

Brightness Improvement of ZnS:Cu Powder Electroluminescence by Mixed Layer

Jong-Chan Lee* and Dae-Hee Park**

Abstract - In this paper, to discover the brightness improvement of ZnS:Cu powder electroluminescence (EL), a new structure is proposed in which phosphor and dielectric are mixed between electrodes. Dielectric and phosphor material are BaTiO₃ and ZnS:Cu, respectively. The effect of the mixed layer on EL sample is considered the improvement of source efficiency. Although the number of electrons introduced into the phosphor increases only modestly, the high electric field region of phosphor grains increases comparatively in the characteristics of brightness-voltage. Furthermore, the relaxation occurs through leading and trailing edge pairs, which is relatively efficient in characteristics of decay time. With these results, we found that the brightness of newly proposed ZnS:Cu powder electroluminescence was 167.24 cd/m² at ac voltage of 100V and frequency of 400Hz.

Keywords: Brightness Improvement, Electroluminescent, ZnS:Cu, Powder, A.C.

1. Introduction

Electroluminescent (EL) devices are based on the phenomenon of the direct conversion of electrical energy into light energy by various means of excitation of the optical modes of condensed matter. It was not until Destriau [1] reported on the influences of electric fields on a luminescent material that EL was born. Later, powder EL devices were commonly used as backlights for liquid crystal displays. A study on brightness improvement of power EL devices has been carried out by researchers concerned with phosphor having high performance and intense brightness [2], dielectric and dispersive binders with high dielectric constant [3], and multi-layer structure [4].

In this paper, a new structure is proposed in which phosphor and dielectric are mixed and positioned between electrodes in order to improve the brightness of ZnS:Cu powder, which has been used as a conventional material in EL devices. The optimal thickness of the mixed layer is also tested.

2. Experiment

Generally, the powder EL device consists of a phosphor and dielectric layer mixed with an organic solution for a dispersive binder between transparent and back electrodes. The thicknesses of the phosphor and dielectric layer is

about 15~50 μm .

In this experiment the screen-printing method is used to create the multi-layers consisting of phosphor, dielectric and back electrode. The squeezing pressure, the drawing speed of the squeeze, the viscosity of pastes and the emulsion of the screen are important factors to consider in the achievement of desired thickness. The 200 mesh screen is used to efficiently control the thickness of the EL film layer.

The following materials are required in preparation for ac powder EL; organic high dielectric binder, phosphor powder, dielectric powder, transparent electrode film and silver paste for back electrode. Cyanoresin (CR-S, Shin-Etsu Chemical Co. Ltd.) is used as a dispersive binder and N,N-Dimethylformamide (Junsei Chemical Co. Ltd.), the solution of CR-S, is mixed in concentrations of 10~40 wt. % (weight percent). To dissolve CR-S, it agitates until the solution becomes viscous and clear. ZnS:Cu with average grain size of about 20 μm is used as a phosphor and is mixed with the binder solution in the ratio of 1:2 (binder: ZnS:Cu) in weight. BaTiO₃ is used as a dielectric and is also mixed with the binder solution in the ratio of 1:3 (binder: BaTiO₃) in weight. ITO film (sheet resistance of 300 Ω/\square , Toray 125L) as a transparent electrode and silver paste for the back electrode are used, respectively. Following the preparation as mentioned above, the ZnS:Cu layer is printed on ITO film. Subsequently, the phosphor printed on the sheet is dried in a drying oven for 10 minutes at 80°C. The dielectric layer and back electrode layer are also printed and dried as the same processing conditions.

As shown in Fig. 1 (a), ITO/ZnS:Cu/BaTiO₃/Ag of the

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conventional structure is made into a phosphor layer with thickness of 32 μm and a dielectric layer with the thickness of 15 μm . ITO/ZnS:Cu+BaTiO₃/Ag of the new structure are made into a single emitting layer with a thickness of 35~55 μm in Fig. 1 (b). The fabricated samples are estimated by voltage and frequency dependence of brightness, and decay time.

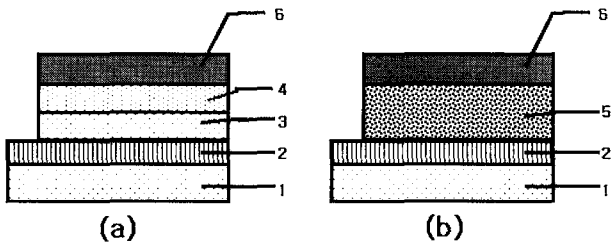


Fig. 1 Side view of the electroluminescent structures (a) ITO/ZnS:Cu/BaTiO₃/Ag, (b) ITO/ZnS:Cu+BaTiO₃/Ag
1. PET film; 2. ITO layer; 3. ZnS:Cu layer; 4. BaTiO₃ layer; 5. Mixed layer of ZnS:Cu and BaTiO₃; 6. Ag electrode

3. Results and discussion

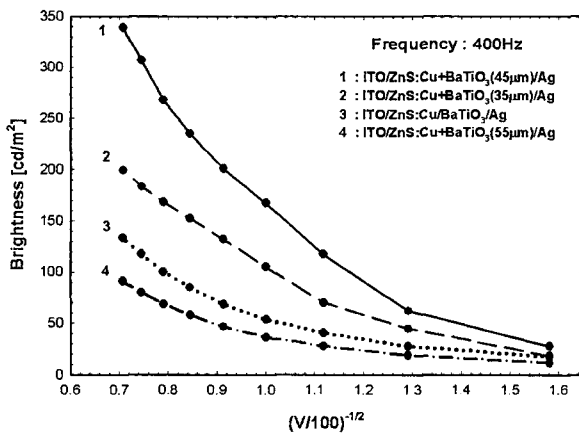


Fig. 2 Voltage dependence of brightness with various EL samples at frequency of 400Hz
1. ITO/ZnS:Cu+BaTiO₃(45 μm)/Ag; 2. ITO/ZnS:Cu+BaTiO₃(35 μm)/Ag; 3. ITO/ZnS:Cu/BaTiO₃/Ag; 4. ITO/ZnS:Cu+BaTiO₃(55 μm)/Ag

Voltage dependence of EL samples with green emission is presented in Fig. 2. The measurements are performed with an ac voltage (0~200V) at the frequency of 400 Hz in room temperature. From Fig. 2, it can be seen that the brightness of EL samples with different structures changes exponentially as a function of applied voltage in accordance with the following [5]:

$$B = B_0 \exp\left(-\frac{V_0}{V^{1/2}}\right) \quad (1)$$

where, B and V are the brightness and applied voltage, respectively. Other initial parameters of B₀ and V₀ depend on the phosphor particle size, ratio of binder, thickness of layer, frequency of the alternating voltage and temperature.

The brightness improvement can be seen in that ITO/ZnS:Cu+BaTiO₃/Ag is the mixed structure with phosphor and dielectric materials rather than the conventional structure of ITO/ZnS:Cu/BaTiO₃/Ag. The highest brightness of 167.24 cd/m² at ac voltage of 100V and 400 Hz is observed at the mixed layer of 45 μm thickness. This brightness is improved up to three times higher compared to the conventional structure.

The slopes in Fig. 2 are dependent on the electric field concentration, and changes significantly according to the variations of structure and thickness properties. On the contrary, the parameter B₀ characterizes the external electron source and is just a little bit different. The effect of the mixed layer on EL sample is considered an improvement in source efficiency. Although the number of electrons introduced into the phosphor increase only slightly, the high electric field region of phosphor grains increases comparatively. Especially, the highest electric field is introduced to ZnS:Cu phosphor at the thickness of 45 μm .

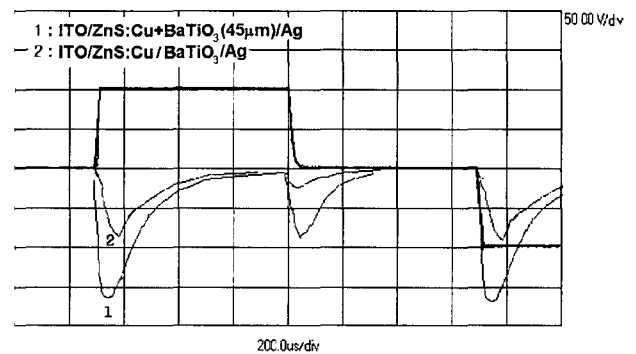


Fig. 3 The characteristics of decay time at 400Hz
1. ITO/ZnS:Cu+BaTiO₃(45 μm)/Ag; 2. ITO/ZnS:Cu/BaTiO₃/Ag

Generally, ac powder EL emission by time dependence as shown in Fig. 3 consists of two peaks, coincident with the leading and trailing edge of the applied wave form, which decays exponentially over a period of milliseconds [6]. The trailing edge emission has been known as a process involving the recombination of electrons with ionized dopant centers upon removal of the external electric field [7, 8].

From Fig. 3, it can be seen that the electrical properties

of the structures are changed significantly with a variation of the structure. The total integrated luminance of ITO/ZnS:Cu+BaTiO₃/Ag is increased rather than that of the conventional structure of ITO/ZnS:Cu/BaTiO₃/Ag. It is possible to account for the decay in luminance. At high fields, a greater number of dopant centers are excited, therefore it is more likely that a mixed structure of ITO/ZnS:Cu +BaTiO₃/Ag will be easy to excite. As a result, the relaxation occurs through leading and trailing edge pairs, which is a relatively efficient process.

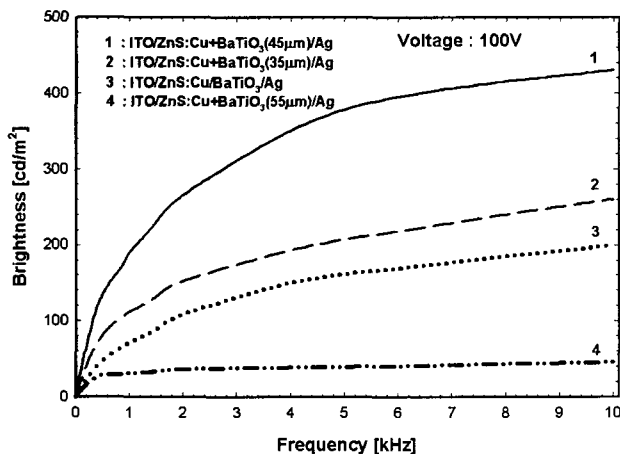


Fig. 4 Frequency dependence of brightness with various EL samples at voltage 100V
 1. ITO/ZnS:Cu+BaTiO₃(45 μ m)/Ag; 2. ITO/ZnS:Cu+BaTiO₃(35 μ m)/Ag; 3. ITO/ZnS:Cu/BaTiO₃/Ag; 4. ITO/ZnS:Cu+BaTiO₃(55 μ m)/Ag

The frequency dependence of brightness for the different structures measured at a supply voltage of 100 V is shown in Fig. 4. From Fig. 4, the brightness increases rapidly at low frequency, but then appears to saturate. It can be seen that the brightness saturates at a frequency above 10 kHz. The brightness of the ITO/ZnS:Cu+BaTiO₃(45 μ m)/Ag EL structure increases more than 2.5 times that of the conventional structure of ITO/ZnS:Cu/BaTiO₃/Ag. As the frequency increases, the number of leading and trailing edge emissions per second increases, and the power consumption increases. At low enough frequencies so that each emission of the leading and trailing edge decreases to zero, the average light intensity will vary in direct proportion to the number of emissions.

However, there is a finite decay time associated with each leading and trailing edge emission. When the frequency becomes high enough, each emission begins to overlap so that a new emission starts before the previous one has entirely decayed. Then the increment of frequency no longer imparts a proportional increase in the average light intensity and the saturation effect begins to appear. Further investigations are necessary in order to obtain

substantial insight into the source carrying the charge.

4. Conclusion

In this paper, to obtain the brightness improvement of ZnS:Cu powder electroluminescence, a new structure was proposed.

1) The highest brightness of 167.24 cd/m² at ac 100V, 400 Hz is observed using a mixed layer of 45 μ m thickness. The effect of the mixed layer on the electroluminescent sample is considered as the improvement of source efficiency. Although the number of electrons introduced into the phosphor increases only slightly, the high electric field region of phosphor grains increases comparatively. In particular, the highest electric field is introduced to ZnS:Cu phosphor at 45 μ m thickness.

2) At high fields, more dopant centers are excited, therefore it is more likely that a mixed structure of ITO/ZnS:Cu+BaTiO₃/Ag will be easy to excite. As a result, relaxation occurs via leading and trailing edge pairs, which is a relatively efficient process.

3) The brightness of the ITO/ZnS:Cu+BaTiO₃(45 μ m)/Ag electroluminescent structure increases 2.5 times rather than the conventional structure of ITO/ZnS:Cu/BaTiO₃/Ag. At frequencies high enough so that each emission of leading and trailing edge increases to zero, the average light intensity will vary in direct proportion to the number of emissions.

Further investigations are necessary in order to obtain substantial insights into the origin of the charge.

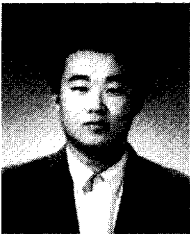
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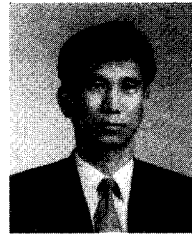
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