The Journal of Korea Vacuum Science & Technology
Vol. 3, No. 1, April 1999, pp. 90~94

New design and its characteristics of full color anode panel for field emission display

J. I. Han, S. K. Park, W. K. Kim and M. G. Kwak

Korea Electronics Technology Institute, Pyung Taek, Kyung Gi, 451-860, Korea

(Received February 22, 1999)

Abstract – Field Emission Displays (FEDs) require enhancement in both driving methods and process techniques to improve the display image quality. However, from the point of view of manufacturing, it is difficult to find methods and techniques to realize low cost manufacturing. New and simple color phosphor screen designs were suggested with non-crossed electrode lines and full color anode panels for small area displays were demonstrated. To avoid unwanted reaction with gases produced from phosphors in a high vacuum glass container, a very thin polyimide layer was coated on the phosphor screen. Moreover, to improve the display image quality, black matrix composed of inorganic materials was fabricated. This paper describes the performance and characteristics of the new full color anode panels.

I. Introduction

Although FEDs have been the hope for the next generation flat panel displays, there are still many difficulties to overcome. Nowadays FEDs are suitable for many small-size display applications. Recently low power consuming FEDs modules were developed by Pixtech and Futaba Corporation, which present luminance as high as that of CRTs. However, FEDs could not become a commercially viable display without low cost manufacturing techniques. Generally because anode switching driving method were connected to every R, G and B pixel one another in order to improve the luminance at low voltage, the anode wiring gets too complicated and multi-layered electrodes are needed [1-4]. Consequently low cost manufacturing such as the powdered phosphor, and a thick film process cannot be applied to. Although other manufactures modified anode switching schemes with two anode terminals have also the non-crossed anode wiring matrix, the increase of cross-talk and the difficulties of drive scheme still remain as problems. Furthermore because the phosphor screen in FEDs was coated on the transparent conductors unlikely in CRTs, the phosphors are directly exposed to the high vacuum and the electron beam. In such a situation, the phosphors and the harmful gases from the phosphor powders degrade the emitters and the vacuum states.

A new and simple anode screen design with non-crossed anode lines is suggested in this work. Full color anode panels with a protection layer for small area displays whose size were 0.7" and 4" were fabricated by the spin coating and photo-lithography process.

II. Experimental

For a full color anode screen, sulfide phosphors powder such as ZnS:Ag,Cl (B), ZnS:Cu,Al (G), Y_2O_2S:Eu (R) with or without the coating of In_2O_3 and the oxide phosphors (ZnO:Zn (G), $ZnGaO_4$:Mn(G), $CaTiO_3$:Pr(R)) were spin-coated and patterning was done by a photolithography process with water soluble photo-resister. Also, for the high contrast and color purity, the black matrix composed of inorganic materials was formed between pixels. The harmful gases (CO, CO_2) from the phosphor powder contaminate the emitter tips and degrade the vacuum states. It is a primary mechanism for degradation. The phosphor screen can be aluminized like CRTs at the higher voltages (>4 kV), but most FEDs work at lower anode voltages than CRTs. To avoid these problems, the protection layer, polyimide with high thermal resistance and low outgassing products, was thinly coated on the phosphor screen. In this work we examined the performance and characteristics of the new anode panel with non-crossed electrode lines, a black matrix and an outgassing protection layer in terms of the brightness, transmittance, I-V measurement for various phosphor materials, thickness and passivation layers and so on. The surface morphology of phosphor layer was observed using SEM (Scanning Electron Microscopy) and outgassing gases at high vacuum state were analyzes by a RGA (Residual Gas Analyzer).

III. Results and discussions

Figure 1 shows the anode wiring structure of the conventional anode switching full color FEDss panel. Since R, G and B electrode inevitably cross one another as shown in Figure 1, the anode wiring becomes too complicated and multi-layered structure is formed by line-crossing, which is composed of an electrode layer, an insulating layer and an electrode layer. Due to its configuration, it is very difficult to fabricate the anode panel by the phosphor powder thick film process. Figure 2 demonstrates our proposed design fabrication process to overcome these problems without the loss of the anode switching driving merits such as no cross-talk and high quality image.

These stripe anodes are designed in the vertical direction and the anode wiring consist of two sets of comb-shaped anode connection and one green phosphor electrode line that is not crossed with other lines. Therefore, the thick film process of the phosphor powder can be achieved due to its simple and unique configuration.

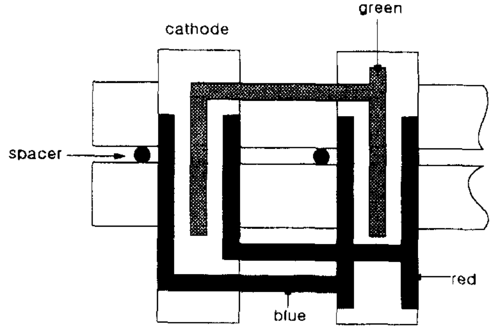


Fig. 1. A schematic of electrodes in conventional anode structures.

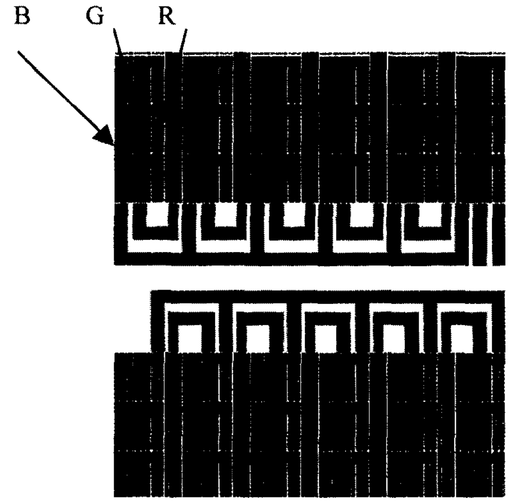


Fig. 2. Electrodes in new designed anode structure.

From I-V measurement, it is proved that the dominant factor of brightness of phosphor screen is not the thickness but the number of layer of phosphor screen. The light emitted from first particle layer seems to be scattered by electrons transmitted and reflected through other layers. It can be concluded that the ideal phosphor screen was constructed with 2 layers of particles which have uniform surface morphology through dusting process. Figure 3 and 4 present the variation of CL brightness with phosphor layer and the cross sectional view of phosphor screens with different layers, respectively.

For the high contrast and color purity, the black matrix was formed between pixels as given in Figure 5.

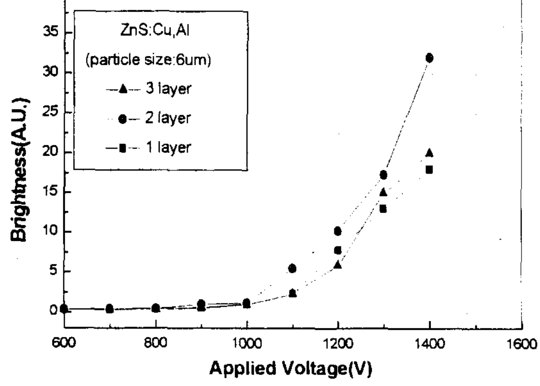
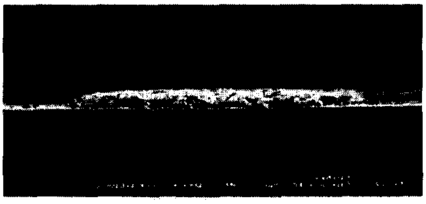


Fig. 3. Variation of CL brightness with phosphor layers.

(a) 1 layer

(b) 2 layer



(c) 3 layer

Fig. 4. Cross sectional view of phosphor layer by SEM (Mean Powder Size : 3 μm).

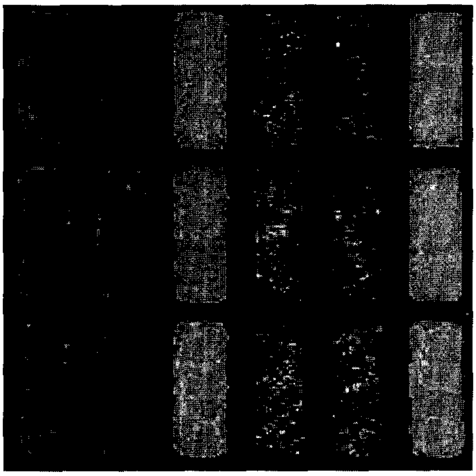


Fig. 5. Anode panel with R, G and B phosphor pixels and black matrix.

In FEDs, black matrix has been so directly exposed to high vacuum state and accelerating electrons that it should have chemical and mechanical stability. The material used in experiments is JB 4500 (Product of Dupont) which has high electric and thermal resistance (more than $10^{10}\Omega$, 600°C) and few outgassing. Figure 6 shows the experimental setups for outgassing from the phosphor screen and black matrix. The sample was loaded on the main chamber connected to a Residual Gas Analyzer and Brightness was measured by a spectrometer.

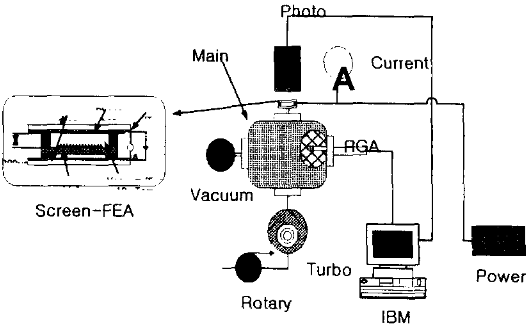


Fig. 6. A schematic illustration of the high vacuum system containing RGA.

As mentioned above, FEDs do not use the high acceleration potentials which is required for aluminized phosphor screen. This is due to the complication in making suitable standoffs. Consequently, phosphor screen design consists of the thick film of phosphor powder and ITO electrode. The evident advantage of this structure is that low acceleration voltage can be applied. But a drawback of this approach is a direct exposure the phosphor layer to the high vacuum and accelerating electrons. In such a situation, the phosphor particles more readily contaminate the cathode, and the harmful gases from the phosphor screen degrade the vacuum state and cathode. For the improvement of mechanical stability of phosphor and the protection of harmful gases from phosphor screen, Polyimide (Products of Nissan Chemicals) with high thermal and electrical resistance was coated on the phosphor screen by spinning. Polyimide is the most widely used dielectric material due to its high themal stability, processability in solution form and low dielectric constant (3.5). This material is expected to be very useful for many kinds of electronic applications because of low thermal stress, as well as excellent thermal stability (more than 400°C), mechanical properties [5-7]. Polymer materials like a polyimide have many

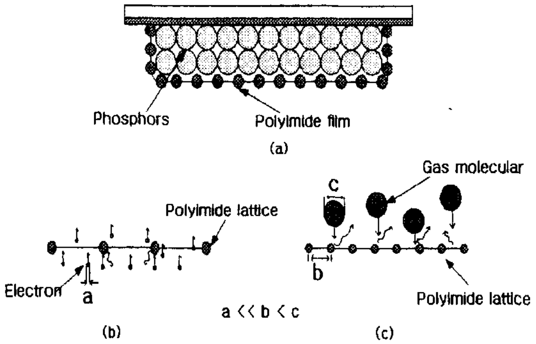
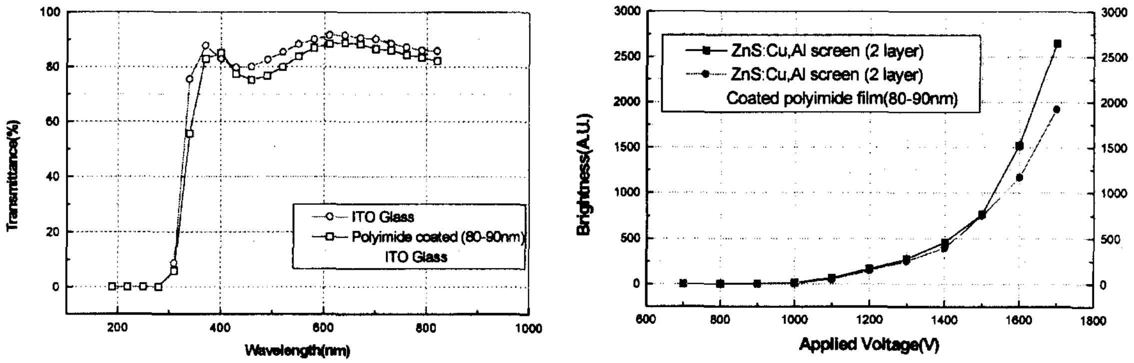


Fig. 7. *Physical modeling of polyimide film on the phosphor screen.*

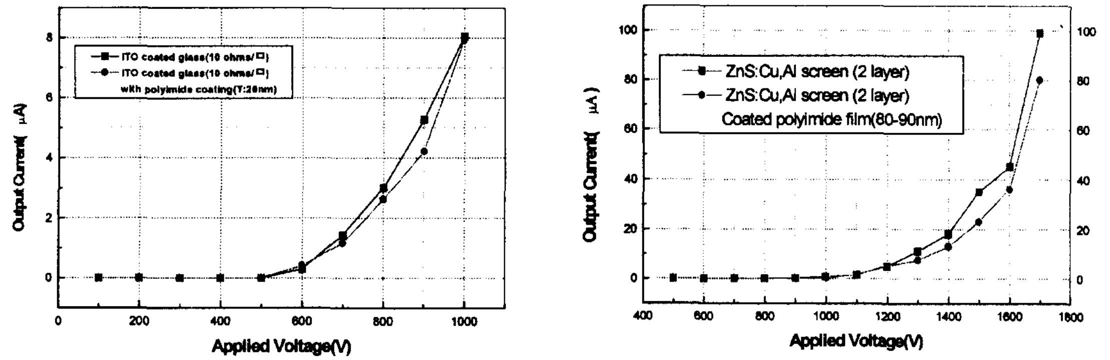
broad voids in terms of electrons, so it admits the transmission of electrons emitted from cathode but the harmful gases from phosphor screen can not be transmitted. Figure 7 shows these mechanism through physical modeling.

Also, it improves mechanical property of phosphors, that is the adhesion stability of phosphors. The distance of lattice of Polyimide is broad enough for electrons to transmit but not enough for gases. Outgassing products resulting from the samples were measured during operation by a residual gas analyzer. Several phosphors powder used in this works showed similar outgassing spectra with major peaks corresponding to H_2, CO, CO_2 and their fractional products. In this residual gas analysis, the spectrum obtained in the ultra-high vacuum without the sample was considered as a reference. In the phosphor panel without polyimide coating, the gases such as H_2, CO_2, CO and O_2, were detected, while the residual gas detected in the sample with polyimide coating was only H_2, which means polyimide film layer protects other outgassing products. It means that the cathode and high vacuum state were maintained containing similar optical and electrical



(a) Transmission characteristics

(b) Brightness characteristics

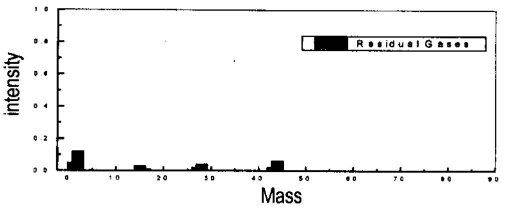


(c) I-V curve characteristics

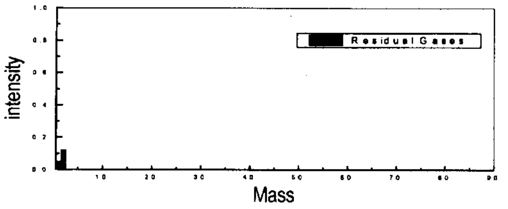
Fig. 8. Effect of polyimide protection layer on ZnS:Cu, Al phosphor panel.

Table 1. Specification of full color anode plate

	0.7 screen	4 screen
Pixel size	300 μm × 300 μm	180 μm × 45 μm
Pixel pitch	400 μm	225 μm
Resolution	75 × 75	320 × 240
Active screen size	10 mm × 10 mm	75 mm × 54 mm
Phosphors	ZnS:Ag,Cl +In_2O_3- Blue ZnS:Cu,Al+ In_2O_3- Green Y_2O_2S:Eu+ In_2O_3- Red ZnO:Zn - Green $ZnGaO_4$:Mn - Green $CaTiO_3$:Pr - Red	ZnS:Ag,Cl + In_2O_3- Blue ZnS:Cu,Al + In_2O_3- Green Y_2O_2S:Eu + In_2O_3- Red ZnO:Zn - Green $ZnGaO_4$:Mn - Green $CaTiO_3$:Pr - Red
Black matrix	OD : 1.5~2 Resistivity : 10^{10} Ω	OD : 1.5~2 Resistivity : 10^{10} Ω



(a) Residual Gas Products : 1-2(H_2), 43-44(CO_2), 27-28(CO), 16(O_2)
Screen:ZnSCu,Al PhosphorScreen ;
Vacuum Range : 5.0 x 10^{-7} Torr,
Applied Voltage : 1.5 kV;
Divided Pressure Range : 1.0 x 10^{-8} Torr



(b) Residual gas products : 1-2(H_2),
Screen : ZnS:Cu,Al screen coated with PI film;
Vacuum range : 5.0 x 10^{-7} Torr;
Applied voltage : 1.5 kV ;
Divided pressure range : 1.0 x 10^{-8} Torr

Fig. 9. RGA spectrum of gas generated from ZnS:Cu, Al (a) without polymide film and (b) with polyimide film.

properties of phosphor screen as shown in Figure 8.

Figure 9. shows the results of Residual Gas Analysis. Table 1. lists the specification of full color anode plate fabricated in this experiments

IV. Conclusion

In order to improve the image quality and performance, new structure of the anode switching phosphor panel which consists of the powdered phosphor screen, non-crossed addressing lines, black matrix formation and protection layer using polyimide film was suggested. It was found that the anode plate with the excellent brightness and high contrast could be fabricated with few outgassing products.

References

[1] R. Meyer, *Proc. Of Euro Display 93*, pp. 189-192, 1993.
[2] S. K. Park, J. I. Han, W. K. Kim, M. K. Kwak, D. H. Kim and I. K. Lee, *Proceeding of 2nd KSID*, pp. 117-119, 1998.
[3] S. K. Park, J. I. Han, W. K. Kim, M. K. Kwak and D. H. Kim, *Abstract book of IUMRS-ICEM-98*, p. 67, 1998.
[4] R. Meyer, *Proc. Of SID 91*, pp. 437-490, 1991.
[5] Ronald J. Jensen *Mat. Res. Symp. Proc.* **108**, p.73.
[6] Shunichi Numata *Mat. Res. Symp. Proc.* **108**, p. 113.
[7] David wei wang *Mat. Res. Symp. Proc.* **108**, p. 125.