Influence of Silicon and Seed Particles on the Reconstruction Characteristics and Exaggerated Grain Growth of MgO Protective Layer by Over-Frequency Accelerated Discharge in ACPDPs

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Keywords : MgO, reconstruction, EGG, silicon, seed particle, charged cluster

Abstract

The influences of silicon and MgO seed particle on the reconstruction characteristics of MgO protective layer were investigated to clarify the mechanism of reconstruction and exaggerated grain growth (EGG) in AC-PDP. The reconstruction and EGG are closely correlated with the driving force for nucleation and growth, interface energy and initial size distribution of MgO protective layer in plasma space during discharge in AC-PDP.

1. Introduction

In AC-PDP, a protective layer plays a very important role for the protection of dielectric and electrode layer as well as the promotion of discharge characteristics. Magnesium oxide (MgO) film is widely applied for the protecting layer due to its high anti-sputtering characteristic and secondary electron emitting ability 1. Generally, MgO (111) textured structure is used in industry due to high productivity with fast growth rate on amorphous dielectric layer in AC-PDP. On these reasons, MgO protective layer is the key material and necessarily required to be developed because it dominates the lifetime and discharge characteristics of AC-PDP.

The degradation of MgO protective layer has been one of the most important problems in AC-PDP that should be solved for the advance in PDP technology. The degradation of MgO protective layer has been explained simply by erosion but the mechanism is still unclear 2,3. Therefore, the variations of MgO protective layer by discharge in AC-PDP are of great importance to be studied for the advance of high efficiency AC-PDP. Recently, the mechanism of reconstruction characteristics and exaggerated grain growth (EGG) on MgO protective layer by discharge in AC-PDP was newly proposed by the defect-assisted 2-D and/or 3-D nucleation and growth of charged clusters mainly through evaporation and condensation process due to cyclic damages under low energy ion flux distribution with extremely low sputtering yield of MgO protective layer in plasma space strongly affecting the electronic states of MgO surface during discharge process in AC-PDP 4,5. On these backgrounds, the influences of silicon and MgO seed particle on the reconstruction and EGG of MgO layer by over-frequency accelerated discharge were investigated to clarify the mechanism of reconstruction and EGG during discharge in AC-PDP.

2. Experimental

AC plasma display panels with undoped and Si-doped MgO protective layers were prepared and MgO layers with textured structure were grown to <111> preferred orientation. Also, MgO seed particles were added to the MgO layer to investigate the effect of Si and MgO seed particle on the reconstruction and EGG behaviors. Prepared panels were discharged by over-frequency accelerated discharge for sufficiently long time to investigate the influences of Si and MgO seed particles on the reconstruction and EGG characteristics of MgO protective layer. After discharge, the panels were separated and MgO protective layer in the front panel was analyzed. The variation in the morphology of MgO protective layer was observed by field emission scanning electron microscope (FE-SEM) and structural variations were analyzed by X-ray diffraction (XRD) and grazing incidence X-ray diffraction (GIXD) using synchrotron radiation at Pohang light source (PLS) in Korea.

3. Results and discussion

Figure 1 show the typical morphology of as-grown MgO (111) textured protective layer and seed particle added on the MgO protective layer. Triangular pyramid shape of MgO layer is {100} facets due to the reconstruction of MgO (111) surface to minimize the surface energy related with Madelung potential and added seed particles are much larger than matrix grains of MgO protective layer.

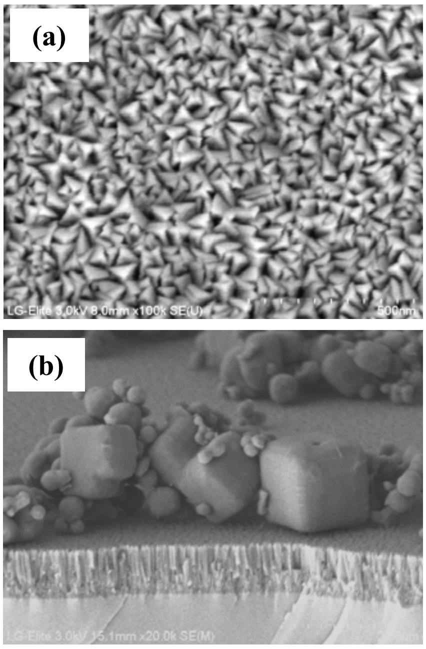

Fig. 1. SEM image of as-grown MgO (111) textured protective layer and MgO seed particles in AC-PDP.

Figure 2 reveals the variation in the morphology of undoped and Si-doped MgO protective layers by over-frequency accelerated discharge in AC-PDP. The typical reconstruction process of MgO (111) textured protective layer and grain growth were observed at the MgO surface by discharge consuming triangular pyramid shape of the MgO layer, as revealed in Fig. 1 (a). However, the reconstruction characteristics revealed a preferred orientation in both cases with the same direction and thus, these results indicate evidently that material transfer of MgO layers is strongly affected by the electric field of sustain operation regardless of doping elements during over-frequency accelerated discharge in AC-PDP.

EGG occurred in the matrix of undoped MgO protective layer and very large grains were identified consuming the matrix grains revealed in Fig. 2 (a) and Fig. 3 (a). However, EGG was drastically suppressed by the addition of Si during discharge in AC-PDP, as shown in Fig. 2 (b) and Fig. 3 (b), and this is believed to the change of interface energy due to the addition of Si to MgO protective layer.

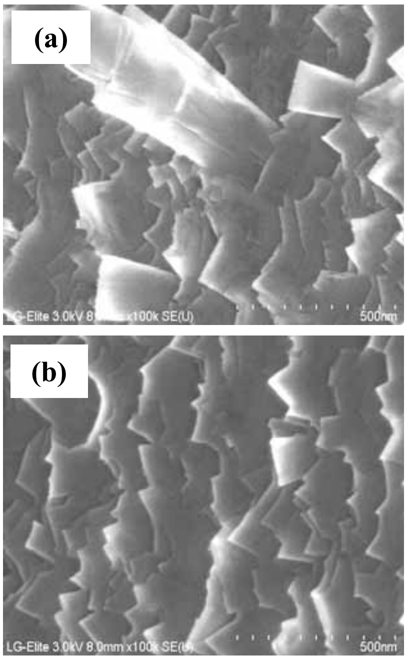

Fig. 2. SEM images of the morphology of (a) undoped and (b) Si-doped MgO surface by over-frequency accelerated discharge in AC-PDP.

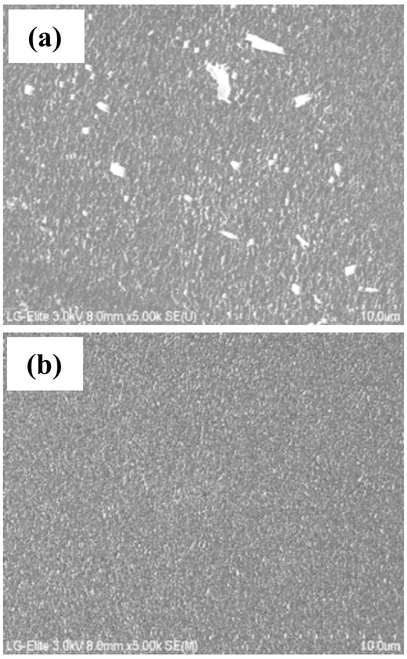

Fig. 3. SEM images of discharged regions in (a) undoped and (b) Si-doped MgO by over-frequency accelerated discharge in AC-PDP.

XRD profiles for out-of-plane and in-plane of MgO (111) textured protective layer before and after over-frequency accelerated discharge in AC-PDP revealed that the intensities of (111) and (220) planes were nearly similar but slightly broadened by discharge. In contrast, the tendency of (200) plane was quite different that the intensity for *h*-scan of (200) plane was drastically increased and this behavior indicates that the reconstruction process proceeds to <200> preferred orientation by discharge, as revealed in Fig. 4. However, the increase of (200) plane was drastically suppressed by the addition of Si and this is well consistent with the results in Fig. 2 and 3.

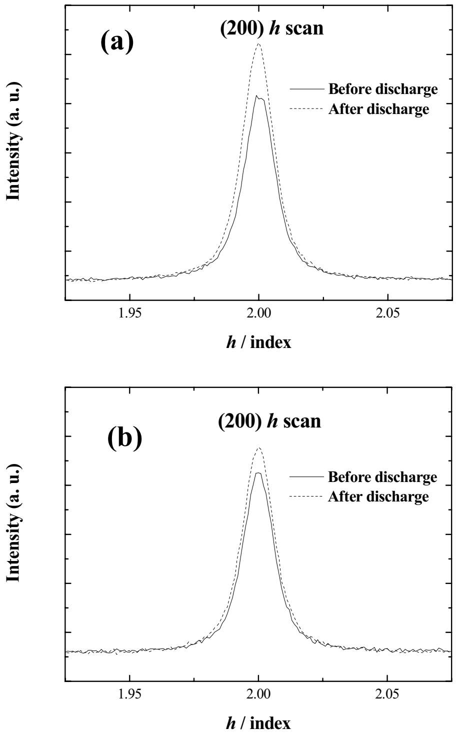

Fig. 4. XRD profiles of (200) plane of (a) undoped and (b) Si-doped MgO layer before and after over-frequency accelerated discharge in AC-PDP.

Grazing incidence X-ray diffraction (GIXD) profiles showed that (200) peak, which was not detected in the initial stage, increased significantly after over-frequency accelerated discharge in both cases as shown in Fig. 5. This indicates that the surface reconstruction and EGG happens to the preferred orientation related with {200} faces by discharge under electric field in AC-PDP. However, the intensity of (200) plane was drastically suppressed by the addition of Si and these results are in good accordance with the previous results of Fig. 2, Fig. 3 and Fig. 4. Therefore, these results are attributed to the suppression of reconstruction process and EGG by the addition Si resulting in the variation of interface energy of MgO protective layers in plasma space during discharge in AC-PDP.

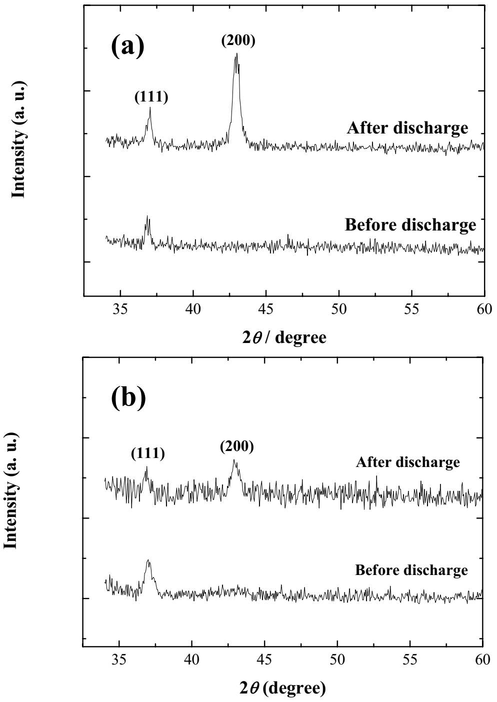

Fig. 5. GIXD profiles of (a) undoped and (b) Si-doped MgO layer before and after over-frequency accelerated discharge in AC-PDP.

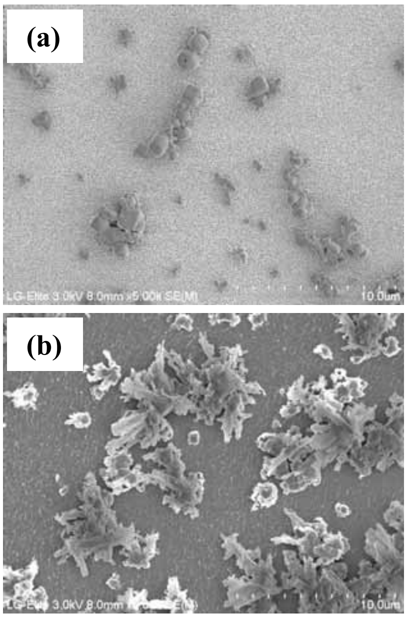

Fig. 6. SEM images of MgO protective layer added seed particles (a) before and (b) after over-frequency accelerated discharge in AC-PDP.

Figures 6 revealed the variation in the morphology of MgO protective layer by the addition of MgO seed particles before and after over-frequency accelerated discharge in AC-PDP. In case of MgO protective layer with the addition of seed particles, the reconstruction and EGG are strongly influenced by the addition of MgO seed particle to the protective layer. Material transfer concentrated on seed particles and thus, EGG was accelerated by the addition of MgO seed particle during discharge in AC-PDP. These results indicate that the reconstruction process and EGG are strongly influenced by the initial size distribution of MgO protective layer.

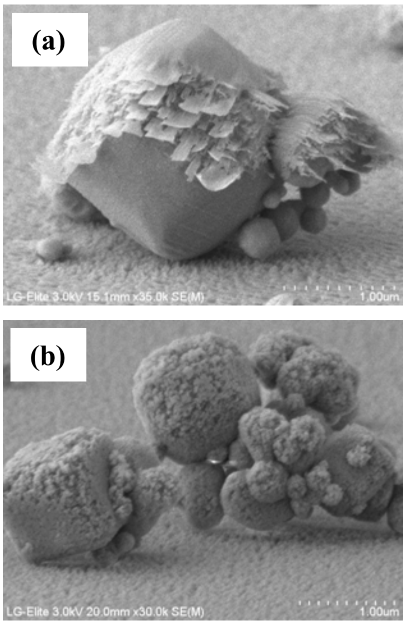

Fig. 7. SEM images of MgO protective layers added seed particles at (a) discharged and (b) gap regions after over-frequency accelerated discharge in AC-PDP.

Generally, charged clusters are known to be easily formed in plasma space. In both cases, grain growth was happened not by the atomic unit resulting in epitaxial growth maintaining the shape of MgO seed particles but by cluster formation through gas phase nucleation in plasma space resulting in 3-D nucleation and growth at the surface of MgO seed particles, as shown in Fig. 7 (a) and (b). Besides, the growth behaviors at discharged and gap regions were quite different and this indicating a strong electric field dependence at sustain discharged region. The growth morphology on the MgO seed particles at the gap region was observed to be like cauliflower structure, which is often observed in charged clustered model, and it suggests the strong evidence of cluster formation in plasma space during discharge in AC-PDP.

In this study, the reconstruction and EGG are closely correlated with the driving force for nucleation and growth, interface energy and initial size distribution of MgO protective layer during discharge in AC-PDP. Besides, the evidence of grain growth through charged clusters was identified by the addition of MgO seed particle to the protective layer and thus, material transfer during grain growth is believed to occur by charged clusters in plasma spaces. Therefore, these results confirmed that the surface reconstruction and EGG during discharge in AC-PDP can be explained by defect-assisted 2-D and/or 3-D nucleation and growth of charged clusters under the electric field of sustain operation. These behaviors are closely correlated with the electronic states at the surface of MgO protective layer and this is expected to be one of the most important parameters to affect discharge characteristic in AC-PDP.

4. Summary

The mechanism for the reconstruction process and EGG of MgO protective layer in AC-PDP were proved and confirmed for the first time by the influences of silicon and seed particle. Reconstruction characteristics and EGG can be well explained by defect-assisted 2-D and/or 3-D nucleation and growth of charged clusters mainly through evaporation and condensation process due to cyclic damages under low energy ion flux distribution with extremely low sputtering yield of MgO protective layer during discharge in AC-PDP and it is believed to give an important clue for the advance of PDP technology.

5. Acknowledgements

The authors thank to Pohang light source (PLS) for the valuable helps and experiments at PLS were supported in part by MOST and POSTECH.

6. References

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