Organic Electronics 50 (2017) 94–99

Contents lists available at ScienceDirect

Organic Electronics

journal homepage: www.elsevier.com/locate/orgel

Color switching behaviors of organic bistable light-emitting devices fabricated utilizing an aluminum-nanoparticle-embedded tris(8-hydroxyquinoline)aluminum layer and double emitting layers

Ji Hwan Lee [a], Yong Hun Lee [b], Dong Chul Choo [b], Tae Whan Kim [a, b, *]

[a] Department of Information Display Engineering, Hanyang University, Seoul, 04763, South Korea
[b] Department of Electronics and Computer Engineering, Hanyang University, Seoul, 04763, South Korea

ARTICLE INFO

Article history:
Received 14 March 2017
Received in revised form
30 June 2017
Accepted 13 July 2017
Available online 18 July 2017

Keywords:
Organic bistable light-emitting devices
Organic bistable devices
Organic light-emitting diode
Color switching behavior

ABSTRACT

Organic bistable light-emitting devices (OBLEDs) with an aluminum (Al)-nanoparticle-embedded tris(8-hydroxyquinoline)aluminum (Alq_3) layer and double emitting layers (EMLs) were fabricated to investigate their color switching behaviors. Scanning electron microscopy images showed that Al nanoparticles were formed on the Alq_3 layer. The Al nanoparticles in the Alq_3 layer improved the storage margin of the organic bistable devices (OBDs), and the double EMLs changed the emission color of the organic light-emitting devices (OLEDs) according to the variations of the ON and the OFF states of the OBDs. The variations of the ON and the OFF states of the OBDs could be clearly distinguished by the color switching of the OLED. The luminances of the OBLEDs with double EMLs in the ON and the OFF states were 641.80 and 22.25 cd/m^2, respectively, and their CIE coordinates at 20 V were (0.42, 0.46) and (0.51, 0.47), respectively, which corresponded to the ON and the OFF states of the OBLEDs.

© 2017 Published by Elsevier B.V.

1. Introduction

Investigations involving the development of nonvolatile organic bistable devices (OBDs) have mainly focused on improving their memory margin and long-term stability [1–5]. In addition, the operating speed of the OBDs in a series-connected dataline has been found to be smaller than that in a parallel-connected dataline [6]. Moreover, some studies concerning the bistable behavior of OBDs at the same voltage for increasing memory margin have been performed [7,8], and, in particular, OBDs with a metal-nanoparticle-embedded organic layer have been found to show memory effects [9–19]. Studies on organic light-emitting diodes (OLEDs) with field-effect transistors reported that dual-functional devices could be produced [20–23].

Furthermore, much research on organic bistable light-emitting devices (OBLEDs), fabricated by combining an OBD and an OLED, has been conducted to investigate the feasibility of controlling the optical properties of OLEDs by using OBDs [24–30]. Because the OBD and the OLED are connected in series, the OBD in the OBLED was found to be able to control the luminance intensity of the OLED. However, to date, the luminance switching performance of OBDs has not been sufficient for them to be used as bistable memory devices for controlling the OLED in the OBLEDs because of the relatively low ability to distinguish between the low-resistance (ON) and the high-resistance (OFF) states due to the small ON/OFF ratio of OBDs. When the OBD is in the ON state, sufficient current is supplied to the OLED because almost the entire bias voltage is applied to the OLED. However, because the current supplied by series-connected OBDs is relatively small, the emission intensity of the OLED is not significantly increased. Even though some studies on OBLEDs with large memory margins have been done [24–30], systematic investigations of the color switching behaviors in OBLEDs have, to the best of our knowledge, not yet been performed.

This paper reports data for the color switching behaviors of OBLEDs fabricated utilizing an aluminum (Al)-nanoparticle-embedded tris(8-hydroxyquinoline)aluminum (Alq_3) layer and double emitting layers (EMLs). Scanning electron microscopy (SEM) measurements were performed to characterize the structural properties of the Al nanoparticles embedded in the Alq_3 layer.

---

[*] Corresponding author. Department of Information Display Engineering, Hanyang University, Seoul, 04763, South Korea.
E-mail address: twk@hanyang.ac.kr (T.W. Kim).

http://dx.doi.org/10.1016/j.orgel.2017.07.023
1566-1199/© 2017 Published by Elsevier B.V.

Current-voltage (I-V) measurements were carried out to investigate the electrical bistable properties of the fabricated OBLEDs containing Al nanoparticles embedded in an Alq_3 layer. Current density-voltage-luminance (J-V-L) measurements were also carried out to investigate the electrical and the optical properties of the OBLEDs. Electroluminescence (EL) and Commission Internationale de l'Eclairage (CIE) chromaticity-coordinate measurements were performed to investigate the color switching behaviors of the OBLEDs.

2. Experimental details

The OBLEDs used in this study were fabricated on indium-tin-oxide (ITO)-coated glass substrates with thicknesses of 150 nm. The ITO-coated glass substrates were cleaned in acetone and methanol for 20 min each at room temperature by using an ultrasonic cleaner and were then thoroughly rinsed in de-ionized water. After the ITO-coated glass substrates had been chemically cleaned, they were dried using N_2 gas with a purity of 99.99% and cured using UV-ozone for 20 min. The organic layers and the metal electrodes were deposited on the ITO-coated glass substrates at a substrate temperature of 25 °C and a system pressure of 9×10^{-7} Torr.

Fig. 1 shows a schematic diagram of the OBLEDs used in this work. Two kinds of OBLED structures were fabricated to examine their luminescence intensities and EL spectra for the color switching characteristics. All OBLEDs consisted of an OBD unit and an OLED unit, and all had the same OBD unit, Al (100 nm)/Alq_3 (50 nm)/Al nanoparticles (10 nm)/Alq_3 (50 nm)/Al (100 nm), but some had different OLED units. The structure of the OLED unit for the type I OBLED was, from top to bottom, an Al (100 nm) cathode/LiF (1 nm) electron injection layer (EIL)/Alq_3 (30 nm) EML/Alq_3 (30 nm) electron transport layer (ETL)/N,N′,-bis-(1-naphthyl)-N,N′-diphenyl1-1′-biphenyl-4,4′-diamine (NPB) (40 nm) hole transport layer (HTL)/1,4,5,8,9,11-hexaazatriphenylene hexacarbonitrile (HAT-CN, 10 nm) hole injection layer (HIL)/ITO-coated glass substrate. The structure of the OLED unit for the type II OBLED was, top to bottom, an Al (100 nm) cathode/LiF (1 nm) EIL/1,3,5-tris-(N-phenylbenzimidazol-2-yl)benzene (TPBi) (30 nm) ETL/7% bis(2-phenylbenzothiazolato)(acetylacetonate)iridium(III) ($Ir(BT)_2$(acac))-doped 1,3-bis(cabazol-9-yl)benzene (mCP) (100 nm) EML/mCP (100 nm) interlayer/8% bis(3,5-difluoro-2-(2-pyridyl)phenyl-(2-carboxypyridyl)iridium(III) (FIrpic)-doped mCP (100 nm) EML/4,4′-cyclohexylidenebis[N,N-bis(4-methylphenyl)benzenamine] (TAPC) (40 nm) HTL/ITO-coated glass substrate. While the OLED for the type I OBLED contained only one EML, that for the type II OBLED had two. The double EML was employed to produce a white color by combining blue and orange colors, and each EML was connected by an mCP interlayer. The mCP interlayer prevented diffusion of the excitons generated in each EML due to the large triple-exciton bandgap of the mCP interlayer, resulting in improved luminous efficiency. The evaporation rates of all the organic layers and the cathode were approximately 1 Å/s.

The I-V characteristics of an OBD unit were measured by using a Keithley 2400 Digital Source Meter. The structural properties of the Al nanoparticles were measured by using SEM (NOVA NANO SEM 450). J-V-L, EL, and CIE chromaticity-coordinate measurements on the OBLEDs were performed in a dark box by using a spectroradiometer (CS-1000A, Minolta).

3. Results and discussion

The OBLEDs used in this study consisted of OBD and OLED units, which acted as data storage units and optical readers, respectively. The current density in the OBLEDs was controlled by using the memory states of the OBD unit. The I-V characteristics of the OBD units are shown in Fig. 2. When a forward bias voltage (V_{OBD}) was applied to the OBD, the OBD was initially in an OFF state. However, the current dramatically increased at an applied voltage of 1.1 V because of carrier trapping in the trap sites, resulting in the OBD changing from the OFF state to the ON state. When a reverse bias voltage of 4 V was applied to the OBD, the resistance state changed again from the ON state to the OFF states due to the detrapping of electrons from the trap sites. Al nanoparticles were deposited thermally on the Alq_3 organic layer, and their average size was about 20 nm, as shown in Fig. 3. Because Al nanoparticles assist in the trapping and the detrapping of electrons in the trap sites of the Alq_3 organic layer, the current state of the OBD unit can be steadily switched by adjusting the V_{OBD}. The ON/OFF ratio of the OBD unit was approximately 100.

Fig. 4 (a) and 4 (b) show voltage stress test results for the prolonged period of time to evaluate the stability of the OBD and multi cycle switching test to confirm the re-writable/re-erasable ability of the OBD, respectively. The voltage stress measurements were conducted on both the ON and the OFF states by applying a read voltage of 0.4 V above 5000 s. The currents of the OBDs were

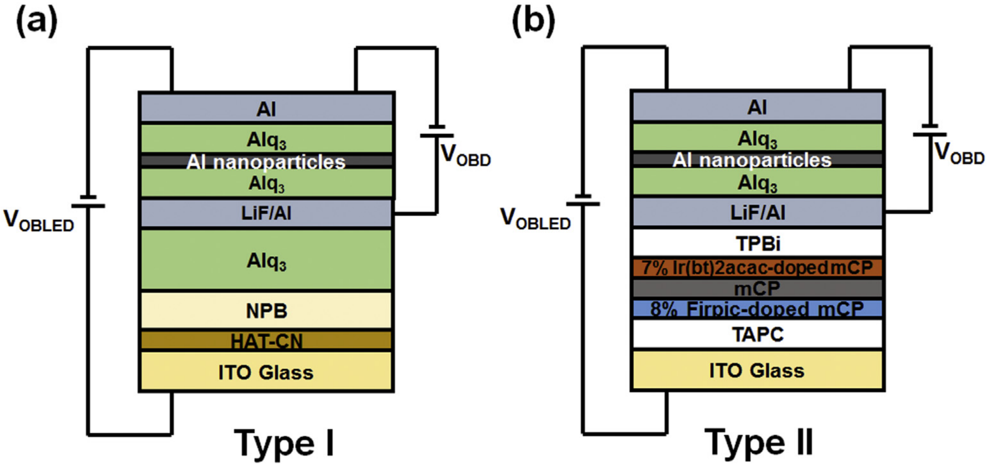

Fig. 1. Schematic diagrams of (a) type I and (b) type II OBLEDs.

Download English Version:

https://daneshyari.com/en/article/5143735

Download Persian Version:

https://daneshyari.com/article/5143735

Daneshyari.com