Characterization of electrophoretically deposited low voltage phosphors mixed with In_2O_3 conducting powders for field emission display

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Abstract

Primary emphasis was placed on the electrophoretic deposition of low voltage phosphor to indium-tin oxide-coated glass for the application of field emission display. The phosphor deposited by various parameters, such as deposition time and applied voltages was examined in detail. In addition, a comparison was made by analyzing luminance properties of the phosphor mixed with and without conducting In_2O_3 powder of less than 1um size. The measurement was performed as a function of In_2O_3 concentration from 3% to 15% by weight. The enhanced impact of indium powder mixing on the phosphor was clearly demonstrated by aging performance curve at 1000V excitation voltages with a current density of 1mA/cm^2

Introduction

Exciting opportunities for next generation of flat panel display (FPD) device are increasingly arising in a field emission display (FED) device because of its superior properties, compared with other possible FPD devices [1-2]. With the development of low voltage phosphor, one of important prerequisites for future commercialization of the FED device is efficient deposition of the phosphor on the ITO glass in order to achieve higher brightness. In addition, surface modification of the phosphor has critical effects on the brightness of the FPD device due to high resistivity of the phosphor, resulting in insufficient luminance at low electron excitation voltages. One is to provide effective energy migration into deep grain using chemical reaction [3-4]. The other is to improve the conductivity of insulating phosphor by mixing the phosphor with conducting materials and doping impurity into the phosphor, resulting in removing surface charge on the phosphor [5].

In this letter, an electrophoretic procedure was done in the usual way to deposit low voltage phosphor on ITO glass by varying deposition time and applied voltages. As a reliable test of the phosphor, addition effect of In_2O_3 powder on the phosphor was also investigated and compared with the phosphor without In_2O_3 conducting powder.

Experimental

The deposition suspension is basically composed of phosphor particles in isopropyl alcohol (IPA) containing a $Mg(NO_3)_2$ nitride of 10^{-4} mole. The screening experiment was carried out in a bath container with a stainless metal mesh. The metal mesh was used as an anode and the ITO glass was placed on the cathode plate. As shown in this figure, both of anode and cathode plates were parallely oriented to each other at a fixed distance of 1.5 cm. They were connected to a dc high voltage power supply through a current monitor.

In an initial effort to determine optimum deposition conditions of the electrophoresis, typical deposition parameters were chosen and investigated. Figure 1 plots the deposition weight (mg/cm^2) as a function of bias voltage under various deposition times. The deposition weight is defined as an amount of the deposited phosphor per unit deposited glass area. The deposition time ranged from the 10 sec to 60 sec to choose appropriate thickness since different screening thickness has significant effect on optical performance of the phosphor. As shown in this figure, with the increase in bias voltage and deposition time, the deposition weight increases, resulting in higher deposition thickness on the glass. Luminescent performance degrades due to higher thickness, especially at low excitation voltages. Therefore, by considering deposition rate and uniformity of the deposited phosphor experimentally, the bias voltage and the deposition time were hereafter fixed to 150V and 20 sec, respectively.

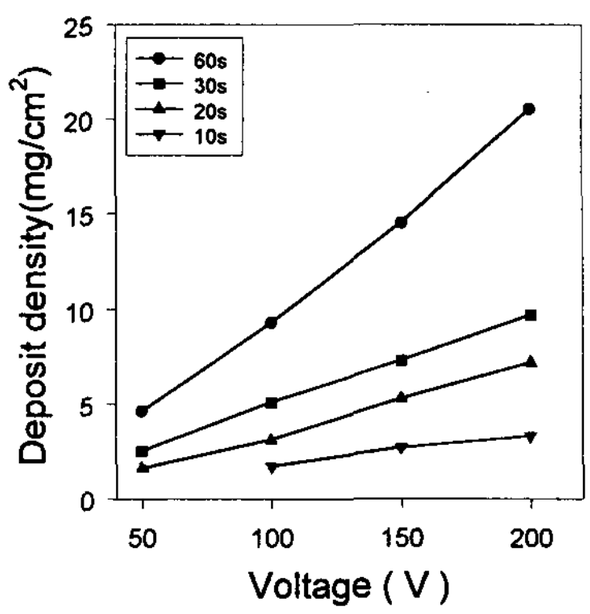

Figure 1. Deposition weight (mg/cm^2) of the phosphor as a function of bias voltage under various deposition times.

Result and Discussion

Figure 2 shows typical cross-sectional SEM pictures of the deposited phosphor on the ITO glass. The deposition condition was fixed at bias voltage of 150V and deposition time of 20 sec after extensive optimization study of the electrophretic deposition. As shown in this figure, homogeneous uniformity in the phosphor thickness was generated at this condition. The In_2O_3 conducting powders, which was observed on the phosphor surface as white particles, have been found to efficiently discharge the accumulated potential at the phosphor surface during irradiation by electron

beam. It results in improving radiation stability in the aging test shown in figure 4. Also, the emission spectra of the screened phosphor were matched to those of the bulk powder phosphor, shown in this figure. The spectrum was essentially unaffected, regardless of electrophoretic deposition process and addition of indium powder to the phosphor. This result is quite similar to that previously reported by other group. It is directly due to the fact that simple indium mixing to the phosphor does not cause any formation of a solid solution or any different phases on the phosphor. It is expected that there does not appear to be any chemical reaction between ZnS and In_2O_3 or no change in the composition of the phosphor. The PL intensities degrade with increasing In_2O_3 concentrations. It is basically attributed to non-radiative properties of the In_2O_3 conducting powder.

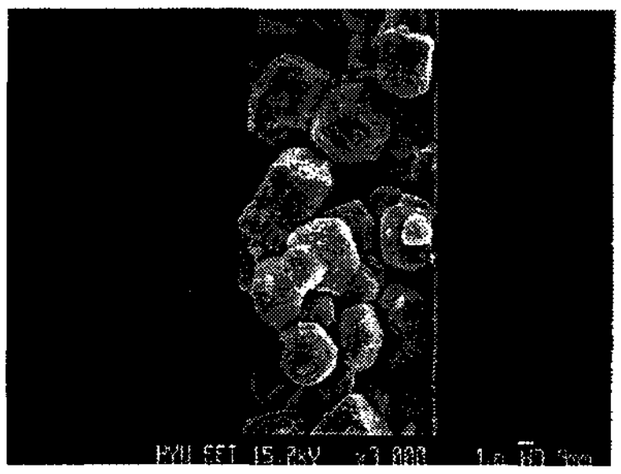

Figure 2. Cross-sectional SEM views of the deposited phosphor on the ITO glass with 10% indium concentrations

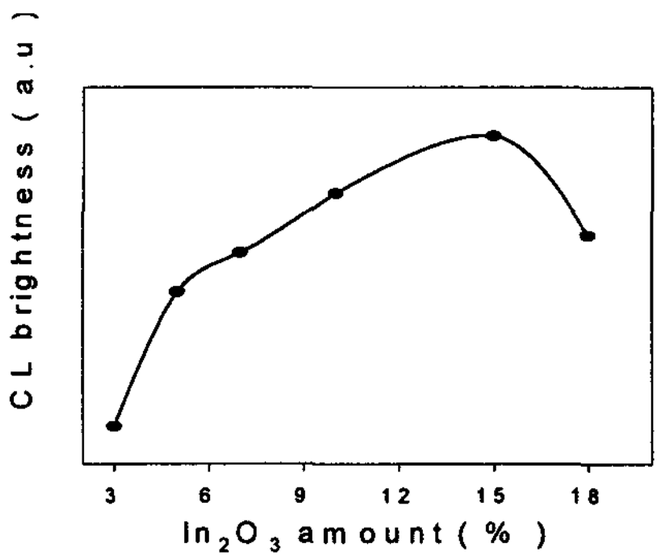

Figure 3. Cathodoluminescent response of the phosphor at various Indium concentrations

Figure 3 presents CL responses for the deposited phosphor at various indium concentrations. The amount of indium was varied from 3% to 15% by weight. The phosphor was excited at 1000V with a current density of 50uA/cm^2. As shown in this figure, the CL intensity increases linearly with increasing indium contents and is reached at about 15% concentration. However, at about 15% addition, inadequate aggregation of excess indium powder frequently takes place in the phosphor surface, giving rise to poor uniformity in the conducting powder distribution. This trend has been found more dominant for about 15% concentration, In addition, the CL intensity starts to decrease at more than 15%, not shown in this figure. It is thought that excess indium concentration as non-emitting material has increasingly detrimental effects on the brightness at higher contents that 15%. In view of this optimum addition of indium powder to the phosphor surface for future application of real FPD panels should be chosen at about 10% concentration even though the brightness at 10% was lower than that at 15%.

Figure 4 presents aging performance curve as a function of electron exposure time under DC operation. As shown in this figure, the brightness for the phosphor without indium powder drops to zero rapidly. It might be due to surface bound electrons or plasmon de-excitation at the phosphor surface during prolonged electron beam irradiation at excitation voltages [6]. However, in other cases with indium powder, the brightness reached a constant value of less than 10% degradation, which results from excellent resistance to electron charging effect or fast discharging-up effect by indium conducting powder. As shown in figure 5(a) and (b), simple tradeoff exists between decreasing brightness and discharging effect with the addition of conducting powder to the phosphor. However, it can be concluded that the conducting powder such as In_2O_3 is essentially necessary for reliable operation of real FED panels when excited at low electron excitation voltages.

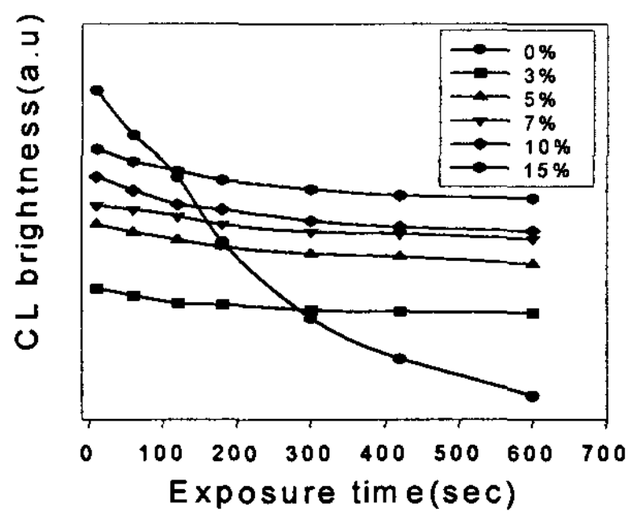

Figure 4. Aging performance curve as a function of time

Summary

Primary deposition parameters of deposition time and applied voltages were investigated and characterized. In addition, the mixing impact of In_2O_3 conducting powder on the phosphor was observed in detail. The mixing of indium powder to the phosphor leads to significant improvement in the aging performance of the phosphor

Acknowledgements

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