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Preparation of aluminum film on phosphor screen for field emission display

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Abstract

The phosphor screen for field emission display (FED) was made by using cellulose acetate butyrate as a binder dissolved in butoxyethyl acetate. Before baking at temperatures lower than 500°C, the aluminum film was formed on the screen. This screen has nearly two times the brightness in comparison with pure screen. The FED panel was successfully made using Al film coated phosphor screen and demonstrated an image of high brightness and relatively good quality which is suitable for practical application. © 1999 Elsevier Science S.A. All rights reserved.

Keywords: Phosphor screen; Aluminum film; Field emission display

1. Introduction

Flat panel displays including LCDs, VFDs and FEDs have received increasing attention for the potential application of phosphor screens. Like the VFD, the FED is a vacuum display, featuring all of the advantages of the cathode ray tube (CRT), but with a flat panel. Compared to active matrix liquid crystal displays (LCDs), FEDs generate three times of brightness with greater viewability and wider temperature range at the same power level [1].

There are several techniques for making phosphor screens, such as spin coating followed by lithography, electrophoresis, and screen printing. A very smooth phosphor screen can be obtained by using the methods of combination of both spin coating and lithography. But these processes are complex and the chemicals used are very toxic mixtures composed of various chemical compounds. On the other hand, some researchers adopted electrophoresis to prepare phosphor coatings [2,3]. By using this process, the thickness of the screens can be easily controlled. Moreover, there are only few researchers who have successfully prepared the full color screens by using electrophoresis [4]. Screen printing having the advantages of easy processing and low cost is a simple method to prepare relatively smooth phosphor screen. But it has the limitations of size and thickness (size $> 50\,\mu$m, thickness $> 1\,\mu$m). Due to the above mentioned reasons, it is easily possible to make both smooth plane and controllable phosphor screens using screen printing technique. Therefore, in the present study, we employed the screen printing method for fabricating the phosphor screens.

In addition, the commercial phosphor screens in the color television CRTs need an aluminization process to apply a thin aluminized coating to the back side of the phosphor screen. The Al films provide a mirror finish that reflects light from the screen which would otherwise be lost within the tube. Thus tubes after this treatment have improved brightness and enhanced picture contrast. The application of desired aluminized mirror film on the back surface of the multi-phosphor screen is a delicate procedure. In the first step it involves wetting or water dampening phosphor screen followed by a set time to promote complete dampening coverage of the screen. Next a thin film of lacquer is applied over the back side of the dampened screen to provide a surface upon which mirror coating is formed. A thin layer of aluminum coating is laid over the lacquer film, and finally the lacquer is removed by baking whereupon the smooth reflective aluminum coating remains supported directly by phosphor screen. It is essential to utilize the lacquers as an intermediate processing support so that the aluminum mirror can be obtained. However, these processes are complex and the lacquer used as an intermediate in CRT is a very toxic mixture composed of many chemical compounds. In this letter, we tried to simplify the processes of making alumi-

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nized phosphor screens and avoid the use of toxic chemical compounds. By using screen printing and special binder, we could make a smooth phosphor screens thereby simplify the aluminization process. Further, this aluminized screens have been successfully assembled into FED panels and showed high brightness and picture contrast.

2. Experimental procedure

The phosphor screens for FEDs were made by using screen printing to pile up 2–3 layers thick phosphor powders on glass substrates. The number of layers of the phosphor powders was determined on the basis of the equations reported in an earlier paper [5]. The soda-lime and Corning 1737 glasses were utilized as the substrates. The phosphor slurry with suitable rheological behavior was prepared first before printing. The cellulose acetate butyrate (CAB) [6] used as the binder was dissolved in a solvent of ethylene glycol monobutyl ether acetate (butoxyethyl acetate) or ethylene glycol monobutyl ether laurate (butoxyethyl laurate). The binder solution was composed of 5–52.5% butoxyethyl acetate (solvent) and 17.5–35% CAB (binder) based on the weight of the slurry. The composition of the phosphor powders used was $Y_2O_2S:Tb$. The solid contents of the phosphor slurry were about 30–60 wt.%. The mixture of phosphor powders and binder solution was blended for 20 min using a three roller miller. Fig. 1 illustrates the thermal characteristic curve of the phosphor slurry, indicating that the volatile materials in the slurry were removed at around 450°C.

After preparing the slurry, the phosphor thick films were obtained by using screen printing. Then the aluminum coating with the thickness of 500–3000 Å was evaporated on some phosphor films. The films with and without aluminum coating were heated at 450–480°C for 2 h. For brightness measurement, the phosphor films were installed in a demountable chamber. The focused electron beam was irradiated on the phosphor films with various voltages at a current density of 1.7 $\mu A\ cm^{-2}$.

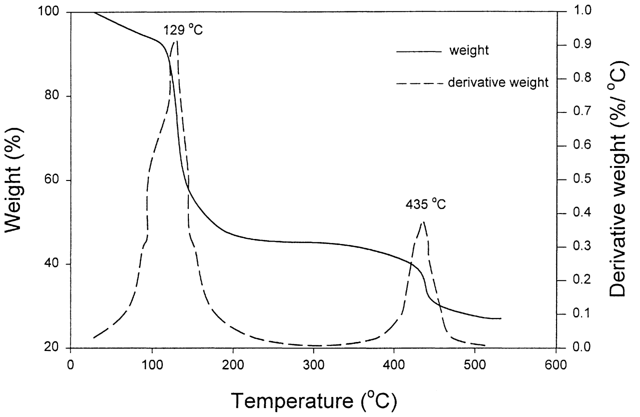

Fig. 1. Thermal characteristics of the phosphor slurry.

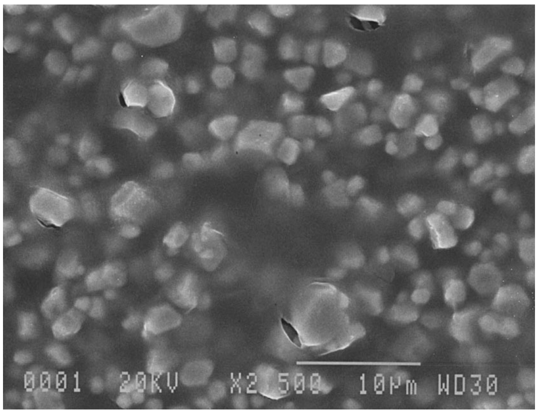

Fig. 2. SEM micrograph of the $Y_2O_2S:Tb$ phosphor film with 1000 Å thick Al coating.

3. Results and discussion

Fig. 2 indicates the micrograph of scanning electron microscopy (SEM) of the $Y_2O_2S:Tb$ phosphor film with 1000 Å thick aluminum coating prepared by using screen printing. There exists pores in the Al film of size smaller than 5 µm. The phosphor particles indicate relatively uniform distribution as revealed in Fig. 2. The change in the brightness with various electron beam energies for the $Y_2O_2S:Tb$ phosphor films without and with aluminum coating is illustrated in Fig. 3. The two curves shown in the figure intersect at about 4 keV, which implies that above 4 keV the light emitted from the phosphor powders toward electron beam can be reflected to the viewers due to Al film as a reflector. Therefore, the induced brightness of the Al film coated screen is higher than that of phosphor screen without Al film when the electron energies are above 4 keV. In addition, compared to the phosphor screen without Al film coating, the Al-film coated screens generate nearly two times brightness at 9 keV. The slope of the curve with Al film is nearly 3.6 in the range of 2–4 keV operating voltage. This Al film coated phosphor screen was used for the

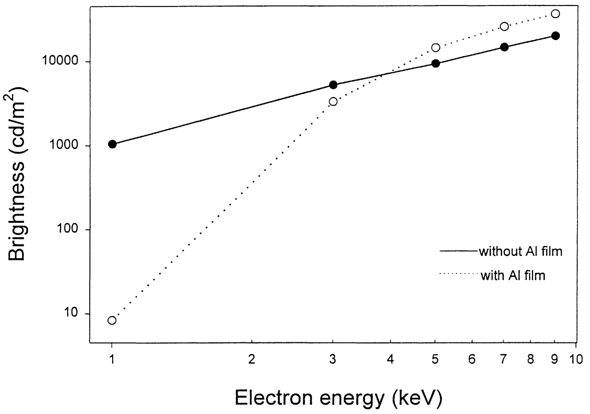

Fig. 3. Variation of brightness with electron energy for phosphor screens with and without Al coating.

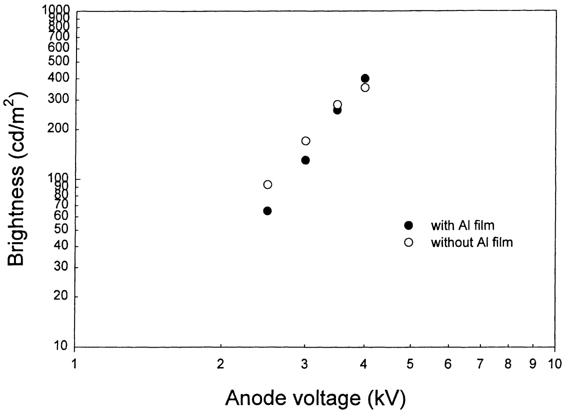

Fig. 4. Variations of brightness of phosphor screens with and without Al coating in FED panels with anode voltage.

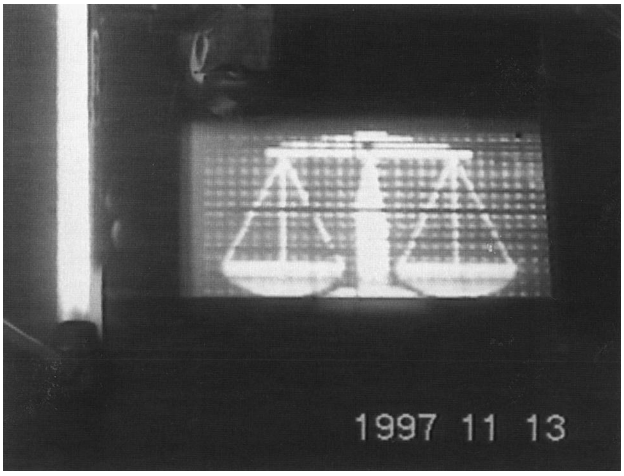

Fig. 5. Image of FED panel with Al coated phosphor screen.

fabrication of the FED panel. At the same operating voltage range (anode voltage $V_a = 2$–4 kV, gate voltage $V_g = 90$ V), the brightness of the screen in the panel is 400 cd m^{-2} and the slope of the curve as shown in Fig. 4 is 3.8, which is similar to the slope of 3.6 for an original phosphor screen as indicated in Fig. 3. This implies that the panel screens show similar working behaviors with the original screens. Based on the results shown in Figs. 3 and 4, the Al film coated phosphor screen would be able to be applied to assemble FED panels. The image of the screen installed as a FED panel is illustrated in Fig. 5.

4. Conclusions

Due to the use of cellulose acetate butyrate dissolved in butoxyethyl acetate, we can easily perform screen printing method to obtain the Al-film coated phosphor screen which owns the 'mirror effect'. The present fabrication process demonstrates that the screen could be made by baking below 500°C and the procedure could also be simplified. The induced brightness of Al film coated phosphor screen is a multiple of 1.7 higher than that of without Al coated one at 9 keV. The Al coated phosphor screen can be served as an anode plate to successfully install FED panel and show the image with brightness of 400 cd m^{-2} at 4 kV.

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