Effects of PEDOT-PSS layer on the characteristics of organic light-emitting diodes with Nile Red

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Organic light-emitting diodes (OLEDs) were fabricated using polymer:Poly(N-vinylcarbazole)(PVK) films, electron transport material:2-(4-Biphenylyl)-5-(4-tert-butyl-phenyl)-1,3,4-oxadiazole (PBD) as the host material and Nile Red as the dopant emission material. Organic layers were prepared by spin-coating the solution of CHCl₃ on the indium-tin-oxide (ITO) coated glasses. The effects of inserting poly(styrenesulfonate)/poly(2,3-dihydrothieno(3,4-b)-1,4dioxin) (PEDOT-PSS) layer between ITO and organic layer on the characteristics of OLEDs with Nile Red were investigated. EL spectra have two main peaks at near 430 nm and 590 nm. By inserting PEDOT-PSS layer, the emission of the peak at 430 nm increased and that of the peak at 590 nm decreased. [DOI: 10.1380/ejssnt.2005.341]

Keywords: Indium-tin-oxide; Nile Red; PVK film; OLED; PEDOT-PSS;

I. INTRODUCTION

An organic electro-luminescence (EL) device has been studying for application to a thin flat-panel display of the next generation since it was reported by Tan and VanSlyke in 1987[1][2]. It has several characters, for example, a high luminance at low driving voltage, self-luminous, etc.

Organic materials for EL devices are generally classified into two classes, the low weight molecular material and the polymer[3]. The organic EL device using the polymer is prepared by the spin-coating method, which is very simple method. The device using the polymer is superior to the one using the low weight molecular material because the spin-coating method is required neither large-scale equipment nor a high vacuum process needed for fabricating the device using the low weight molecular material. Moreover, spin-coating method makes the dye doping possible. The dye doping method is used for the change of luminescence color and the improvement of EL efficiency[4].

In this paper, organic EL devices using PVK films doped with Nile Red were fabricated and the effects of PEDOT-PSS layer on the characteristics of organic light-emitting diodes with Nile Red were investigated.

II. EXPERIMENTAL

Figure 1 shows the molecular structures of Poly(N-vinylcarbazole)(PVK), Nile Red, (2-(4-Biphenylyl)-5-(4-tert-butylphenyl)-1,3,4-oxadiazole (PBD) and poly(styrenesulfonate)/poly(2,3-dihydrothieno(3,4-b)-1,4dioxin) (PEDOT-PSS) used in this study.

The concentration of PVK and PBD in chloroform was 8.3 g/l, respectively, and that of Nile Red was changed from 0 wt.% to 0.6 wt.%. Nile Red-doped PVK thin films were prepared by the spin-coating method on the ITO coated glasses, and Al-Li (99:1 wt.%) electrodes were formed by the vacuum vapor deposition in a vacuum of 10⁻⁶ Torr. If a PEDOT-PSS layer (90 nm) was needed, spin-coating of the layer was carried out before the Nile Red-doped PVK layer was prepared.

In order to investigate the effect of a PEDOT-PSS layer as a hole injection layer on luminous characteristics, two kinds of devices described in Table I were fabricated. We describe single layer EL devices as “ITO/PVK:Nile Red,PBD/Al-Li”, and double layer EL devices with PEDOT-PSS as “ITO/PEDOT-PSS/PVK:Nile Red,PBD/Al-Li”.

Current versus voltage and luminance versus voltage

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characteristics of organic EL devices were measured using a homemade system. A GP-IB programmer was controlled through a GP-IB interface by a computer, and DC voltage was applied to the devices. Voltage, current density and output voltage from a luminance meter were taken in the computer through an Analog/Digital (A/D) converter. The emission detected by a monochromator and a photomultiplier was taken in the computer through the A/D converter. All measurements were performed at room temperature in the atmosphere.

III. RESULTS AND DISCUSSION

A. Effect of PEDOT-PSS layer on luminous characteristics

Figure 2(a) shows luminance versus voltage characteristics, and Fig. 2(b) shows current density versus voltage characteristics of the devices (ITO/PVK;Nile Red,PBD/Al-Li and ITO/PEDOT-PSS/PVK;Nile Red,PBD/Al-Li). Next Fig. 3 and Fig. 4 show EL spectra and the CIE chromaticity coordinates of the devices, respectively.

Current density increased by inserting PEDOT-PSS layer, but luminance decreased as shown in Fig. 2.
FIG. 5: Changes of the luminous and current density characteristics of the devices (ITO/PEDOT-PSS/PVK,Nile Red,PBD/Al-Li) with the Nile Red concentration.

FIG. 6: EL spectra of the devices with the Nile Red concentration

inserting PEDOT-PSS layer, the emission of the peak at 430nm increased and that of the peak at 590 nm decreased as shown in Fig. 3 and CIE chromaticity coordinates of the devices changed from (0.560, 0.403) to (0.471, 0.372).

FIG. 7: CIE chromaticity coordinates of the devices with the Nile Red concentration

B. Change of the luminance characteristics with the Nile Red concentration

The changes of the luminous and current density characteristics of the devices (ITO/PEDOT-PSS/PVK,Nile Red,PBD/Al-Li) with the Nile Red concentration (0 wt.%, 0.2 wt.%, 0.6 wt.%) were shown in Fig. 5(a) and (b), respectively. Maximum luminance was 180 cd/m² at the concentration of Nile Red (0.2 wt.%). The efficiency of the devices was shown in Fig. 5(c). The maximum efficiency of the devices was 0.17 cd/A at the concentration of Nile Red (0.2 wt.%).

Figure 6 shows EL spectra of the devices (ITO/PEDOT-PSS/PVK,NileRed,PBD/Al-Li). The peak near 430 nm decreased as the Nile Red concentration increased. The peak near 430 nm is based on PVK or PBD, and the one near 590 nm is based on Nile Red. Moreover, Fig. 7 shows the CIE chromaticity co-

Table I: The conditions of devices fabricated in order to investigate the effect of a PEDOT-PSS layer on the luminous characteristics and the characteristics of luminance-voltage-current, spectra, the dependance of Nile Red.

| Device | Nile Red [wt. %] | PEDOT-PSS |
|--------|-----------------|-----------|
| A      | 0.2             | nonexistence |
| B      | 0               | existence  |
| C      | 0.2             | existence  |
| D      | 0.6             | existence  |
ordinates of the three devices (0 wt.%, 0.2 wt.%, 0.6 wt.%). The luminescence color was changed from blue (0.234, 0.236) to red (0.549, 0.405) as the Nile Red concentration increased. It can be considered that the change took place for the increase in carriers trapped at Nile Red molecules.

IV. CONCLUSION

By inserting PEDOT-PSS layer, the emission of the peak at 430 nm increased and that of the peak at 590 nm decreased. In the devices (ITO/PEDOT-PSS/PVK;NileRed,PBD/Al-Li), the luminescence color changed from blue (0.234, 0.236) to red (0.549, 0.405) as the Nile Red concentration increased.

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