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Research Article

An Analysis of ZnS:Cu Phosphor Layer Thickness Influence on Electroluminescence Device Performances

Pakpoom Chansri,[1] Somchai Arunrungrusmi,[1] Toshifumi Yuji,[2] and Narong Mungkung[1]

[1]*Plasma and Electrical Discharge Laboratory, King Mongkut's University of Technology Thonburi, Bangkok 10140, Thailand*
[2]*Faculty of Education, University of Miyazaki, Miyazaki 889-2192, Japan*

Correspondence should be addressed to Narong Mungkung; narong_kmutt@hotmail.com

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Electroluminescence (EL) device is a new technology; its thickness is within micrometer range which can bend more easily and emit light. However, the thickness of ZnS:Cu phosphor layer may affect the light intensity, so we have analyzed the thickness of ZnS:Cu phosphor layer on EL device. The EL devices consist of ITO:PET/ZnS:Cu phosphor/insulator ($BaTiO_3$)/Ag electrode. The EL devices were fabricated in changing thickness 10 μm, 30 μm, and 50 μm. At 100 V 400 Hz, the luminance of EL devices was 51.22 cd/m^2 for thickness 30 μm more than that of 45.78 cd/m^2 (thickness: 10 μm) and 42.58 cd/m^2 (thickness: 50 μm). However, the peak light intensity was achieved at wavelength of 507 nm which was not influenced by the thickness of the ZnS:Cu phosphor. The use of the ZnS:Cu phosphor layer at thickness 30 μm in the EL device significantly improves the luminescence performance.

1. Introduction

The light-emitting devices such as LCD (liquid crystal display), LED (light-emitting diode) and OLED (organic light-emitting diode), ECL (electrochemical luminescence), and EL (electroluminescence) [1–6] are very popular and widely used in commercial. The fabrication of these devices is difficult for large-area light-emitting devices, in which the vacuum evaporation processes are vacuum-evaporated by drying at high temperature. The organic materials were heated by vacuum evaporation causing the deformation of the molecular structure and a reaction between molecules [5]. Electroluminescence (EL) devices are one choice for the display application. It is a new technology and is the emission of light from a phosphor material layer when an electric current is passed through it [7–11]. EL devices are thin and can bend on the device. It was widely used in display advertise, brightness, and low current. The EL device consists of the dielectric (light-emitting phosphor) layer and two electrode overlapping layers. The structure of the EL devices is the same as a capacitor [12].

For EL devices, the voltage applied is about 100–500 V and frequency is about 400–800 Hz. The electric field flows through the phosphor layer causing the distribution of phosphor material [13] and collision electron fast transfer between the electrode which is based on frequency [14–18].

The light-emitting phosphor material had been developed by researchers such as ZnS:Cu, ZnS:Cu,Cl, ZnS:Mn, and another phosphor material [17–23]. The researchers had researched on EL devices which can explain the following literatures. Han et al. [24] synthesized ZnS:Cu,Cl phosphors with the coating TiO_2 for EL panel that was showing yellow-green color emission. Kim [25] investigates the effect of EL performance by using ZnS:Cu,Cl phosphor powder that was used as emitting organic dye [(phosphor + coumarin 6 (C6)]. High EL intensity performance and response of bluish-green color was found. These researches investigate not the thickness of phosphor layer causing short-time stable. The thick film of light-emitting phosphor layer has importance to luminance performance which may affect to the thickness of light-emitting phosphor layer.

In this paper, we present the optimized thickness of phosphor layer for EL device by screen printing coated on

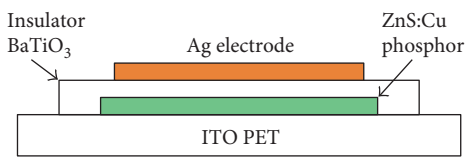

Figure 1: The structure of EL device using ZnS:Cu phosphor.

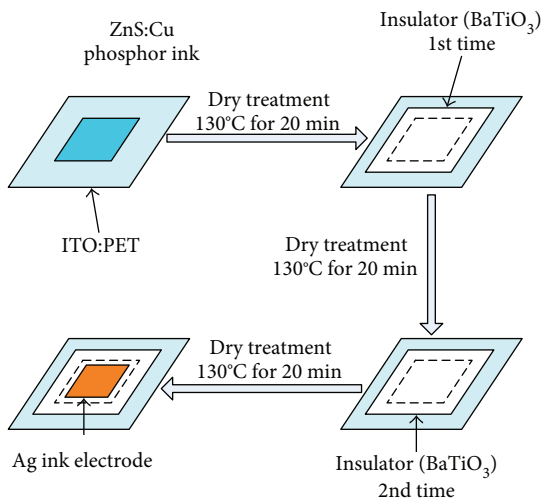

Figure 2: The process of EL device using ZnS:Cu phosphor.

plastic electrode transparent (PET). The phosphor uses ZnS:Cu powder which responded to green color emission. The result of electrical and luminance properties is confirmed to a performance of the EL device. The condition thickness of phosphor layer for EL device is significant to light intensity efficiency.

2. Experimental Setup

Figure 1 shows schematic diagram of EL device which consists of ITO:PET/ZnS:Cu phosphor/insulator ($BaTiO_3$)/Ag electrode. The thickness of ZnS:Cu phosphor was prepared 10 μm to 50 μm. The ZnS:Cu phosphor ink was fabricated by ZnS:Cu phosphor powder at 20–32 μm of resolution (ZnS:Cu phosphor; Osram Sivanier) and binder ink (X-100, Triton). Both materials were mixed by 1 gram of ZnS:Cu phosphor powder and 1.5 of X-100, stirring for 10 min at 800 rpm or 15 min or until homogeneous.

The EL device with ZnS:Cu phosphor was fabricated as mixed ZnS:Cu phosphor ink coated on ITO:PET in the area $3 \times 3\,cm^2$ and dryer treatment 130°C for 20 min. After that, the insulator ($BaTiO_3$) was coated on phosphor ink in the area $4 \times 4\,cm^2$ and dryer treatment 130°C for 20 min (insulator coated on phosphor 2 times) and the Ag electrode was coated on insulator paste in the area $2 \times 2\,cm^2$ and dryer treatment 130°C for 20 min [26]. These were shown in Figure 2. For the luminance and electrical properties, the spectral brightness analyzer (Konica Minolta, CS-2000), AC power supply (Acsoon® AF400M), and digital storage oscilloscope (Tektronix TDS 3014B) were used.

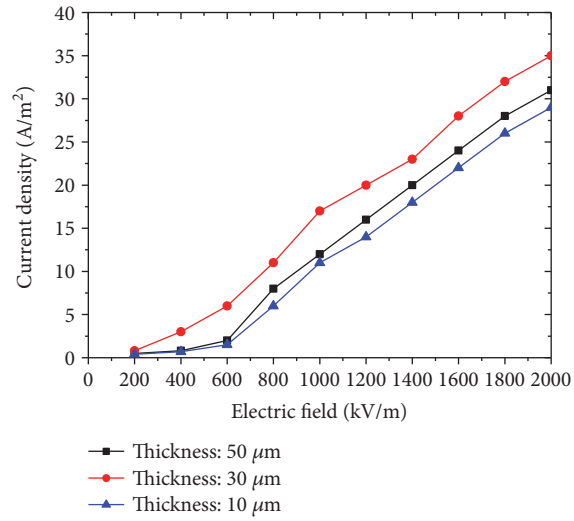

Figure 3: I-V curve of EL device with ZnS:Cu phosphor change in thickness 10 μm, 30 μm, and 50 μm.

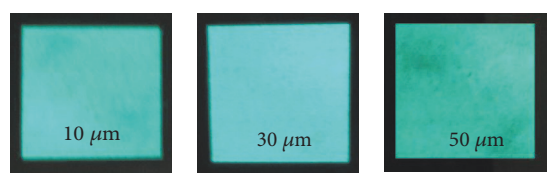

Figure 4: Lighting emission of EL device with ZnS:Cu phosphor change in thickness 10 μm, 30 μm, and 50 μm.

3. Results

3.1. Electrical Properties. Figure 3 shows the relationship between current and voltage (*I-V* curve) of the EL device with ZnS:Cu phosphor change in thickness 10 μm, 30 μm, and 50 μm. The applied input voltage and frequency of the cell were 0–200 V and 400 Hz when it was tested. The maximum current density was 39.2 A/m^2 for thickness 30 μm (thickness: 30 μm) which is more than the maximum current density 27.1 A/m^2 for thickness 10 μm (thickness: 10 μm) and 30.2 A/m^2 for thickness 50 μm (thickness: 50 μm) electrodes, at 1000 kV/m (about input voltage at 100 V). The current of thickness at 10 μm was less than that of thickness at 30 μm due to the electric charge flow through decreases in the area of ZnS:Cu phosphor layer [22]. The current of thickness at 50 μm was more than that of thickness at 30 μm because of the large area of ZnS:Cu phosphor causing distance-free electric field and the electric charge cannot flow from ITO:PET to Ag electrode [27].

3.2. Luminance Properties. Figure 4 shows lighting emission of EL device with ZnS:Cu phosphor change in thickness at 10 μm, 30 μm, and 50 μm. At applied voltage 100 V, the thickness of ZnS:Cu phosphor 30 μm showed brightness more than that of the thickness at 10 μm and 50 μm.

The peak intensity spectra show wavelength and response color. The EL device with ZnS:Cu phosphor layer

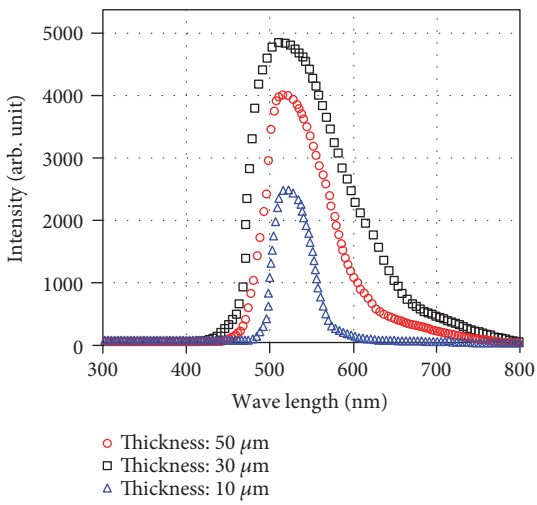

Figure 5: The intensity spectral of EL device with ZnS:Cu phosphor change in all thickness.

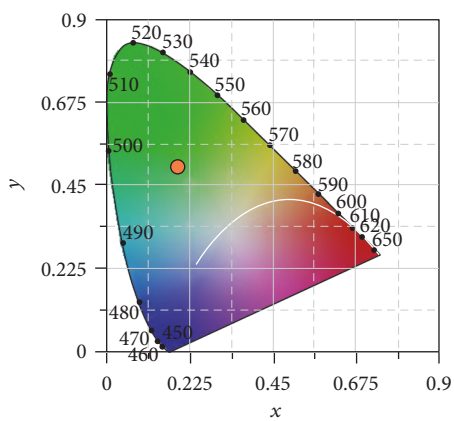

Figure 6: CIE x,y chromaticity diagram of EL device with ZnS:Cu phosphor change in all thickness.

is represented at all thickness for test and build. The light emission spectra of the EL device with ZnS:Cu phosphor change in thickness 10 μm, 30 μm, and 50 μm are shown in Figure 5. The peak intensity at a wavelength of 507 nm was not influenced by the operation condition thickness of EL devices at 100 V AC and 400 Hz. The EL devices showed green-blue emission in all thickness, and thus it was confirmed that the thickness does not influence the EL device's luminous color.

Figure 6 shows CIE x,y chromaticity diagram of EL device with ZnS:Cu phosphor change in thickness which responded to green-blue color. The x,y chromaticity CIE standard was shown in Table 1 which demonstrated an x,y CIE standard of ZnS:Cu phosphor EL devices in the condition of the thickness 10 μm, 30 μm, and 50 μm. The x,y CIE standard was average at $x = 0.1923$ and $y = 0.4788$ which is shown x,y chromaticity diagram in Figure 6.

The luminance of EL device with ZnS:Cu phosphor change in thickness 10 μm, 30 μm, and 50 μm is shown in Figure 7. When the applied voltage and frequency on cell

Table 1: x,y CIE standard of EL devices using ZnS:Cu phosphor.

Thickness of ZnS:Cu phosphor	Lv	x	y
10 μm	45.78	0.1945	0.4698
30 μm	51.22	0.1923	0.4788
50 μm	42.58	0.1933	0.4651

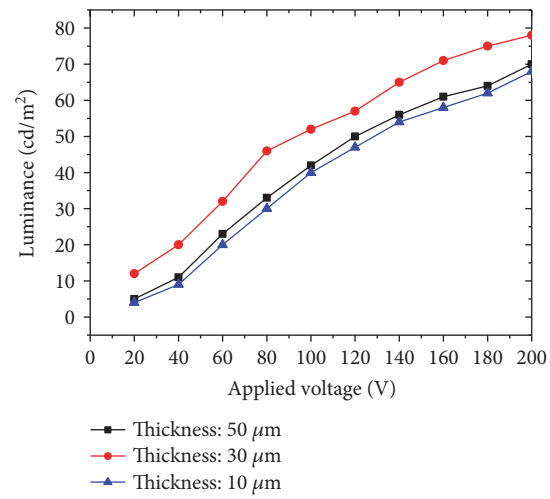

Figure 7: The luminance of EL device with ZnS:Cu phosphor change in thickness 10 μm, 30 μm, and 50 μm.

were 0–200 V and 400 Hz, the voltage of the initial light emission was 20 V for all thickness and the luminance of EL device was 41.78 cd/m^2 for thickness of 10 μm, 51.22 cd/m^2 for thickness of 30 μm, and 45.58 cd/m^2 for thickness of 50 μm at 100 V 400 Hz. The highest voltage of the initial light emission and intensity were thickness of 30 μm due to the thickness more than 30 μm cause the mean free path of the electron area on the surface of ZnS:Cu phosphor is suitable and the efficient faradaic current flow through at ZnS:Cu phosphor are decreased [27–29].

4. Conclusions

Electroluminescence (EL) device using the ZnS:Cu phosphor layer on ITO:PET was fabricated to investigate an effect on the luminescence properties. The performance of EL device with the ZnS:Cu phosphor layer at thickness 30 μm was shown to have a higher luminance than that of thickness at 10 μm and 50 μm at the same operation voltage. Moreover, all thickness had a 20 V of voltage for initial light emission. The electrical and luminance properties of EL device with ZnS:Cu phosphor change in thickness at 30 μm were 51.22 cd/m^2 and 41.9 A/m^2 which were more than those of the other thickness. The wavelength of 507 nm for peak intensity and the light of green color from EL device were not influenced by the change in thickness of ZnS:Cu phosphor. The optimal thickness of the ZnS:Cu phosphor for EL device was thickness 30 μm, which results in significant increase of EL device efficiency.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Acknowledgments

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