Journal of Luminescence 141 (2013) 106–110

Contents lists available at SciVerse ScienceDirect

Journal of Luminescence

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

Enhanced luminance for inorganic electroluminescent devices with a charged electret

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ARTICLE INFO

Article history:
Received 25 September 2012
Received in revised form
11 March 2013
Accepted 15 March 2013
Available online 25 March 2013

Keywords:
Electroluminescent (EL)
Inorganic
Powder
Electret

ABSTRACT

This work proposes a novel inorganic electroluminescent (IEL) device with an electric field built-in (EFBI) technique to reduce its driving voltage and enhance its luminance. The EFBI technique was performed by charging an electret comprising a silicon dioxide film at different temperatures (25–150 °C) in powder electroluminescent (PDEL) devices. The driving voltage of the EFBI-PDEL device decreased by 61.4 V (or 20.5%) under the brightness of 269 cd/m^2, and its brightness increased by 128 cd/m^2 (or 47%) at ac 300 V. The efficiency of the EFBI-PDEL device significantly increased by 0.827 lm/W (or 45.5%) at ac 300 V. The proposed EFBI-PDEL device has advantages of a low-temperature process and low cost, and potential for large-area display applications.

1. Introduction

Powder EL devices (PDELs) possess many advantages including wide viewing angles, wide operating temperature ranges, and inherent ruggedness [1–3]. PDEL devices are easily manufactured using a printing process, which possesses advantages including low-temperature processes, large-area producibilities, and low cost. PDEL is currently one of many potential technologies in the field of information display, and has many valuable applications in backlight units, displays, and billboards. However, the high driving voltage limits the development of PDEL devices in commercial applications. Many studies have been proposed to improve the performance of PDEL devices [4–6]. Kim et al. fabricated an alternating current inorganic PDEL device with a top-emission structure [4]. Its efficiency and brightness increased by 50% and 40%, respectively, compared with that with the bottom-emission structure. In our previous research, a carbon nanotube (CNT)-incorporated dielectric layer was introduced into PDEL devices to reduce power consumption and enhance luminous efficiency [6]. An increase of 50% in luminous efficiency was achieved after single-walled CNTs were added into the devices. This study introduces a charged electret into a PDEL device to enhance its device performance. The electret is composed of materials that can be electrically charged [7–12]. By using a thermal charging process, electrical charges can be injected into the electret and trapped in defect sites. The effects of the charging temperature and time on brightness and efficiency of the PDEL device are investigated.

2. Experimental methods

The fabrication process of the proposed PDEL device, called the electric field built-in (EFBI)–PDEL device, is divided into three parts: the top substrate process, the bottom substrate process, and the EFBI process. The top and bottom substrates were combined and sealed to form the EFBI-PDEL device. The detailed fabrication processes are as follows:

This experiment used flexible transparent substrates (polyethylene terephthalate, PET) as the top and bottom substrates. An indium-tin-oxide (ITO) film with a thickness of approximately 180 nm was first sputtered on the top substrate. A ZnS-based phosphor (DuPont LuxPrint 8150L paste) was then coated by using screen printing, and then baked at 130 °C for 10 min. The thickness of the phosphor layer was approximately 40 μm. Finally, a dielectric layer ($BaTiO_3$, DuPont LuxPrint 8153 paste) was coated on the phosphor layer by using screen printing, and then baked at 130 °C for 5 min. The thickness of the dielectric layer was approximately 14 μm. Fig. 1(a) and (b) shows the cross-section and plane-view SEM photographs of dielectric/phosphor layers. The particle sizes of the phosphor and dielectric layer are approximate 15 ± 3 and 0.6 ± 0.2 μm. In the bottom substrate process, an ITO film was deposited by radio frequency (RF) sputtering. Thereafter, silicon nitride (SiN_x) and silicon oxide (SiO_x) thin films were deposited

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http://dx.doi.org/10.1016/j.jlumin.2013.03.020

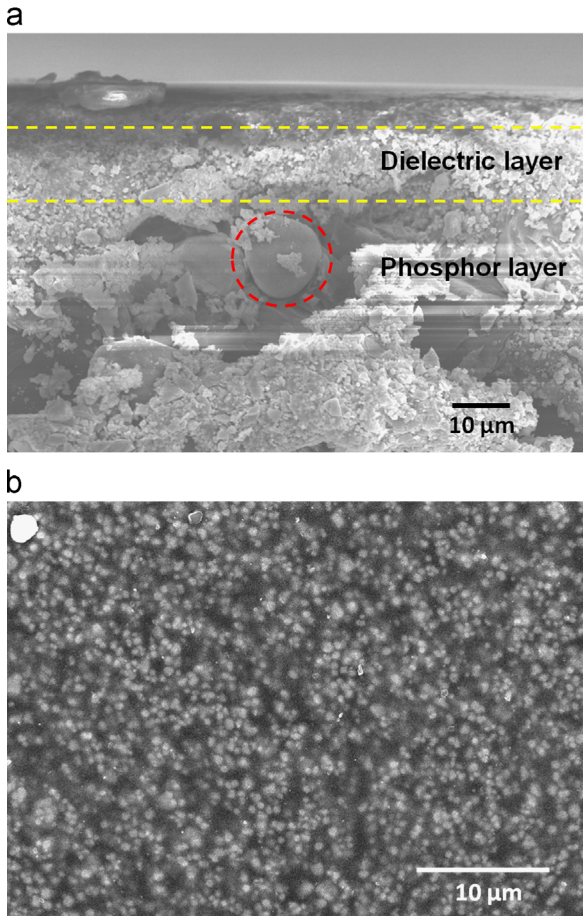

Fig. 1. (a) cross-section and (b) plane-view SEM photographs of dielectric/phosphor layers.

continuously by using plasma-enhanced chemical vapor deposition (PECVD) as a charge protection and an electret layers, respectively. The deposition temperature was 130 °C, and the RF powers were 340 W and 300 W for the SiN_x and SiO_x films, respectively. Fig. 2 exhibits the cross-section SEM photograph of the SiO_x/SiN_x/ITO thin films. The thickness of the SiO_x/SiN_x/ITO thin films are approximate 160/250/180 nm. The equivalent dielectric constant of SiN_x+SiO_x film measured from the capacitance-voltage characteristics was 4.9. The area of the devices is 4.25 cm × 4.25 cm. This experiment uses a corona charging system to charge the electret, as shown in Fig. 3. The charging process was divided into three steps: (1) pre-annealing at 50 °C for 10 min, (2) thermal charging at a temperature of 25–150 °C for 5–30 min, and (3) post-annealing at 50 °C for 10 min. Heating in the charging process could increase the opportunity of charge trapping in deep-level defects, and hence, enhance the accumulated charges in the electret [13]. The charging ambient air was at a pressure of approximately 760 Torr. The distance between the grid and the SiO_x layer was 10 cm, and the space between the corona bar and the grid was 5 cm. The voltages of the charging bar and the grid were 15 kV and 2 kV, respectively. After charging, the top and the bottom substrates were bonded together using a lamination machine to complete the device process. The luminance was measured by a luminance colorimeter (KLEIN, K8).

3. Results and discussion

The structures and equivalent circuit models of the traditional PDEL device and the proposed EFBI-PDEL device are shown in

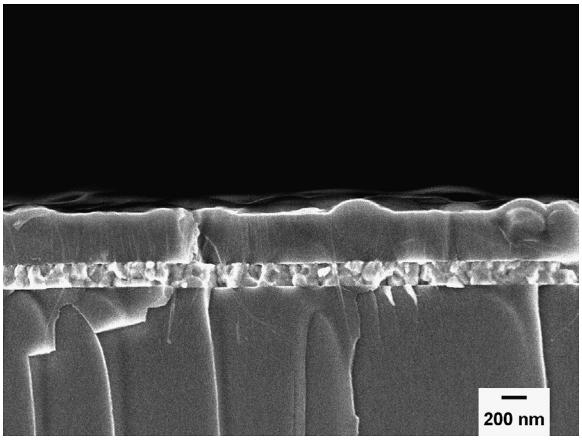

Fig. 2. The cross-section SEM photograph of the SiO_x/SiN_x/ITO thin films.

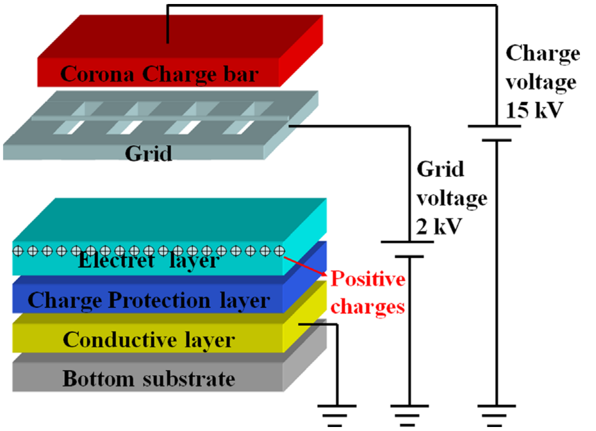

Fig. 3. Schematic diagram of the corona charging system used in this study.

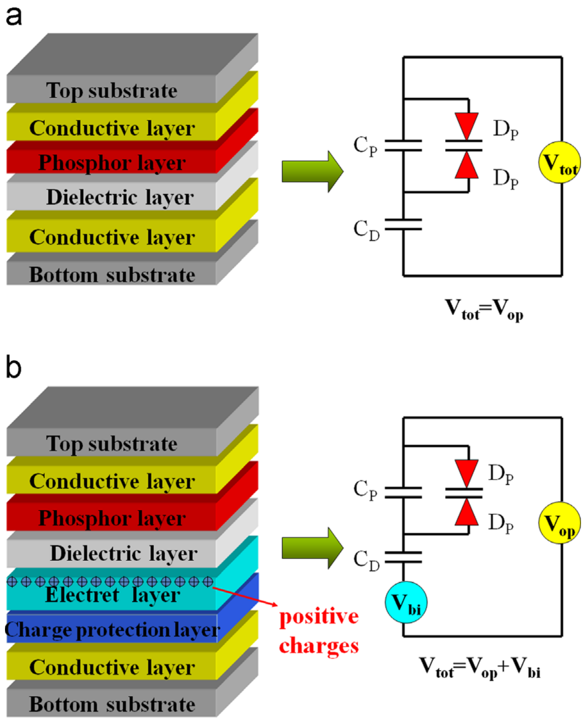

Fig. 4. Schematic structures and device circuit model of the traditional PDEL device and the proposed EFBI-PDEL device.