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High Efficiency White Organic Light-Emitting Diodes with Double-Doped in a Single Emissive Layer

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1. Introduction

Organic light-emitting diodes (OLEDs) have been widely recognized as a technology for flat panel display (FPD) products today and for potential future use in the lighting industry. Several approaches for developing full-color organic displays have been proposed: patterned RGB subpixels, produced by precise shadow masking [1], conversion of blue emissions with fluorescent dyes (CCM) method [2], and white emissions combined with color filters and stacked RGB cells [3]. The phosphorescent materials used were iridium (Ir) and platinum (Pt) complexes with organic ligands, and they were doped as an emissive guest into a charge-transport host material of the emissive layer [4]. In the study, we report the white phosphorescent OLEDs (PHOLEDs) with a single emissive layer doped with a blue phosphorescent material and a red material.

2. Experimental

The inset in Fig. 1 shows the structure of devices studied in this work, in which indium-tin oxide (ITO) on glass acts as an anode and the stacked LiF/Al as a cathode. ITO with a thickness of 150 nm and a sheet resistance of 15Ω/sq was used as a substrate in the PHOLED. After the substrate was loaded into an evaporation system, organic layers were sequentially fabricated at a rate 1 ~ 2 Å/s onto substrates by thermal evaporation from resistively heated tantalum boats, at a base pressure of 2 ~ 5 x 10^{-6} Torr. The evaporation rate and thickness of the film was determined using an oscillating quartz thickness monitor (Sycon STM-100). The active area of the devices, defined by the overlap of the ITO and the Al electrodes, was 0.3×0.3 cm^2. All devices were encapsulated in a dry nitrogen glove box. A single light emitting layer (EML) consisting of the 4,4'-N,N'-dicarbazole-biphenyl (CBP) host was deposited while being simultaneously doped with 8 wt% bisfs4,6-difluorophenyld-pyridinato-N,C2g (picolinato) (FIrpic), and 0.4-1 wt% [2-methyl-6-[2,3,6,7-tetrahydro-1H,5H-benzo[ij]quinolizin-9-yl!ethenyl]-4H-pyran-4-ylidene] propane-dinitrile (DCM2) via thermal co-deposition from three independent source boats.

The luminance-current density (L-J) and the current density-voltage (J-V) characteristics were measured using a Topcon SR-1 luminance meter at room temperature and an HP4156A precision semiconductor parameter analyzer. The electroluminescent (EL) spectra and the Commission Internationale De L'Eclairage (CIE) coordinates of these devices were also obtained using a Topcon SR-1.

3. Results and discussions

Figure 1 shows the J-V characteristics of white PHOLEDs. It was found that the doping concentration of DCM2 increases, the devices' turn-on voltage decreases. It means that organic phosphorescent materials, often adopted as dopants dispersed in a suitable host material, usually have high bandgap energies and good carrier transport properties. We also discuss the luminance efficiency vs. current density characteristics of white PHOLEDs as a function of the doping concentration of FIrpic and DCM2 in CBP. The phenomenon of triplet- triplet annihilation is observed at a high current density [5]. Fig. 2 shows the CIE of white OLEDs with the various doping concentration of DCM2. The device with 0.6% DCM2 concentration has the CIE coordinates of x =0,36 and y =0,39. It is highly close to the ideal white light with the CIE coordinates of (0.33,0.33). Fig. 3 shows the luminance efficiency vs. current density curves for all devices. The efficiencies of devices doped with 1 wt% DCM2, 0.8 wt% DCM2, and 0.6 wt% DCM2 are 14.7, 15.5, and 16.2 cd/A, respectively. For these devices, a gradual decrease of efficiency is observed at high current density, which has been attributed to triplet-triplet annihilation observed in all electrophosphorescent devices. We find excitons form in CBP with a ratio of 25% singlet to 75% triplet. So, the doped concentration of DCM2 is decrease, more excitons can be diffused to FIrpic device and make device's luminance efficiency arise. Because of the phenomenon, so we can know the luminance efficiency can rise a few with DCM2's decrease. Since DCM2 is a polar molecule, higher doping concentrations lead to a redshift in the emission [6] along with a substantial increase in aggregate induced quenching, which lowers the efficiency.

4. Conclusions

We have demonstrated a white PHOLED with double-doped a single emissive layer. The single emissive layer consists of 91.4 wt.% CBP, 8wt.% Firpic and 0.6wt.% DCM2, respectinely. The white OLED has a luminous efficiency of 16.2 cd/A at 4.17 mA/cm^2. The Commission Internationale de L'Eclairage (CIE) coordinates are x=0.36 and y=0.39, which close to the ideal white light with the CIE coordinates of (0.33,0.33).

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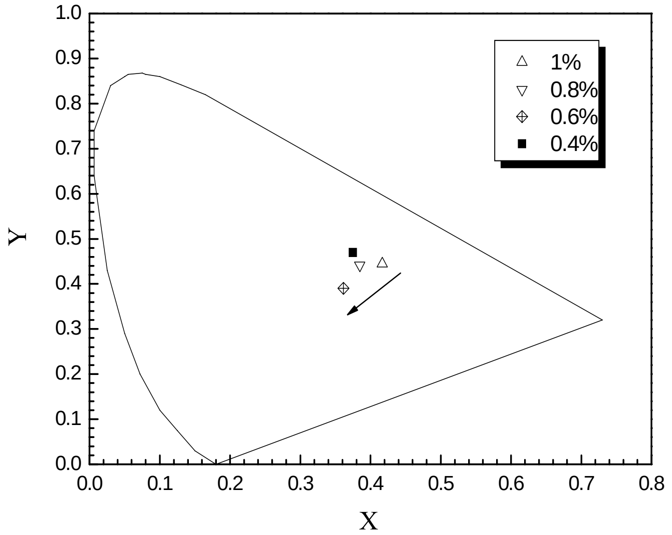

Fig. 2 CIE coordinates of white PHOLEDs.

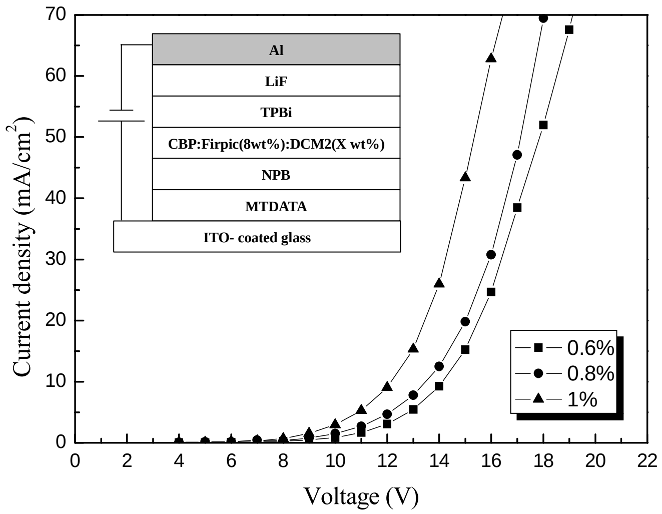

Fig 1. The current density-voltage (J-V) characteristics of the white PHOLEDs. Inset: The device's structure of the white PHOLED studied.

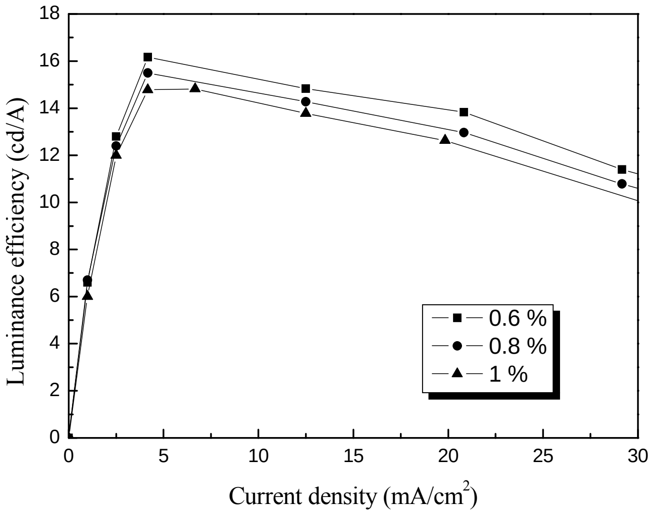

Fig. 3. The luminance efficiency-current density characteristics of the white PHOLEDs.