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SCIENCE DIRECT

Thin Solid Films 483 (2005) 346–350

thin solid films

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Investigation into the effect of LiF at the organic interface on electroluminescence

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Received 17 June 2004; accepted in revised form 15 December 2004
Available online 16 February 2005

Abstract

A novel device structure was fabricated having a LiF layer at the interface between hole-transporting layer and electron-transporting layer, such as, Indium-Tin Oxide (ITO)/poly(2-methoxy-5-(2'-ethyl-hexyloxy)-1,4-phenylene vinylene)(80 nm)/LiF(1 nm)/8-tris-hydroxyquinoline (Alq_3)(20 nm)/LiF(0.5 nm)/Al. The luminance of the above device was one magnitude higher compared with an analogue device without LiF. In order to investigate the effect of LiF at organic interfaces, another device with recombination region located at the electron-transporting layer, ITO/N,N-diphenyl-N,N bis(3-methy-phenyl)-[1-1-biphenyl]-4-4-diamine(40 nm)/LiF(1 nm)/Alq_3(40 nm)/LiF(0.5 nm)/Al, was also prepared. Spectra and performance of the two devices were measured and compared. It was found that the insertion of 1 nm continuous LiF layer between organic interfaces not only improved the electron injection but also suppressed the hole transport.

PACS: 78.60.Fi; 73.40.Ty; 73.61.Ph
Keywords: Organic electroluminescence; LiF; Interface

1. Introduction

Enhancement and optimization of charge injection and transport are very important issues in achieving bright and efficient organic light-emitting diodes (OLEDs). Much effort has been made to improve and balance hole and electron injection to the emitting layer. The use of insulating thin layers between the metal cathode and the organic/polymer layer had dramatically improved lifetimes and quantum efficiency in organic-based LEDs [1–4]. Such as the insertion of an insulating layer (typically LiF [5–8]) between the organic layer and the cathode could increase the electron injection, it was also found that an ultrathin LiF layer inserted between an anode and an organic layer could also enhance hole injection [9]. Both improved the luminance and efficiency of OLEDs. However, the effect of LiF on organic electroluminescence remains ambiguous.

In this work, we inserted a LiF layer into the hole-transporting/electron-transporting interface. A device structure was fabricated, i.e. indium-tin oxide (ITO)/poly(2-methoxy-5-(2′-ethyl-hexyloxy)-1,4-phenylene vinylene) (MEH-PPV)(80 nm)/LiF(1 nm)/8-tris-hydroxyquinoline (Alq_3)(20 nm)/LiF(0.5 nm)/Al, in which the recombination region was located at the hole-transporting layer. The luminescence observed was ten times higher than an analogue device without LiF.

In order to investigate the effect of LiF at organic interfaces, another device with the recombination region located at the electron-transporting layer was also prepared. The structure of the device is ITO/N,N-di-phenyl-N,N-bis(3-methy-phenyl)-[1-1-biphenyl]-4-4-diamine(TPD)(40 nm)/LiF(1 nm)/Alq_3(40 nm)/LiF(0.5 nm)/Al. The device performance shown is completely discrepant. As the emission region changes from the hole-transporting layer to the electron-transporting layer, the luminance from the devices with emitting region located at the electron-trans-

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0040-6090/$ - see front matter
doi:10.1016/j.tsf.2004.12.049

porting layer is reduced after inserting a LiF layer in comparison to the device without LiF. This is in contrast to the first device with emitting region located at the hole-transporting layer. Utilizing the location of the emission as a probe, we demonstrate that LiF plays a role in improving electron injection and blocking hole injection between the organic layers.

2. Experimental details

As a parallel comparison, two devices were prepared: The first one has structures of ITO/poly(2-methoxy-5-(2′-ethyl-hexyloxy)-1,4-phenylene vinylene)(MEH-PPV)(80 nm)/LiF/8-tris-hydroxyquinoline (Alq_3)(20 nm)/LiF/Al in which MEH-PPV acts as the light-emitting layer and the hole-transporting layer; the other is ITO/N,N-diphenyl-N,N bis(3-methy-phenyl)-[1-1-biphenyl]-4-4-diamine(TPD)(40 nm)/LiF/Alq_3(40 nm)/LiF/Al in which Alq_3 acts as the electron-transporting and the light-emitting layer. Two similar devices without the internal layer LiF were also prepared for comparison. The ITO coated glass substrates (with a sheet resistance of 80 Ω/□) were cleaned by detergent solution and swabbed with ethanol, which was then rinsed with deionized water. After cleaning, the substrates were dried in an oven. MEH-PPV was spin-coated onto ITO from a solution of tetrahydrofuran (THF) at a concentration of 5 mg/ml. LiF, Alq_3 and TPD layers were deposited under pressure of 10^{-3} Pa. The deposition rates were 0.1 nm s^{-1} and 0.8 nm min^{-1} for the organic and LiF layers, respectively. The thickness of LiF inserted between two organic layers was 1 nm. The deposited rate was monitored with a quartz crystal thickness monitor.

The current–voltage characteristic of the devices was measured on a Keithley Source Meter 2410. Luminance of the devices was measured using Photo Research Light Meter 650. Electroluminescence (EL) and photoluminescence (PL) spectra were obtained via a Spex Fluorolg-3 spectrophotometer.

3. Results and discussions

Four bilayer devices were fabricated in order to investigate the function of LiF at organic/organic interface. These devices were denoted as A1 and A2 for ITO/MEH-PPV(80 nm)/Alq_3(20 nm)/Al with and without LiF at organic/organic interface; and B1 and B2 for ITO/TPD/Alq_3/Al with and without LiF at organic/organic interface. Their energy level diagrams and devices structures were shown in Fig. 1. Recombination regions of the devices A1 and A2 were located at the electron-transport layer, but those of devices B1 and B2 at the hole-transporting layer.

3.1. Emitting layer at hole-transport layer

In our experiment, it is shown that the emission region of devices A1 and A2 are located at the hole-transporting MEH-PPV layer. In device A1, ITO/MEH-PPV(80 nm)/LiF/Alq_3(20 nm)/Al, 1 nm-thickness of LiF was inserted between MEH-PPV and Alq_3. Alq_3 thickness of the devices A1 and A2 were the same. The device A1 with the LiF layer showed a maximum luminance of 1207 cd/m^2, which is about one magnitude higher than the device A2 without the LiF layer. At the same time, the current density of device A1 was lower than that of device A2 driving at the same voltage (Fig. 2). This illustrates that the increase in luminance and efficiency of the device relates to the LiF layer. We attribute this improvement of device performance to the enhancement of electron injection from Alq_3 to MEH-PPV, which is caused by the interface dipole at the Alq_3/LiF interface [10]. Furthermore, the thickness of LiF inserted between two

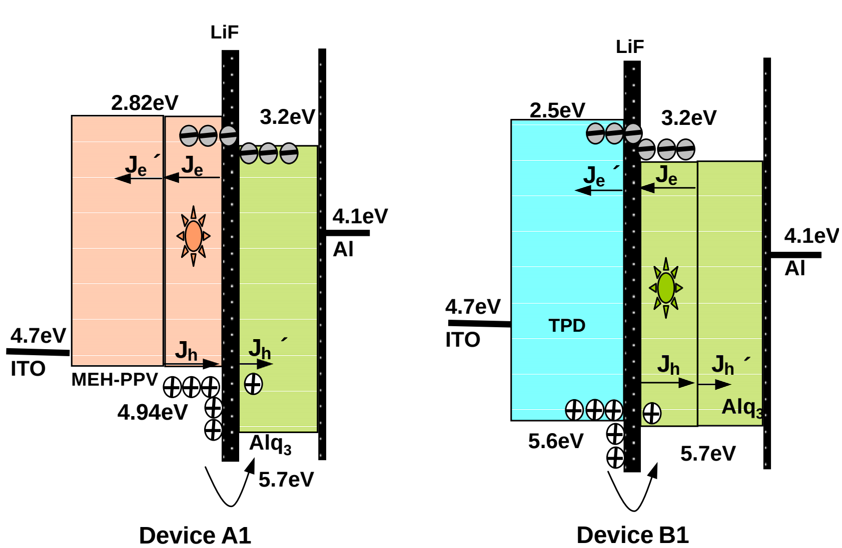

Fig. 1. The devices structure and the schematic energy level diagram.