Electron Emission Characteristics of $12CaO\ 7Al_2O_3$ for Glow Discharge in Plasma Display Panel

Mi-Yeon Lee, Hak-Nyun Choi, Jeong-Yeol Kim*, Kuk-Sun Hong*, and Yong-Seog Kim
Department of Materials Science and Engineering, Hongik University, Seoul 121-791, Korea
Department of Materials Science and Engineering, Seoul National University, Seoul 151-742, Korea
Phone: +82-2-322-0644 E-mail: dlaus40@naver.com

Abstract
In an attempt to enhance secondary electron emission characteristics of PDP, $12CaO\cdot 7Al_2O_3$ electride was used as electron emission layer of PDP discharge cells. The compound was synthesized by Ca-treatment and its electron emission behavior during the glow discharge was measured. The results indicated that the spayed electride reduces the discharge voltage by ~20 volts and decrease the discharge delay by more than 70%.

1. Introduction
MgO coating on transparent dielectric layer has been used as secondary electron emission material for glow discharge in PDP discharge cells. The electron emission from MgO, however, has been noted to be affected sensitively by various parameters, including atmosphere, humidity, temperature, aging treatment and impurities. These traits make the coating as one of the most critical elements for PDPs.

MgO compound is a typical ionic compound which has very low intrinsic defect concentration such as vacancies, interstitials, free electrons and holes. Mole fraction of oxygen vacancy concentration was estimated to be ~10^{-29} at 400°C. Therefore, it is expected that small variations of parameters like atmosphere, humidity, and impurities should create extrinsic defects of which concentrations are orders of magnitude higher that the intrinsic defects. This phenomenon will eventually influence the discharge behavior of PDPs.

In order to develop material with intrinsic electron emission behavior, the defect concentration in the materials should be higher than hundreds ppm since the impurity concentration in commercially available materials is in that range. One of the prime candidates is the electride materials. Electride is an ionic compound between electron anion and metallic cation.[1]

Recently, $12CaO\cdot 7Al_2O_3$ compound has been found to exhibits electride characteristics up to 500°C at atmospheric environment. This material has been identified to have local conduction band within global band gap [2]. The local conduction band has similar energy level of F-type centers of MgO which is responsible for secondary electron emission. With the electride, the density of state of the local conduction band is on the order of few percents and has possibility of greatly affect the electron emission during glow discharge of plasma display panel.

In this study, electride was synthesized in powder form and sprayed on the surface of MgO layer to enhance secondary electron and exo-electron emissions. The discharge voltage and apparent yield of secondary electron emission were measured from Paschen curves. In addition, discharge delays of the panels were also measured. The results demonstrated that the use of electride as electron emission layer may improve the electron emission characteristics significantly.

2. Results

2-1. Experimental procedures
$12CaO\cdot 7Al_2O_3$ compound was synthesized by heating $Al(OH)_3$ and $CaCO_3$ compound mixture pellet to 1300°C for 8 hours. In order to completely convert the mixture to a single phase, the reaction product was milled after the reaction and heated again to the same treatment cycle. In order to convert this material to the electride, Ca-treatment was conducted by packing with Ca nugget in a quartz tube. The quartz tube was vacuum sealed and heated to 700~800°C for 40 hours.[3]

$12CaO \cdot 7Al_2O_3$ powder obtained was mixed with MgO powder of 100nm in diameter. The volume fraction of $12CaO \cdot 7Al_2O_3$ powder was 20%. The powder mixture was mixed with organic vehicle to prepare paste for spin coating on front glass substrate. The thickness of the layer formed was approximately 5μm. The front plate was sealed with rear plate which was coated with green phosphor layer to measure luminance and luminance efficiency.

2-2. Band gap structure of $12CaO \cdot 7Al_2O_3$

Band gap structure of $12CaO \cdot 7Al_2O_3$ was examined by measuring absorption at visible-IR range. With the $12CaO \cdot 7Al_2O_3$ compound in as-produced condition, defect levels or local conduction band was detected as shown in Fig. 1. After the Ca-treatment of the compound, absorptions near 2.8 and 0.4eV were detected. This confirms the formation of $12CaO \cdot 7Al_2O_3$ electride.

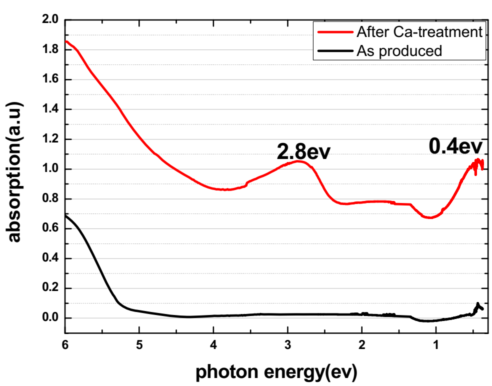

Fig. 1. Optical absorption in visible-IR range on as-produced and Ca-treated $12CaO \cdot 7Al_2O_3$ compound.

For the electride to be used as electron emission layer of PDP, it must undergo thermal cycles up to 570°C under air atmosphere. Thus, thermal stability of the electride was evaluated by heating the electride under air atmosphere in a temperature range from 150 to 460°C. Color of the electride as produced condition is green-black. As the temperature is increased, color of the electride became grey and eventually white at temperature of 460°C.

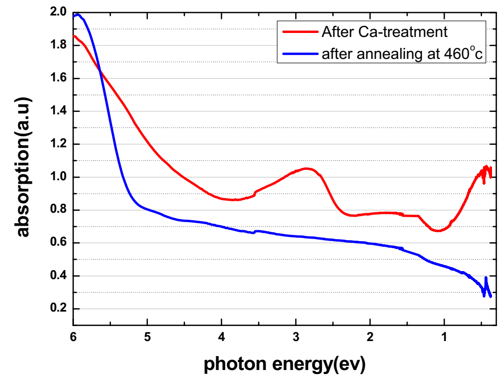

Fig.2.Thermal stability of Ca-treated$12CaO \cdot 7Al_2O_3$ electride.

As shown in Fig. 2, the local conduction band at 2.8eV and trap level at 0.4eV disappeared with the compound when heated at 460°C. This indicates that the thermal stability of electride is rather poor. Thus, in this study, the maximum processing temperature during panel sealing process was kept low as possible.

Cathodoluminescence spectra from the Ca-treated $12CaO \cdot 7Al_2O_3$ compound before and after annealing treatment at 460°C. The energy levels of the defect structures of Ca-treated $12CaO \cdot 7Al_2O_3$ electride appeared similar to those of MgO as shown in Fig. 3. The annealing treatment, however, increased the intensity of the CL spectra.

This may be caused by reduction of state density of local conduction levels in the electride with the treatment.

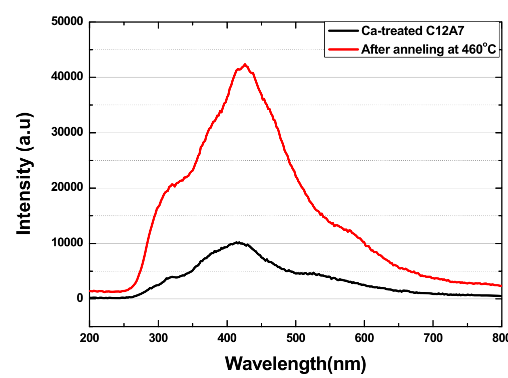

Fig. 3. CL spectra of Ca-treated $12CaO \cdot 7Al_2O_3$ compound prior to and after heat treatment at 460°C.

2-3. Discharge characteristics of test panel with Ca-treated of $12CaO \cdot 7Al_2O_3$ electride

Paschen curve of test panel with Ca-treated $12CaO \cdot 7Al_2O_3$ –MgO powder mixture coated on front glass surface was measured and compared with the panel coated with conventional MgO (Fig. 3). As noted from the figure, the firing voltage was decreased by ~20V with the use of the electride. The results also revealed that the electride increased the yield slightly over that conventional MgO layer.

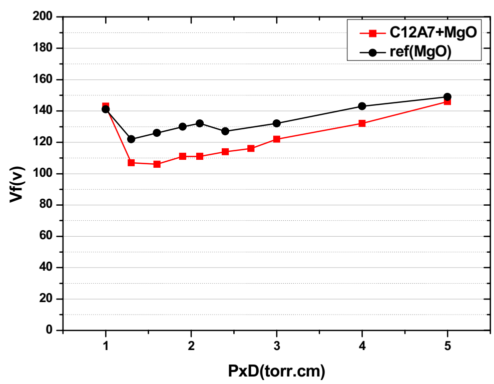

Fig. 4. Paschen curve of MgO with Ca-treated $12CaO \cdot 7Al_2O_3$ electride powder sprayed.

Figure 5 shows the luminance efficiency of the test panel coated with with MgO-20%$12CaO \cdot 7Al_2O_3$ electride powder. As noted from the figure, the luminance efficiency was enhanced approximately 20% with the use of the electride. Higher secondary electron yield from the electride should have contributed to the enhanced luminance efficiency.

Discharge delays test panel coated with MgO-20%$12CaO \cdot 7Al_2O_3$ electride were measured (Fig. 6). The discharge delay of the test panel was significantly reduced with the use of the electride, suggesting emission of priming electrons by the electride

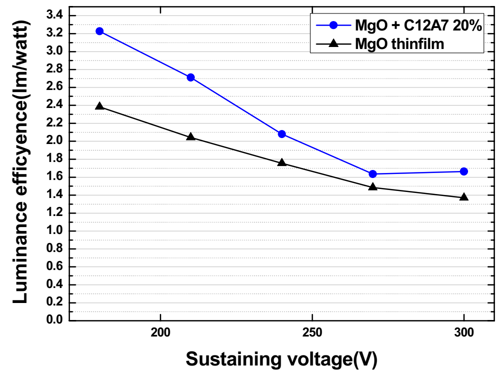

Fig. 5. Lumiance efficiency of test panel coated with MgO-20%$12CaO \cdot 7Al_2O_3$ electride.

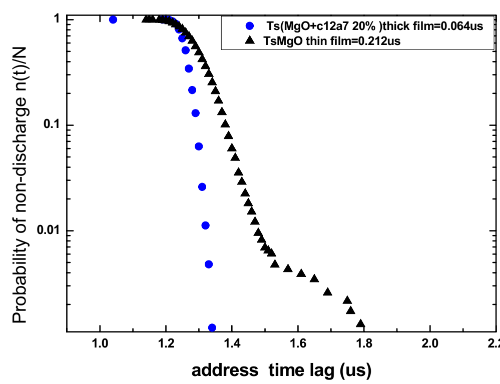

Fig. 6. Discharge delays of test panel coated with MgO-20%$12CaO \cdot 7Al_2O_3$ electride.

3. Conclusion

In this study, $12CaO \cdot 7Al_2O_3$ electride was used as electron emission layer of PDP discharge cells. The compound was synthesized by Ca-treatment and its electron emission behavior during the glow discharge was measured. The results indicated that the spayed electride reduces the discharge voltage by ~20 volts and decrease the discharge delay by more than 70%. These results showed a possibility of using the electride as a new electron emission layer for PDP in future

4. Acknowledgements

This work was supported by Authors would like to thank NRL research program of Korean government for financial assistance for this study.

5. References

[1] JL.Dye,Scientific American,V257(3),66(1987)

[2] V.Sushko,A.L.Shluger,K.Hayashi,M.Hirano,H.Hosono :Thin solid Films V.445,161(2003)

[3] S.Matsuishi,M.Miyakawa,K.Hayshi,T.Kamiya,M. Hirano,I.Tanaka,H.Hosono,science301,626(2003) .