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Excimer emission from a novel ethyne-based fluorescent dye in organic light-emitting devices

Ke-Yin Lai [a], Tse-Min Chu [a], Franklin Chau-Nan Hong [a,*], Arumugasamy Elangovan [b], Kuo-Ming Kao [b], Shu-Wen Yang [b], Tong-Ing Ho [b]

[a]Department of Chemical Engineering and Center for Micro-Nano Technology, National Cheng Kung University, Tainan, 701, Taiwan
[b]Department of Chemistry, National Taiwan University, Taipei, 106, Taiwan

Abstract

A novel ethyne-based fluorescent dye, 10-(4-Dimethylamino-phenyl ethynyl)-anthracene-9-carbonitrile (DMAPEAC), emitting orange/red light was employed as the light emission layer in organic light-emitting devices (OLED). The absorption and photoluminescence (PL) peak of DMAPEAC dispersed in methylene chloride were measured to be 480 nm and 600 nm, respectively. On the other hand, DMAPEAC (3 wt.%) dispersed in tris(8-hydroxyquinoline) aluminum (Alq_3) films deposited on fused silica exhibited two PL peaks at 600 nm and 630 nm. The extra PL peak at 630 nm was shown to be due to the excimer formation by absorption measurement. An OLED device with trilayer structure using *N,N′*-diphenyl-*N,N′*-bis(3-methylphenyl)-(1,1′-biphenyl)-4,4′-diamine (TPD) as the hole transport layer, Alq_3 doped with DMAPEAC as the emission layer, 2,9-dimethyl-4,7-diphenyl-1,10-phenanthroline (BCP) as the hole-blocking and electron-injection layer, and lithium fluoride (LiF)/aluminum (Al) as the cathode. A strong exciton energy transfer from Alq_3 to DMAPEAC was observed as revealed by the electroluminescence (EL) and PL spectra. Maximum brightness of 19,400 cd/m^2 was obtained at 16 V for the device with 1% DMAPEAC in the Alq_3 layer.

Keywords: Organic light-emitting devices; Excimer; Charge transfer complexes

1. Introduction

Since the demonstration of the first heterojunction organic light-emitting devices (OLED) in 1987 by Tang and VanSlyke [1], intense researches have been conducted on the development of OLED due to their potentials in flat-panel displays. The doping of dyes in host materials is often used to modulate the emission wavelength [2–5], enhance the device performance [6,7] and increase the device lifetime [8–10], by energy transfer from host to dye. For full-color applications, it is necessary to develop blue, green and red emitters, with excellent color purity and luminous efficiency. Among them, doping technology is particularly crucial for the red emitter due to the serious concentration quenching effect in red emission. Therefore, red emitters are rarely deposited as a separate layer. They are more often used as the dopants, and diluted in the host molecules [11]. Tang et al. [2] doped pyran-containing compounds in Alq_3 and successfully tuned the emission peak from green to orange/red (600 nm). They were the first group obtaining red OLED. Pyran-based red OLEDs have since become well known and been extensively studied [4,12,13]. Porphyrin compounds and europium chelate complexes have also attracted intense attention in the last decade [14–17]. The tremendous efforts in modifying the moiety of the above compounds have resulted in the development of new long-wavelength red emitters (>630 nm) with high photoluminescence efficiency and fine color purity. But a new series of compounds with new emission mechanism remains useful for red emission.

In this article, a new ethyne-based luminescent molecule for orange/red emission is demonstrated. Fig. 1 shows the

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* Corresponding author. Tel.: +886 62757575 62662; fax: +886 2344496.
E-mail address: hong@mail.ncku.edu.tw (F.C.-N. Hong).

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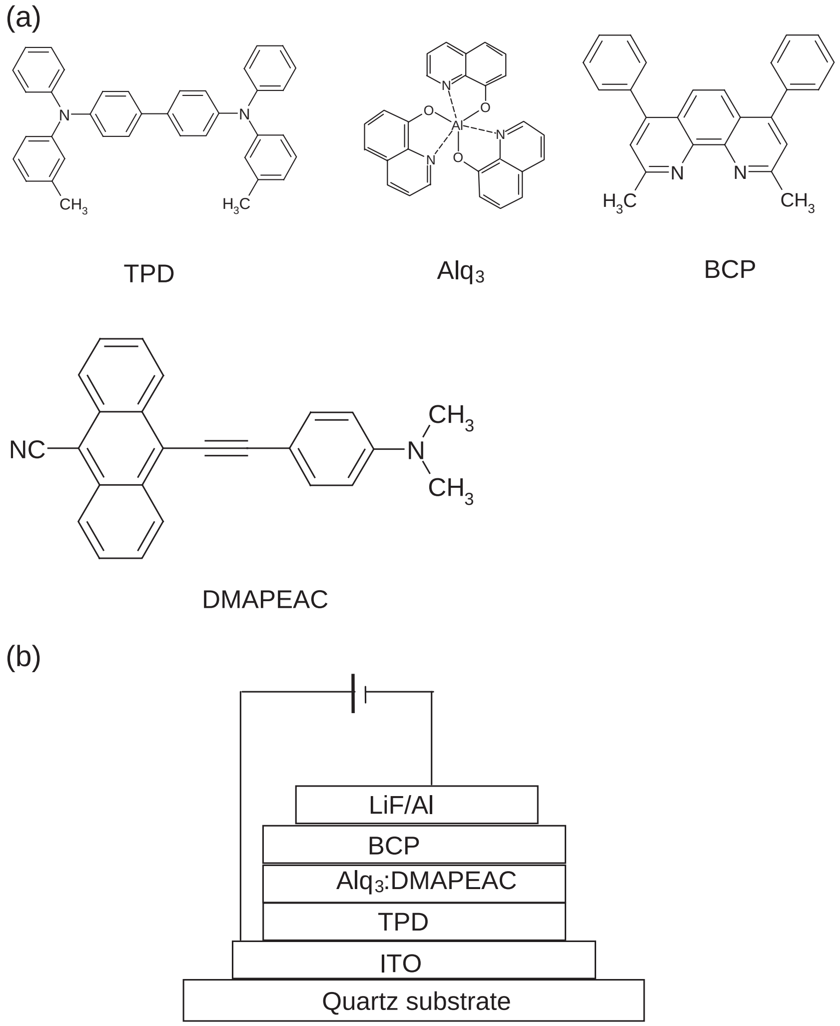

Fig. 1. The structure of OLED device and the species used in this study: TPD, Alq_3, BCP and DMAPEAC.

structure of the novel organic molecule, 10-(4-Dimethylamino-phenyl ethynyl)-anthracene-9-carbonitrile (DMAPEAC), which is different from the three series of compounds mentioned above. DMAPEAC was used as a guest molecule in a host–guest system. Energy transfer and carriers trapping behavior were studied by obtaining the photoluminescence (PL) and absorption spectra of the compound and the electroluminescence (EL) characteristics of the device. Both the emission wavelength and the current–voltage–luminescence (*I*–*V*–*L*) behavior of the device were measured.

2. Experimental details

DMAPEAC was synthesized by coupling the corresponding terminal arylacetylenes with 9-bromo-10-anthronitrile under modified Sonogashira conditions. The synthesis procedures are described in details in reference [18]. The ITO-coated glass substrate (20 Ω/□, Merck-Taiwan Corp.) was first cleaned by ethanol-impregnated paper with mechanical rubbing and then cleaned sequentially with de-ionized water, isopropanol, and alcohol. After being loaded into the plasma system with parallel electrodes, the ITO-glass substrate was first treated by oxygen plasma for around 2 min. The substrate was then transferred to a thermal vaporization system with a base pressure of 3×10^{-6} Torr. The *N,N′*-diphenyl-*N,N′*-bis(3-methylphenyl)-(1,1′-biphenyl)-4,4′-diamine (TPD) (15 nm, Alfa) and tris(8-hydroxyquinoline) aluminum (Alq_3) (50 nm, Alfa) doped with DMAPEAC were then evaporated as the hole transport and the light-emitting layers, respectively. The 2,9-dimethyl-4,7-diphenyl-1,10-phenanthroline (BCP) (10 nm, Aldrich) layer was deposited as the hole-blocking and electron-injection layer. The BCP layer was employed to confine excitons, in order to avoid exciton quenching by the cathode. Finally, lithium fluoride (LiF) (1.5 nm) and aluminum (Al) (100 nm) were evaporated as a stable cathode in air. The device structure is shown in Fig. 1. Doping in the host was achieved by co-evaporating both compounds using two independently controlled quartz crystal microbalances. The evaporation rates of the organic