDs was greatly enhanced, obtaining an efficiency of 9.0 cd/A at the current density of 100 mA/cm^2, while the device with 30-nm-thick CuPc buffer layer only showed an efficiency of 6.4 cd/A at the same current density.

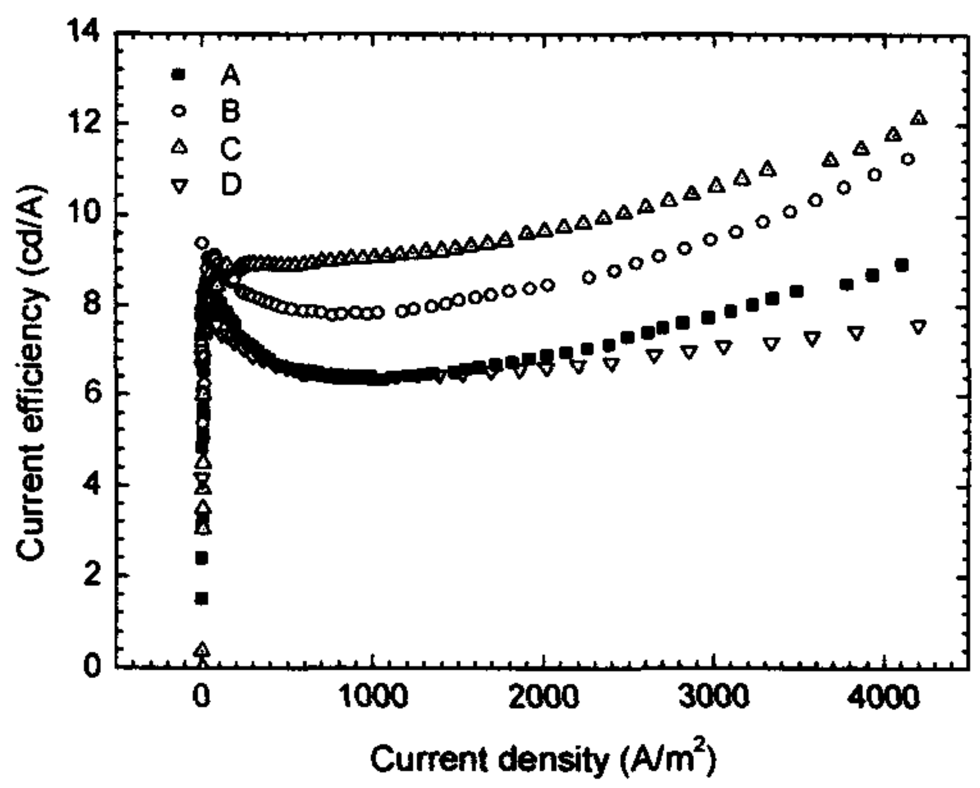

Figure 2 Efficiency-current density characteristics of the devices with the Teflon films of various thicknesses and the conventional device with CuPc buffer layer

According to above results, it can be concluded that Teflon buffer layer was more efficient, compared with CuPc, to enhance OLEDs performance with green emission. In fact, Teflon material shows a wider application potential in full color OLEDs as buffer layer. Here, the absorption spectra of Teflon film (8nm) and CuPc film (30nm) are presented in Fig. 3. It can be found that the 8-nm-thick Teflon film (much thicker than the buffer layer in our work) showed quite low absorption from 200nm to 800nm, especially much lower absorption than CuPc layer in the wavelength range of 200-400 nm and 560-760 nm. Therefore, it can be supposed that Teflon buffer layer would be more advantageous for UV emission and red emission devices application.

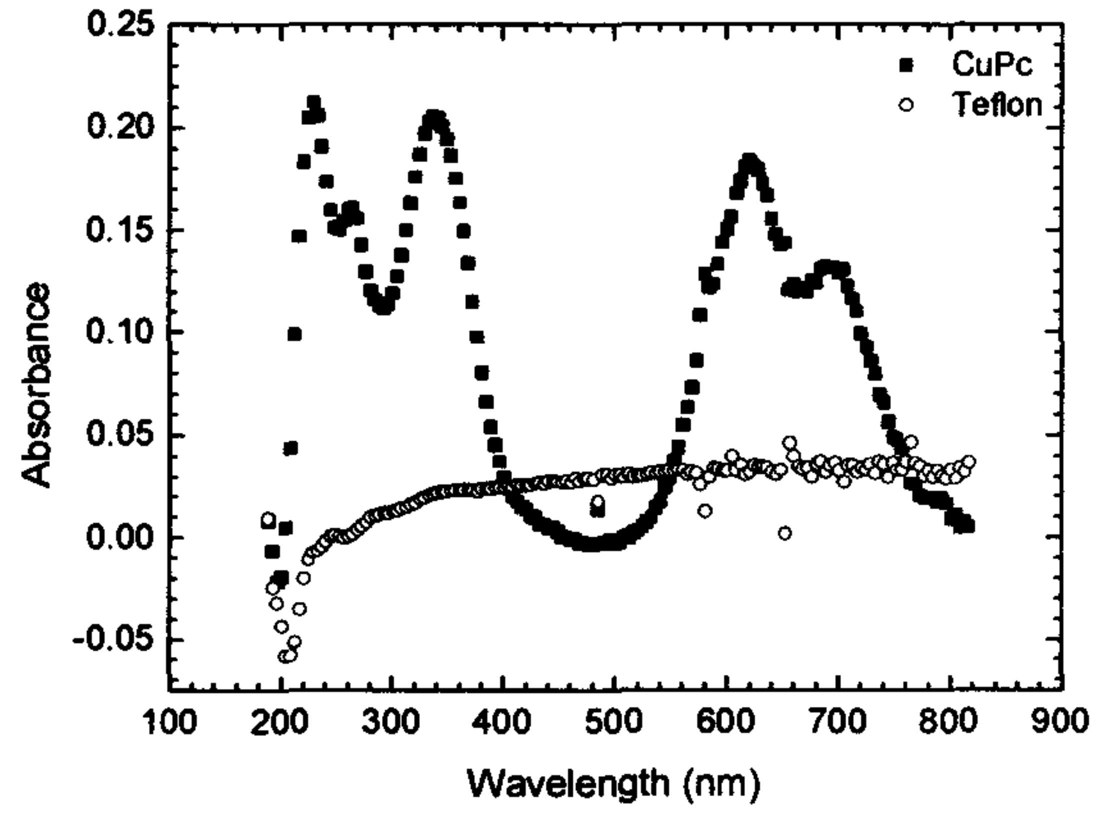

Figure 3 Absorption spectra of CuPc and Teflon layers. The thicknesses of CuPc and Teflon layers are 10.0 nm (CuPc) and 8.0 nm (Teflon), respectively. And the deposition rates are 0.04nm/s (CuPc) and 0.002nm/s (Teflon), respectively.

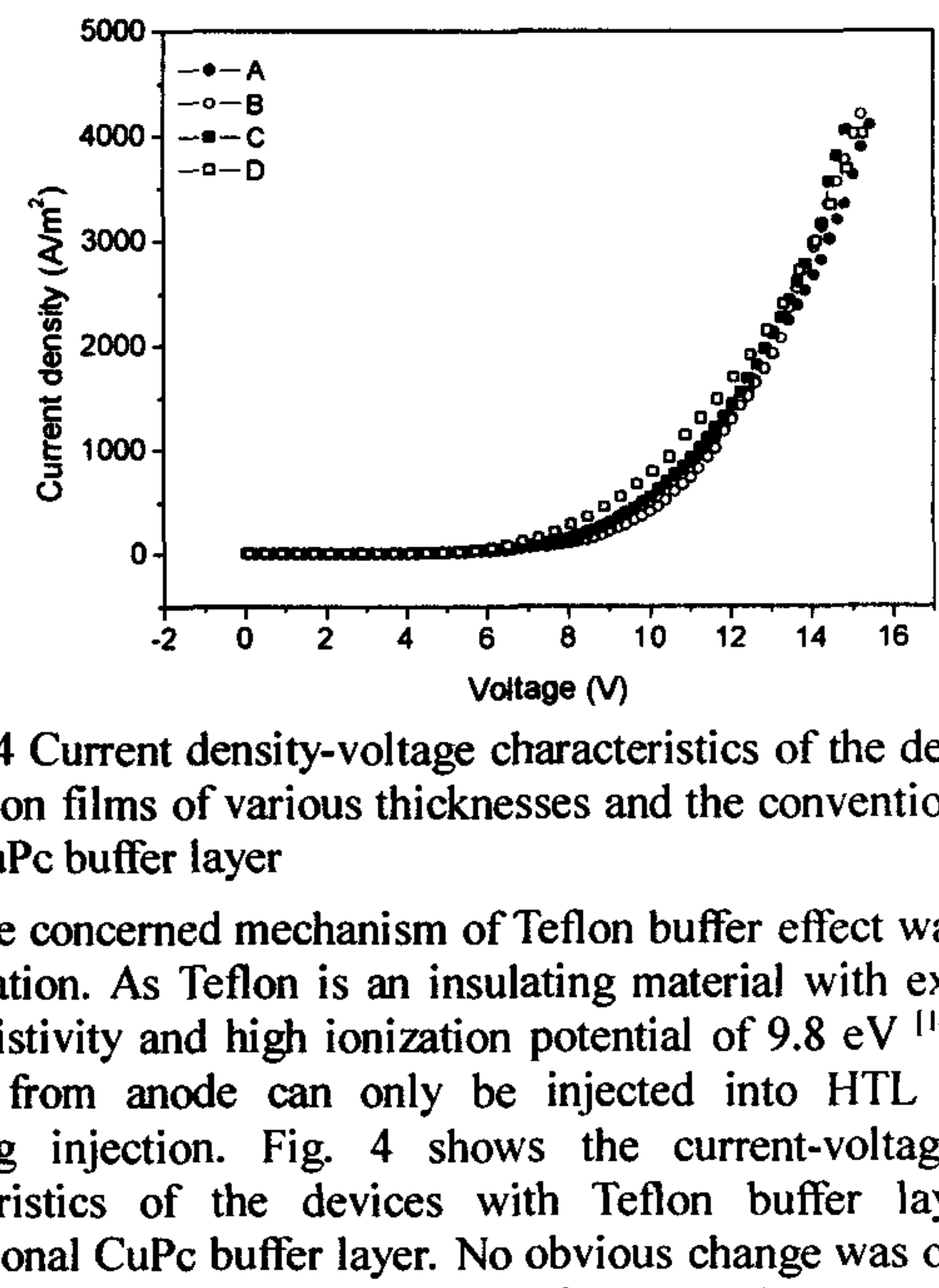

Figure 4 Current density-voltage characteristics of the devices with the Teflon films of various thicknesses and the conventional device with CuPc buffer layer

The concerned mechanism of Teflon buffer effect was under investigation. As Teflon is an insulating material with extremely high resistivity and high ionization potential of 9.8 eV [14], holes carriers from anode can only be injected into HTL through tunneling injection. Fig. 4 shows the current-voltage (I-V) characteristics of the devices with Teflon buffer layer and conventional CuPc buffer layer. No obvious change was observed by varying the Teflon thickness from 0.5 nm to 1.5 nm, otherwise the current densities of Teflon OLEDs were lower than CuPc buffered OLED. Therefore, the enhancement of performance of Teflon buffered OLEDs might be attributed to the improved balance between injected holes and electrons.

4. Conclusion

In summary, double-layer OLEDs with Teflon as buffer layer have been successfully fabricated. And the Teflon buffer layer with appropriate thickness can greatly increase the OLEDs performance, which is much better than the conventional OLEDs with CuPc buffer layer. When the thickness of Teflon is 1.5nm, an efficiency of 9.0cd/A at the current density of $100mA/cm^2$ was obtained, while the device with 30-nm-thick CuPc buffer layer only shows an efficiency of 6.4cd/A at the same current density. Moreover, it is noteworthy that Teflon would be a buffer layer material of great promise for red and ultraviolet emission OLEDs due to its lower absorption in UV and visible range.

5. Acknowledgements

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6. References

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