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Improved white organic electroluminescent devices using fine mesh as an evaporation mask ☆

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Abstract

We describe an improvement of a white organic EL devices using fine mesh as an evaporation mask. The bright white emission was obtained by controlling the ratio of emission area 4,4′-bis(2,2-diphenylvinyl)-1,1′-biphenyl (DPVBi) as a blue emitting layer and 5,6,11,12-tetraphenylnaphthacene (rubrene) as a yellow emitting layer. The device with 2,5-bis(6′-(2′-2″-bipyridyl))-1,1-dimethyl-3,4-diphenylsilole (PyPySPyPy) as an electron transport material showed maximum luminance of 20,200 cd/m^2, maximum efficiency of 11.7 lm/W and maximum external quantum efficiency of 3%. The white emission of Commission Internationale de l'Éclairage chromaticity coordinates was obtained (0.26, 0.33).

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Keywords: Organic electroluminescent devices; White emission

1. Introduction

Organic electronic materials have been used for much technological applications. One of the most interesting applications is an organic electroluminescent (EL) device with excellent properties of low driving voltage and bright emission [1–5]. To achieve a white emission, an additive mixture of three primary colors (RGB) or a complementary color relation is necessary. For example, the following types of devices are considered: (1) multilayer devices with blue, green and red emission layers, (2) doped devices with host material and blue, green and red fluorescence dyes, and (3) single emission layer device with white emission material. Kido et al. reported the white emission from dye-dispersed host polymer [3], and Kishigawa et al. reported the highly efficiency of white emission with maximum EL efficiency of 15 lm/W using an electron injection layer where a cesium metal was mixed with an electron transport material [4]. In the multilayer devices and the doped devices, however, many evaporation sources are necessary for fabrication, and the control of fabrication process is difficult. Previously, we reported simple fabrication technique to obtain the white electroluminescence using a flush evaporation method from single source of mixed materials [5] and nondoped-type white organic EL devices utilizing complementary color and exciton diffusion [6].

In this paper, we describe an improvement of a white organic EL devices using fine mesh as an evaporation mask [7]. For details, reduction of driving voltage is examined using a silole derivative with high electron mobility [8].

2. Experimental

We fabricated the organic EL devices using *N*, *N*′-diphenyl-*N*,*N*′-(3-methylphenyl)-[1,1′-biphenyl]-4,4′-diamine (TPD) as a hole-transport layer, 4,4′-bis(2,2-diphenylvinyl)-1,1′-biphenyl (DPVBi, Idemitsu Kosan) as a blue-emitting layer, and 5,6,11,12-tetraphenylnaphthacene (rubrene) as a yellow-emitting layer. The rubrene is effective for emitting layer even if it were ultra thin state [9,10]. Electron transport layer of

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2,9-dimethyl-4,7-diphenyl-1,10-phenanthroline (bathocuproine: BCP) and 2,5-bis(6′-(2′,2″-bipyridyl))-1,1-dimethyl-3,4-diphenylsilole (PyPySPyPy) were used and compared the device characteristics. The EL devices were fabricated using a conventional vacuum evaporation technique. The ITO coated glass was thoroughly cleaned using the process of scrubbing, ultrasonication, and irradiation in an UV–ozone chamber. The organic layers were sequentially evaporated on the ITO coated glass substrate. The yellow emitting layer of rubrene was deposited using a screen mesh mask. The mesh mask of brand name "alpha mesh screen" was supplied from Hitachi Maxell, Ltd. The size of the screen mesh mask was 400 meshes per inch and aperture ratios of 25%, 34% or 250 meshes per inch and aperture ratio of 37%. Bilayer of ultra thin lithium fluoride (LiF) and aluminum (Al) were used for the cathode.

The sample area was 2×2 mm^2. The current and luminance versus applied voltage characteristics were measured using a semiconductor parameter analyzer (HP 4145A) connected with a luminance meter (Topcon BM-3). The electroluminescence spectra were measured using a Spectrometer (Ocean Optics S2000).

3. Results and discussions

First, the device structure of ITO/TPD(500 Å)/meshed rubrene(10 Å)/DPVBi(150 Å)/BCP(350 Å)/LiF(8 Å)/Al(500 Å) was fabricated. Fig. 1 shows current density (J) and luminance (L) versus applied voltage (V) characteristics of device fabricated using mesh mask having aperture ratio of 34%. The device showed a maximum efficiency of 3.3 lm/W, and a maximum luminance of over 10,000 cd/m^2. The luminance of the

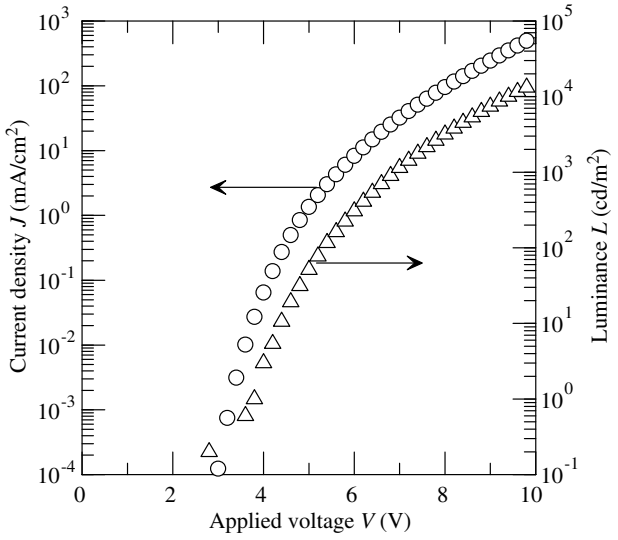

Fig. 1. Current density (circles), luminance (triangles) versus applied voltage characteristics of ITO/TPD(500 Å)/meshed rubrene(10 Å)/DPVBi(150 Å)/BCP(350 Å)/LiF(8 Å)/Al(500 Å) device.

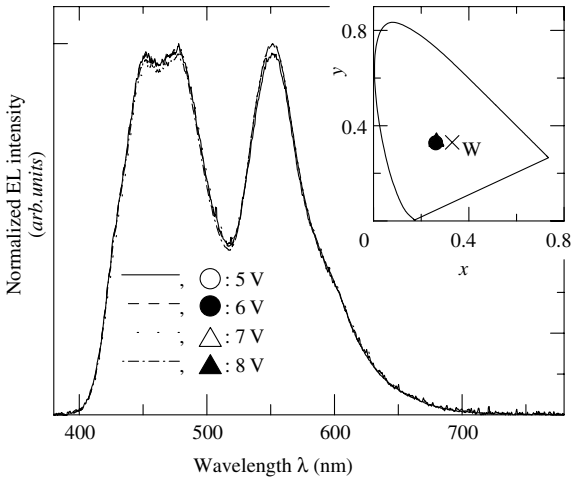

Fig. 2. EL spectra and CIE coordinates as a function of the voltage.

device was roughly proportional to the current density in the overall range. Fig. 2 shows EL spectra and Commission Internationale de l'Éclairage (CIE) chromaticity coordinates. A macroscopic white emission with CIE chromaticity coordinates of (0.26, 0.33) was obtained based on a complementary color of DPVBi (blue) and rubrene (yellow). The EL spectrum was the peak of 482 nm with shoulder of 454 nm originated from DPVBi and the peak of 554 nm originated from rubrene. The spectra perfectly were insensitive to the applied voltage, because thin rubrene layer did not affect the current density versus voltage and luminance versus current density characteristics. Fig. 3 shows a microscopic observation of emission pattern. The microscopic emission pattern like a waffle and the emission patterns were clearly influenced by the shape of evaporation mask. The stacking layers of blue (masked) and yellow (opened) areas are ITO/TPD/DPVBi/BCP/LiF/Al, and ITO/TPD/DPVBi/rubrene/BCP/LiF/Al structures, respectively. In the yellow area, the layer thickness of

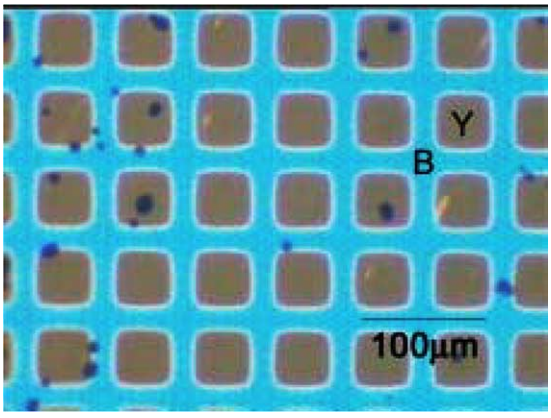

Fig. 3. Photograph of microscopic observation. Signs B and Y are blue and yellow areas, respectively.