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White Polarized Electroluminescence Devices Based on α-Sexithiophene Deposited on Oriented β-Phase Polyfluorene

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1. Introduction

The conjugated polyfluorene (PFO) polymer has been widely researched for application in organic photonic devices due to its efficient blue electroluminescence as well as good charge transport properties. Besides, it also shows liquid chystal properties allowing it to be easily oriented on a substrate to be used for the fabrication of devices that emit polarized blue light [1-3].

We have been aiming at the production of devices that emit white polarized light by combining these blue emitting oriented PFO films with the orange emiting α-sexithiophene (6T) dye by means of different thechniques. For the orientation of PFO films the friction transfer method [4] was employed. For doping 6T into these oriented PFO films one of the techniques employed was the self-developed vapor transportation method. It led to the whitening of the polarized light of the device with a significant increase of the devices' current efficiency, but an intrinsically poor control of the doping amount is a drawback of this process [5, 6]. Another technique employed was the deposition of 6T directly onto these oriented PFO films. By varying 6T thickness an excellent control of the emission color was possible, and devices with white polarized emission were produced, but these devices showed much lower current efficiency [7].

In solid state, PFO might show different conformations at room temperature. The energetically more favorable conformation is a nematic glassy phase with torsional angles between fluorene units (hereafter called N-phase PFO), and another metastable phase, *i.e.*, the one where fluorene units exhibit a more planar conformation known as β-phase PFO (hereafter called β-phase PFO). Both phases show blue emission properties and have been applied in organic devices but with significant differences in their photo physical properties. Our group has reported a significant increase in efficiency of blue emitting devices based on oriented β-phase PFO films as compared to the ones based on oriented N-phase PFO films [3].

So far most of our work on the combination of 6T with PFO for the whitening of emission has been done based on the N-phase PFO. The present work is a report on the use of oriented β-phase PFO films combined with deposition of 6T of various thicknesses to analyze the effect of the amount of the dye on the whitening and on the polarization of the emission. Comparison of photo physical properties of devices produced with N-phase PFO and β-phase PFO is also discussed.

2. Experimental

To produce the oriented thin films of PFO the friction transfer method was employed. It consists of a block of PFO being slid directly onto the substrate at well controlled temperature, speed, and load conditions. In this way the polymer molecules naturally orient themselves on the substrate, in the direction of the sliding movement, forming an oriented PFO film. Subsequent thermal treatment at 180˚C was performed to further improve orientation and surface smoothness. Rapid quenching from 180˚C to room temperature led to the formation of an N-phase PFO film. For the production of β-phase PFO the films were exposed to saturated toluene vapor for about 20 hours.

EL devices were then produced with these oriented PFO (N- and β-phase) films in the following way. After the oriented PFO films (about 50 nm thick) were prepared directly on indium-thin-oxide (ITO) coated glass substrates the samples were inserted into a vacuum chamber. Then 6T was deposited on top with (nominal) thicknesses varying from 0.5 to 6.0 nm. Subsequently 50 nm thick 2,2',2"-(1,3,5-Benzinetryl)-tris(1-phenyl-1-*H*-benzimidazole) (TPBi), which is an electron transport and hole-blocking layer, was evaporated on top of the doped films at $2x10^{-4}$ Pa. Finally, 90 nm thick magnesium-silver (Mg:Ag, 10:1) was deposited as a cathode.

For polarized electroluminescence (EL) measurements, the light was collected with a glass fiber, dispersed in a spectrograph, and detected with a charge-coupled device camera (BWTEK BTC112). The Commission Internationale d'Énclairage (CIE) chromaticity coordinates and the luminance were measured with a luminance-colorimeter (Konica-Minolta CS-100A). All measurements were performed at room temperature, without sample encapsulation.

3. Results and Discussion

Fig. 1 shows the normalized EL spectra of devices based on 6T-deposited β-phase PFO films. The peaks around 439 nm and 465 nm are from PFO while those between 500 nm and 650 nm are from 6T. It can be seen that the region derived from 6T increases with 6T film thickness. The CIE chromaticity diagram for these devices

plus the ones for 1.5 and 6.0 nm are shown in figure 2. It can be seen that white emission is obtained when 6T is about 1.5 nm thick. Similar results were obtained for 6T deposited on N-phase PFO (not shown here) but white emission was only achieved when 6T was about 3.0 nm thick.

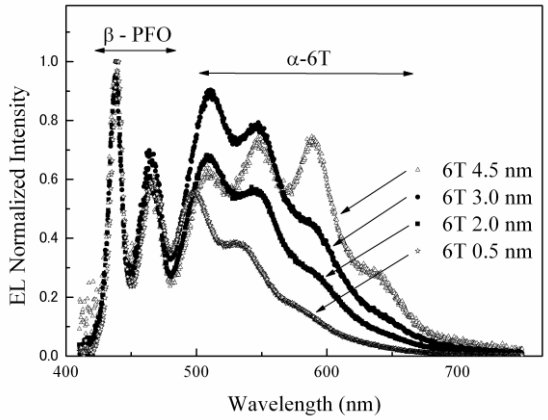

Fig. 1 Normalized EL spectra of devices based on β-phase PFO films with deposited 6T of thicknesses between 0.5 and 4.5 nm and the one without 6T.

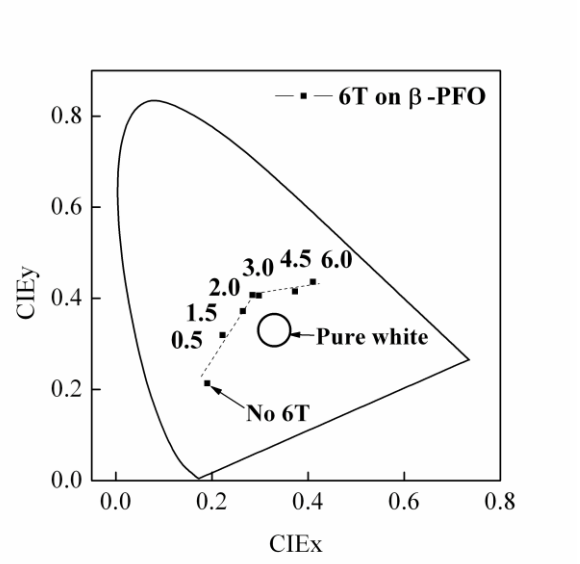

Fig. 2 CIE chromaticity diagram of devices based on β-phase PFO films with deposited 6T of thickness between 0.5 and 6.0 nm and the one without 6T.

The polarization characteristics of these devices have also been studied and figure 3 shows the polarized spectra of the white emitting device, which is based on 6T (1.5 nm)/oriented β-phase PFO film. It can be seen that, for both the PFO and the 6T regions, the electroluminescence with parallel polarization to the friction direction is much stronger that that with orthogonal polarization. Dichroic ratio, *i.e.*, the parallel component to the orthogonal component of the integrated intensities of the polarized EL ($EL_{parallel}$ /$EL_{orthogonal}$) spectra is 25 for this device. This suggests that the 6T molecules are, at least partly, oriented parallel to the direction of friction, *i.e.*, the orientation direction of the PFO layer. The dichroic ratio varies with 6T thickness but, as a general trend, it is higher for the devices based on β-phase PFO films than for those based on N-phase PFO films.

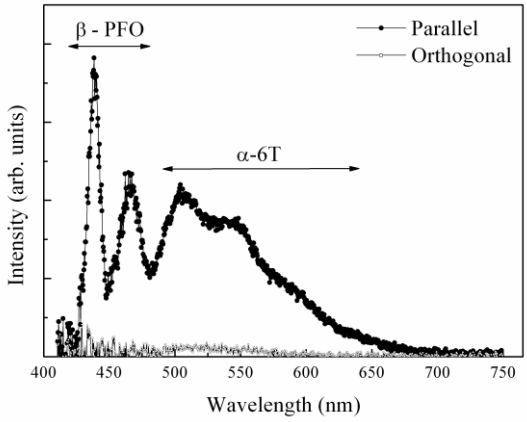

Fig. 3 Polarized spectra of a white emitting EL device based on 1.5 nm thick 6T film on oriented β-phase PFO films.

It was also observed (data not shown) that the deposition of 6T on β-phase PFO films leads to a significant increase of the luminance and current efficiency of the devices compared to those produced with N-phase PFO.

4. Conclusions

Whitening of the polarized emission of EL devices was performed by depositing orange emitting 6T onto blue emitting oriented β-phase PFO films. The excellent orientation of PFO and the, at least partial, orientation of the 6T layer on top leads to a very good polarization of the light emitted by these EL devices.

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