Discharging Characteristics of Green cell Using MgO-Coated $Zn_2SiO_4:Mn^{2+}$ Phosphor in Plasma Display Panel

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Abstract

The charging tendency of $Zn_2SiO_4:Mn^{2+}$ phosphor surface was modified in order to improve discharging characteristic of green cell in an ac-plasma display panel (ac-PDP). The Zinc-silicate ($Zn_2SiO_4:Mn^{2+}$) green-emitting phosphor was coated with magnesium oxide(MgO), which is viable to have positive charge on the surface. After fabricating the green cell with MgO-coated $Zn_2SiO_4:Mn^{2+}$, the electrical and optical properties in the cell were examined. It was found that the dynamic voltage margin could be increased while the address time was reduced. It may be ascribed to the change of charging tendency of $Zn_2SiO_4:Mn^{2+}$ phosphor by MgO coating, which makes it possible to stable wall-charge accumulation. When $Zn_2SiO_4:Mn^{2+}$ phosphor was coated with 1.3wt%-MgO, the address time was reduced 1.2 μs and the address voltage lowered 25 V without any misfiring problem, compared to those of typical $Zn_2SiO_4:Mn^{2+}$ phosphor layer. The luminescence intensity of green cell using MgO-coated phosphor layer was also improved by 10 %.

1. Introduction

In this study, to enhance the address discharge characteristics of the green cell, the surface state of the $Zn_2SiO_4:Mn^{2+}$ phosphor was modified by MgO coating. The main idea of this study is applying an electric field as high as possible between the scan and the address electrodes, utilizing an increased wall voltage by modifying charging tendency of $Zn_2SiO_4:Mn^{2+}$ phosphor. MgO is known as the material, which has most positively charged-surface and was therefore selected as coating material.[1] Besides, MgO has very low sputtering yield and large secondary electron emission coefficient;[2-4] Therefore, it is expected that MgO coating also protect the phosphor surface, as the dielectric layer was protected from sputtering due to ion bombardment in the glow-discharge plasma by MgO-thin films. To confirm the effect of the coated phosphor, the formative and statistical time lags of the address discharge are measured at different green cells of coated and non-coated $Zn_2SiO_4:Mn^{2+}$ phosphor layers. In addition, the dynamic voltage margin and luminescence is also checked relative to a variation in the sustain voltage.

2. Experimental

To adjust the surface charge of $Zn_2SiO_4:Mn^{2+}$ phosphors, we coated surface of phosphor with MgO by using the sol-gel process.[6] Magnesium oxide was selected coating material, because it is the most positively charged,[5] which is very favorable to our purpose. Based on the standard sol-gel processing, $Mg(NO_3)_2$ were first dissolved in pure water and $Zn_2SiO_4:Mn^{2+}$ phosphors were added to the solution and the suspensions were fully dispersed by ultrasonication of 1.67MHz. Ammonia was then dropped into the suspension to control the pH and precipitate the magnesium hydroxide. The coated phosphors were filtered and fired in air at 400℃ for 1hr, in order to oxidize the magnesium hydroxide on the phosphor. The surface morphology and the surface coverage of coated phosphor were optimized by the concentration of dissolved magnesium nitrate, pH of the suspension, and reaction time. Scanningelectron

microscopy (SEM, Philips co. 515) was used for observing the morphology and the size of phosphor particles. The luminescence of phosphor particles were measured under ultraviolet radiation emitted from a deuterium lamp mounted inside the vacuum chamber.

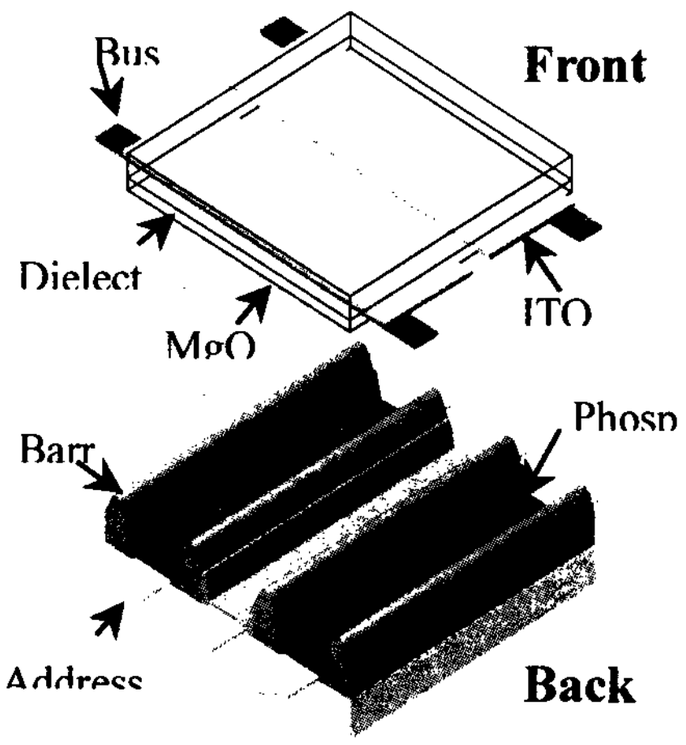


Figure 1. Panel structure used in the experiment

A 4-inch ac-Plasma test panel was fabricated to investigate discharge characteristics. The test panel used in this experiment has the conventional coplanar structure with three electrodes and a stripe type barrier rib, as shown in Fig. 1 with a 1.08-mm pixel pitch and filled with Ne-Xe 4%, 400 torr gas mixture for the standard panel. The driving waveform used in this experiment is shown in Fig. 2. Discharge sustainment was accomplished using a 50 kHz and pulse with a 25% duty ratio. In order to see the addressing discharge time lag (t_d) characteristics, we measured the infrared (IR) light from the lit pixel by using an avalanche photo diode. [7,8] We recorded 200 IR signals for each measurement and analyzed it to determine the address discharge time lag.

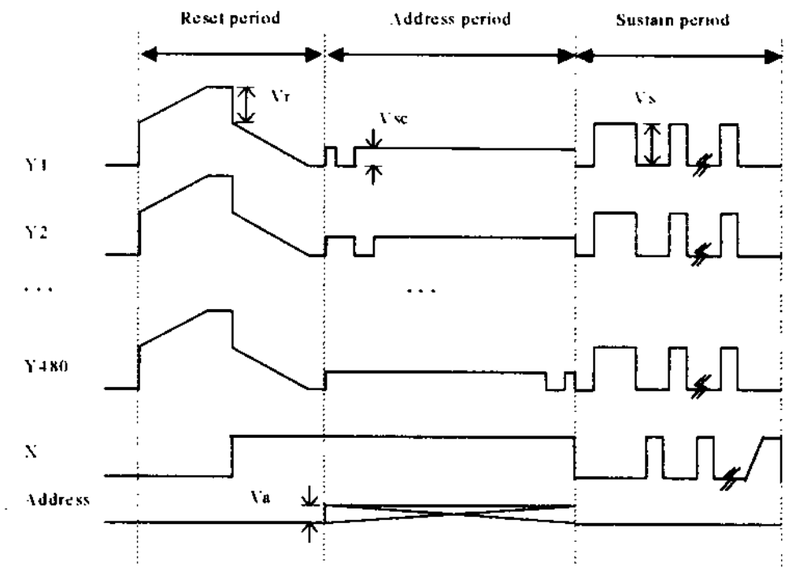


Figure 2. Driving waveform used in the experiment

3. Results and Discussion

Figure 3 shows SEM images of $Zn_2SiO_4:Mn^{2+}$ and MgO-coated phosphors. The pH for precipitation and the reaction time was set to 8 and 15min, respectively. It is observed that the $Zn_2SiO_4:Mn^{2+}$ phosphor has a clean surface and an average particle diameter of about 2 ㎛, as shown in Fig. 3(a). In the MgO-coated phosphors, the number and size of MgO particulate on the phosphor surface increased gradually as the concentration of magnesium nitrate increased in our process. The particulate MgO could be homogeneously coated onto the surface of the phosphor and the coating amounts were easily controlled by adjusting the amount of magnesium nitrate in the precursor solutions. However, the MgO particles were aggregated on the phosphor surface, as the concentration of magnesium nitrate was high in solution. It is obviously shown that the particulate 1.3wt%-MgO is homogeneously coated on the surface of phosphors (Fig. 3(c)).

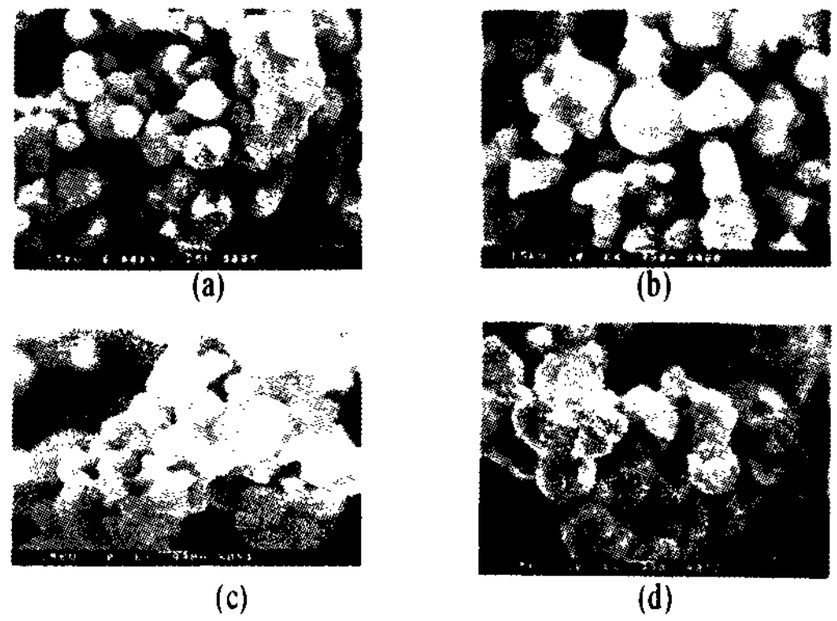


Figure3. SEM images of $Zn_2SiO_4:Mn^{2+}$ phosphor coated with several MgO wt %.
(a) non-coated (b) MgO 0.5wt%
(c) MgO 1.3wt% (d) MgO 2w

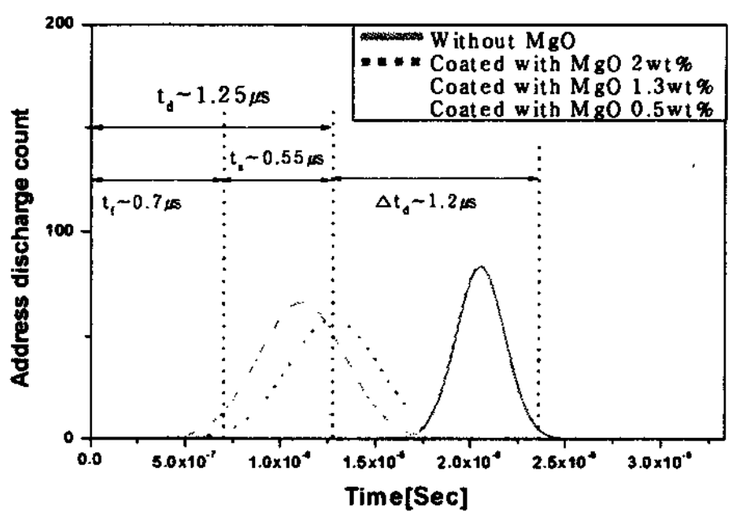
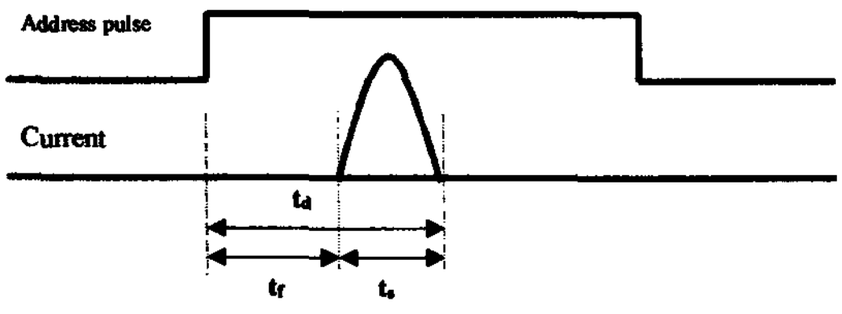


Figure 4. Address discharge time lag as a function of the ratio of MgO coating.

Figure 4 shows the IR-light emission due to the address discharge as a functin of the ratio of MgO coating. According to the statistical nature of discharge, the discharges usually take place with time delays (t_d) after the application of external voltage, as shown in Fig. 5.

Figure 4 shows that the discharge delay time is getting shorter as $Zn_2SiO_4:Mn^{2+}$ phosphor was coated with MgO. At the same scan voltage, when the address voltage is 57.1 V, delay time is about 1.2 μs shorter than that of the case in that $Zn_2SiO_4:Mn^{2+}$ phosphor was not coated.



$$t_d = t_f + t_s$$

Where,
t_d = total time lag
t_f = formative time lag
t_s = statistical time lag

Figure 5. Definition of address discharge time lag

The address discharge time lag depends on the strength of electric field between these two electrodes.[9] From Fig. 6, it is deduced that the wall charge is stably accumulated during ramp reset period as the charging tendency of phosphor was modified by phosphor coating and high electric field was generated between the scan and address electrodes in which the address discharge occurs.

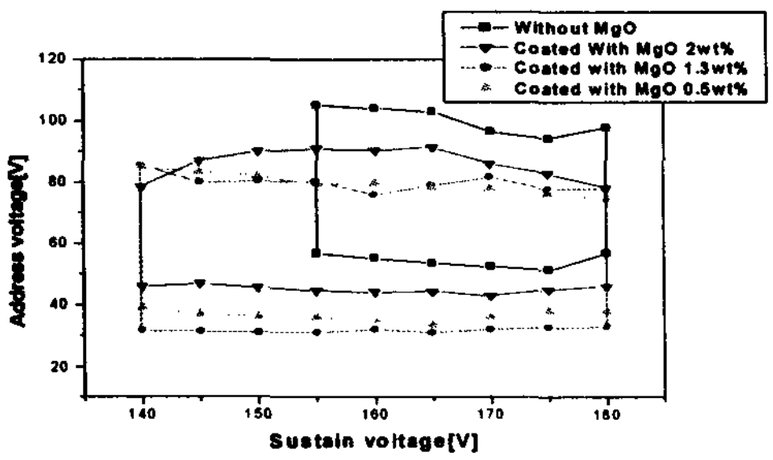
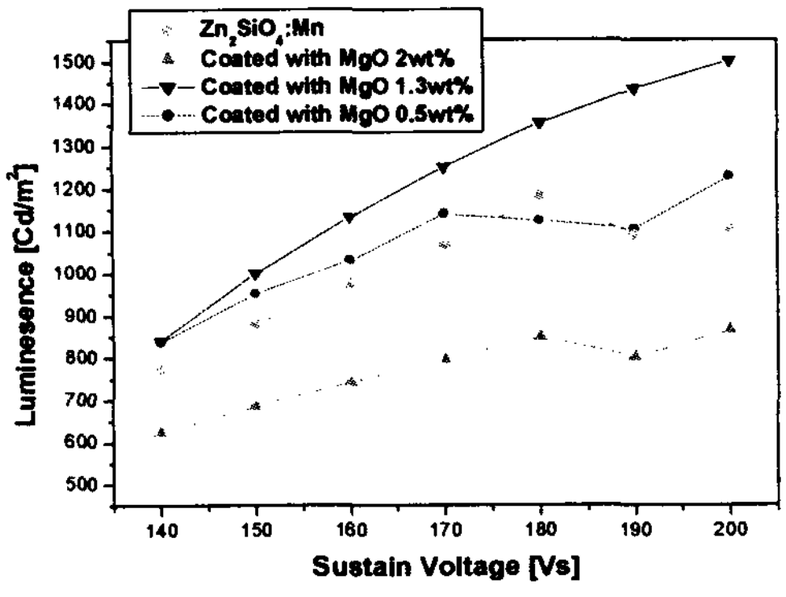
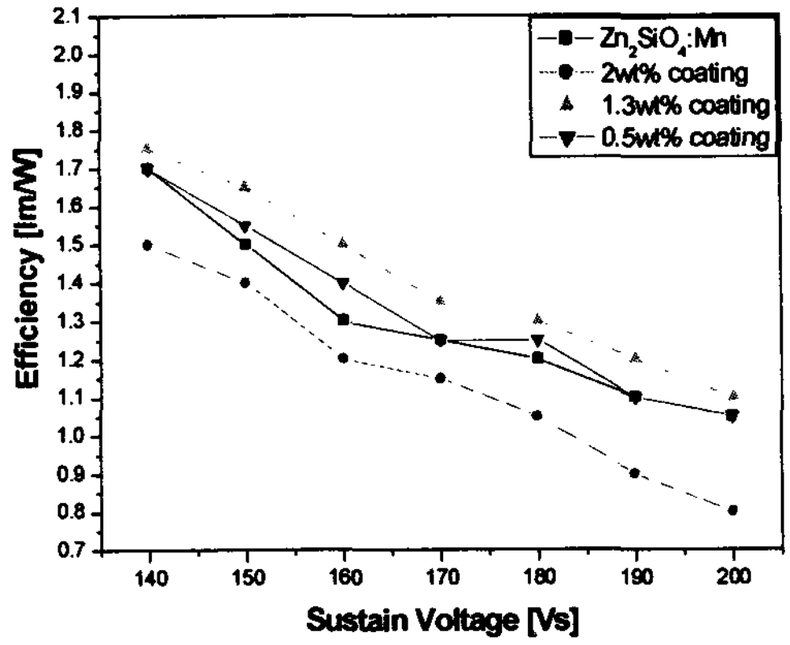


Figure 6. Dynamic voltage margin according to the ratio of MgO coating

The variations in the dynamic voltage margin according to the ratio of MgO coating are illustrated Fig.6. The margin data in Fig. 6 show that $Zn_2SiO_4:Mn^{2+}$ phosphor coating significantly improved the dynamic voltage margin characteristic, when compared with the non-coated $Zn_2SiO_4:Mn^{2+}$ phosphor layer. As indicated by the result for the coated $Zn_2SiO_4:Mn^{2+}$ phosphor of Fig. 6, the voltage level of address pulse was reduced to 30 V with 1.3wt% MgO-coating. It can be explained that the charging tendency of modified phosphor surface helped to accumulate more wall charges on the electrodes, resulting in a wide stable dynamic voltage margin as shown in Fig. 6.



(a)



(b)

Figure 7. Luminescence and its efficiency of each panel as a function of sustain voltage
(a) Luminescence (b) Luminescence efficiency

Figure 7(a) shows the luminescence of each cell as sustain voltage increases. The green cell made with MgO-coated phosphor had a better luminescence than the reference green cell, which had no MgO

treatment. Better luminescence, even after MgO-coating of $Zn_2SiO_4:Mn^{2+}$ phosphor, is believed to be from stronger discharge.

The luminous efficiency (η) is shown as the following equation:

$$\eta = \frac{\pi SB}{V(I - I_0)}$$

where ***S***, ***B***, and ***V*** indicate the luminous area, luminance and applied voltage, respectively. ***I*** means the discharge current on the condition that all of pixels in the measured region are discharged, while I_0 indicates the displacement current on the condition that all of pixels in the same region are not discharged. Figure 7(b) shows that the luminous efficiency as a function of the sustaining voltage. The amount of VUV generation is an important factor that affects the luminous efficiency of PDP, because the PDP uses the micro-discharge in order to generate VUV for excitation of phosphor. The luminous efficiency decreases with increase of the sustaining voltage, because more power flows to ionization rather than to excitation. The luminous efficiency of coated $Zn_2SiO_4:Mn^{2+}$ phosphor layer was also higher than thatof non-coated phosphor. Higher luminous efficiency of MgO-coated phosphors is well explained by the fact that relative large amount of VUV were generated by the strong discharge in the cell.

4. Conclusion

In this work, we proposed MgO-coating of $Zn_2SiO_4:Mn^{2+}$ phosphor for improving the characteristics of an address discharge, including a reduced address time and increased dynamic voltage margin, based on the property of phosphor surface. It was demonstrated that the surface charge of the phosphor layer in the green cell of ac-PDP could be modified through the coating of MgO on the phosphor for compensating the negative surface charge of $Zn_2SiO_4:Mn^{2+}$ phosphor. Consequently, it was found that the address discharge characteristics of green cell were improved by the high electric field effect between address and scan electrodes due to the stable wall charge accumulation during the reset period. When the $Zn_2SiO_4:Mn^{2+}$ phosphor was coated with 1.3wt%-MgO, green cell exhibited the best address discharge characteristics, including a lower address voltage of 25 V with a shorter address time of 1.2 μs and no misfiring problem, compared to non-coated $Zn_2SiO_4:Mn^{2+}$ phosphor layer. Moreover, the improvement of brightness was observed due to the increased discharge efficiency.

5. Reference

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