MgO Properties Depending on E-beam Evaporation Rate and Its Effects on the PDP Discharging Characteristics

Sang Jik Kwon*, Yong Jae Kim, Zhao Hui Li, Kwang-Ho Kim, Dal Ho Lee
Dept. of Electronics Eng., Kyungwon University, San 65, Bokjung-dong, Soojung-gu, Seongnam City, Kyunggi-do 461-701, Korea
Tel: +82-31-750-5319, E-mail: sjkwon@kyungwon.ac.kr

Abstract
Effects of the evaporation rate of MgO films using electron beam were investigated on the MgO properties and the discharge characteristics of the plasma display panel (PDP). The evaporation rate was changed from 3 Å/sec to 15 Å/sec at a substrate temperature of 300 ℃. MgO properties such as crystal orientation, surface roughness, contact angle, and film structure were inspected using XPS, AFM, drop shape analysis and SEM. We also studied the relation between MgO properties and PDP discharging characteristics. The minimum firing voltage and maximum efficacy were obtained at evaporation rate of 5 Å/sec. In the MgO film deposited at 5 Å/sec, (200) orientation was most intensive and surface roughness was minimum.

1. Introduction
One of very successful technologies for large-format displays is the plasma display panel (PDP). However, for its further expansion in share of the large-sized display market, it is great importance to reduce the cost of manufacturing and improve its luminous efficiency. Most issues in reducing PDP fabrication cost are focused on reducing the processing time. MgO process is also one of the processes limiting the throughput of PDP fabrication. MgO thin film is generally used for protecting the dielectric layer of ac PDP owing to its good anti-sputtering property and the large secondary electron coefficient resulting in the lower firing voltage. Until now, it is well known that electron beam evaporation is most effective method for depositing MgO film on the dielectric layer. However, it takes too long time for obtaining a relatively large thickness such as 5,000 Å with a limited evaporation rate. In order to reduce the processing time, higher evaporation rate is necessary. But, there is a trade-off between deposition rate and PDP performance.

In this study, we have observed the MgO properties and the PDP discharge characteristics with different evaporation rate. Through the comparison between MgO properties and PDP characteristics, we were going to find the optimum evaporation rate for PDP performance and the main factor affecting the PDP efficiency of several MgO properties such as orientation, surface roughness, and contact angle etc.

Orientation, surface roughness, contact angle, and columnar structure were measured using x-ray diffractometer (D/MAX-2200, RIGAKU), atomic force microscopy (XE-150, PSIA), drop shape analysis (G10/DSA10, KRÜSS), and SEM (S-4700, HITACHI) respectively. And the PDP panels with active diagonal size of 2 inch were fabricated using a photo-aligner (EV 620), a screen printer (MT-550TV), electron-beam evaporator, and furnace, etc. The discharging characteristics of the PDP were measured using a vacuum chamber with oscilloscope (TDS 540C), current probe (TCP-312A), color meter (CS-100A).

2. Experimental Procedures
Figure 1 shows the cell structure of the PDP panel fabricated for the experiment. The PDP panel in our study is composed of two glass substrates (PD-200, ASAHI glass, Japan). The glass plate has a size of 6 cm × 9 cm and a thickness of 2.8 mm. The size of effective luminescent area is 3.5 cm × 3.5 cm. All the processes were done using a photo aligner, a screen printer, a furnace, and an in-vacuum sealing and characterization system, etc. installed in a clean room. For the front panel, bus electrodes were printed on the ITO-patterned glass using screen printing method, and then dielectric layer was printed over the bus electrodes with a thickness of about 24 μm, and then MgO layer was deposited using an e-beam evaporator on the dielectric layer with a thickness of 5,000 Å.

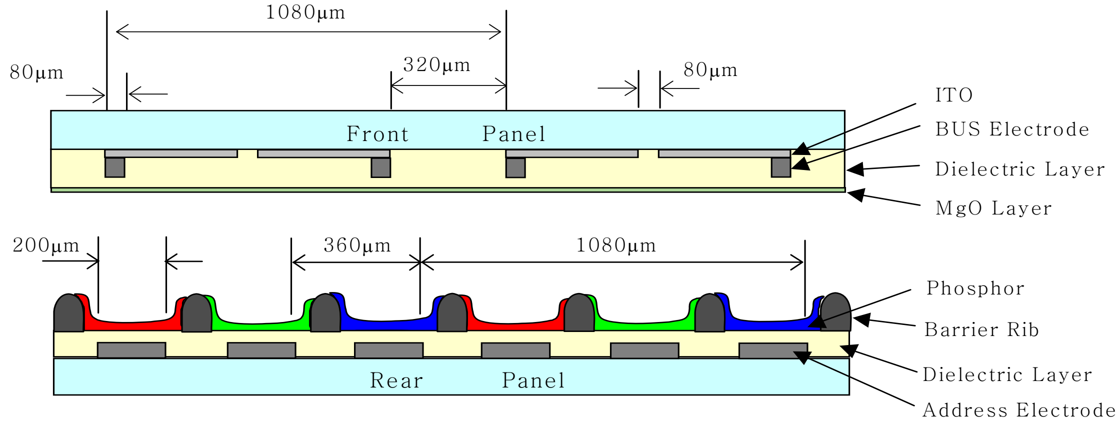


Figure. 1. The cell structure of 2" test panel fabricated for the experiment

The deposition rate was varied from 3 to 15 Å /sec with a substrate temperature of 300 °C. For the rear panel, address electrodes were first printed on the glass substrate, and the dielectric layer, of which thickness is about 24 μm, was printed over the address electrodes, then the barrier ribs with a height of 120 μm were printed on the dielectric layer using screen printing method, and finally the phosphor layer was printed between the barrier ribs.

In order to investigate the electrical and optical characteristics of PDP, the front glass plate and the rear glass plate were placed into a vacuum chamber, facing each other with a gap distance given by the barrier ribs. The chamber was evacuated to 1×10^{-6} torr using a turbomolecular pump. The Ar gas was filled up to 250 torr and the panel was annealed at 300 °C for 1 hour. After annealing, the chamber was again evacuated to the base vacuum level of about 1×10^{-6} torr at room temperature. After evacuation, the gate valve of the turbomolecular pump was closed and the gas mixture of Ne with 4% Xe was introduced into the chamber until the gas pressure indicated by a pressure gauge was reached to 400 torr. Driving pulse voltages were supplied to sustain (X) and Scan & Sustain (Y) electrodes of the front glass plate. Address (Z) electrodes of the rear glass plate were maintained at ground level. The frequency of the rectangular pulses was 50 kHz and the width of the pulse was 3.0 μs. The discharge current including displacement current was measured using a current probe (TCP-A312) and luminous efficiency was measured using a chroma-meter (CS-100A).

3. Results and Discussion

We have observed the XRD spectra for the MgO films deposited on the dielectric layer with different deposition rate and annealed at 300 °C for 1 hour. As shown in Fig. 2, (200) orientation is preferred for relatively low deposition rate such as 3, 5, 7 Å /sec and disappeared as the deposition rate increases higher than 10 Å /sec. It is noticed that the (200) peak was most prominent at 5 Å /sec. Interestingly, the surface roughness was changed inversely to the change trend of (200) peak depending on the deposition rate.

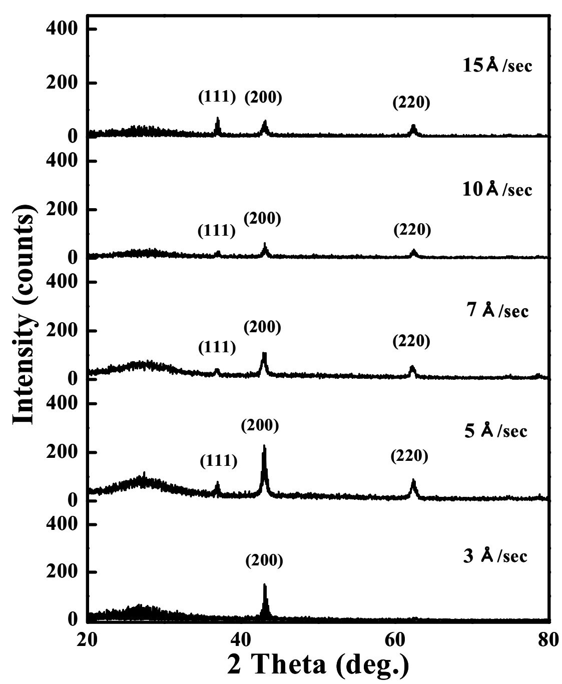
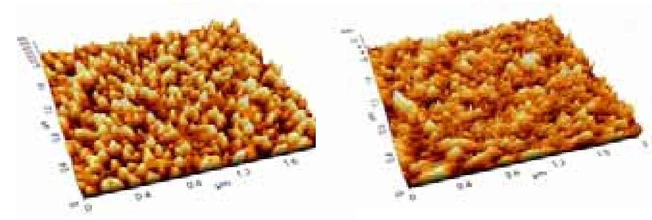
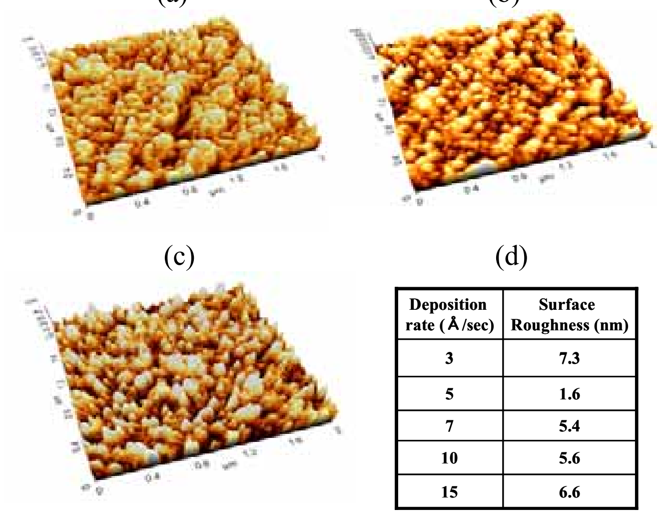


Figure. 2 XRD spectra of MgO films deposited with the different MgO deposition rate.



(a) (b)

(c) (d)



Deposition rate (Å/sec)	Surface Roughness (nm)
3	7.3
5	1.6
7	5.4
10	5.6
15	6.6

(e) (f)

Figure. 3 AFM surface roughness of MgO films deposited with different MgO deposition rate : (a) 3, (b) 5, (c) 7, (d) 10, (e) 15 Å /sec and (f) summary.

That is, the surface of MgO film deposited at 5 Å /sec was most smooth as shown in the AFM photos of Fig. 3. However, the contact angle of the as-deposited MgO film on the dielectric layer was largest at 5 Å /sec as shown in Fig. 4.

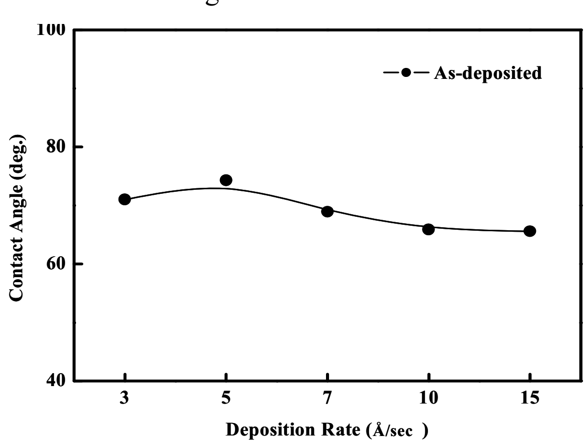


Figure. 4. Contact angle of as-deposited MgO films with different MgO deposition rate

The firing voltage(V_f) is defined as the applied voltage between the electrodes X and Y when the first cell turns ON, The sustain voltage(V_s) is defined as the voltage when the first cell turns OFF. Figure 5 shows the dependences of V_f and V_s on the deposition rate for the annealed PDP panels.

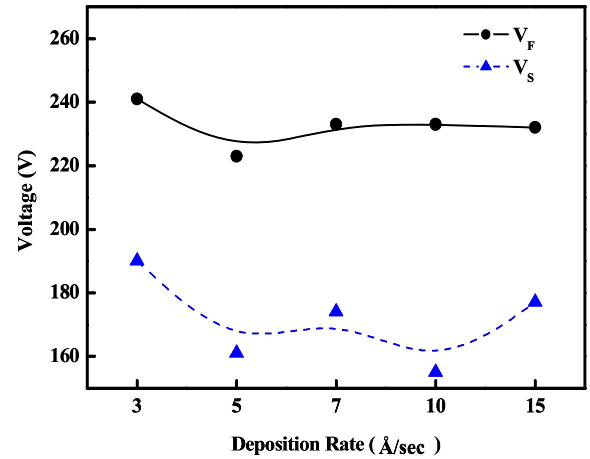


Figure. 5 Firing voltage variation with various MgO deposition rate

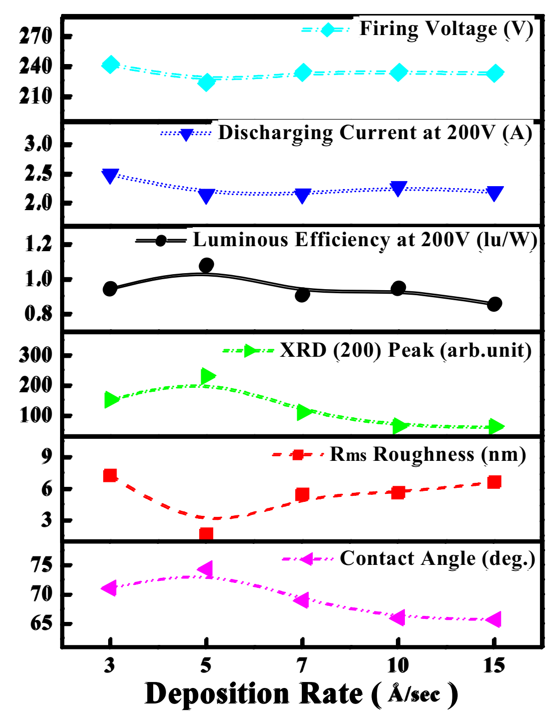


Figure. 6 Comparison between MgO properties and PDP discharging characteristics depending on MgO deposition rate

It is seen from Fig. 5 that the firing voltage is minimum as 223 V at 5 Å /sec and the resultant luminous efficiency(η) is maximum as 1.1 lm/W at the same deposition rate. It is well known that the discharge characteristics are so much dependent on the species, the content of gas mixture, the discharge gas pressure, and the crystallinity and the density of MgO protective layer [1-4]. In this experiment performed with different MgO deposition rates, we can see that the crystallinity of (200) orientation and surface roughness are very important factors affecting the firing voltage and efficiency, which is well summarized in the Fig. 6 showing the comparisons between above all factors with different deposition rates.

4. Conclusuina

We have observed the MgO properties and PDP discharge characteristics with several different deposition rate such as 3, 5, 7, 10, and 15 Å/sec. Of those rates, 5 Å /sec resulted in the minimum discharge inception voltage of 223 V. The MgO film deposited at 5 Å /sec has the most preferred (200) orientation, most smooth surface, and largest contact angle. These results indicate that the optimum deposition rate should be founded for obtaining the preferred (200) orientation and smoother surface of MgO protecting layer which seem to be major factors of MgO properties for enhancing PDP performance.

5. Acknowledgements

This work was supported by GRRC program

6. References

[1] G. Oversluizen, S. Zwart, M. F. Gillies, T. Dekker, T. J. Vink, Microelectronics J. 35, 319(2004).

[2] E. H. Choi, H. J. Oh, Y. G. Kim, J. J. Ko, J. Y. Lim, J. G. Kim, D. I. Kim, G. S. Cho, and S. O. Kang, Jpn. J. Appl. Phys. 37, 7015(1998).

[3] A. Saito, T. Maeda, M. Tone, T. Shiga, S. Mikoshiba, SID04 Digest, 210(2004)

[4] Z. N. Yu, J. W. Seo, S. J. Yu, D. X. Zheng, J. Sun, Surf. And Coatings Tech., 162, 11(2002)