Current Applied Physics 10 (2010) 1378–1382

Contents lists available at ScienceDirect

Current Applied Physics

journal homepage: www.elsevier.com/locate/cap

The effects of high purity MgO nano-powders on the electrical properties of AC-PDPs

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ARTICLE INFO

Article history:
Received 13 February 2010
Received in revised form
28 April 2010
Accepted 30 April 2010
Available online 8 May 2010

Keywords:
PDP
Protective layer
MgO powder
Discharge voltage

ABSTRACT

A major goal in plasma display panel technology is to reduce power consumption and increase efficiency. A candidate method to accomplish this goal is to increase the Xe content in discharge gases. However, this method has the weak point of increasing discharge voltages. High purity MgO powders made by the self-reaction method are adopted to overcome this disadvantage. From scanning electron microscope analysis, particles of the powders were observed to have very sharp edges, and the impurity content is very low according to inductively-coupled plasma mass spectrometry analysis. Moreover, the powders show a very high photo-induced electron emission and exo-electron emission, and have a very low concentration of oxygen vacancies by cathodoluminescence. Finally, the discharge voltage of high purity MgO powder-adopted films is reduced by about 34% compared to that of conventional films.

1. Introduction

Much attention has been given to flat panel displays for high definition television (HDTV). Alternating current plasma display panels (AC-PDPs) are especially promising for large screen size displays because of their fast response time, good color purity, wide viewing angle, and low cost. However, their power consumption needs to be reduced, their efficiency increased, and their lifetime prolonged [1,2].

MgO thin films have been used as a protective layer in AC-PDPs due to their high stability against ion bombardment, low optical loss, high thermal stability, and good electrical insulating properties. Moreover, MgO thin films reduce the discharge voltage of AC-PDPs due to their high secondary electron emission coefficient. Nevertheless, a more effective protective layer is needed to meet the demand of advanced high definition PDPs. For this reason, various attempts have been made to improve the characteristics of the protective layer [3–8]. It is widely known that the efficiency of PDPs could be increased by using a high Xe concentration in discharge gases; however, this approach has the disadvantage of increasing discharge voltage [9].

We examined the effects of high purity MgO powders on discharge voltage. Four types of MgO powders were made, and they were coated on MgO films. The shapes, purity, electron emission properties, oxygen defects, and discharge voltages were evaluated.

2. Experimental

To evaluate the effects of MgO powders on electrical properties, four types of MgO powders, SCP, Terrace, DJ50F, and DJ200F were fabricated. Schematics of fabricating methods are shown in Fig. 1. SCP powders were made from Mg chips. At first, the Mg chips were heated using a heat source such as a torch. After a few minutes, the Mg chips had self-reacted. Mg was evaporated in the air during the reaction. Finally, MgO powders were made by reaction of Mg vapors with oxygen. Terrace powders were made by the reaction of Mg powders and oxygen in the flame. The DJ-series powders were made by melting the Mg chips and were different each other in average particle size.

To evaluate the discharge properties of four types of MgO powders, disk-type PDP cells were fabricated and the discharge voltage was measured as a function of Xe content. Electron emission properties were evaluated using photoemission and exo-electron emission apparatus. The surface morphology was examined using a field emission scanning electron microscope (FE-SEM), and the crystallographic orientation was characterized using an X-ray diffractometer (XRD). The defect states of the MgO powders were characterized by cathodoluminescence and the impurities were checked by inductively-coupled plasma mass spectrometry (ICP-MS).

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doi:10.1016/j.cap.2010.04.011

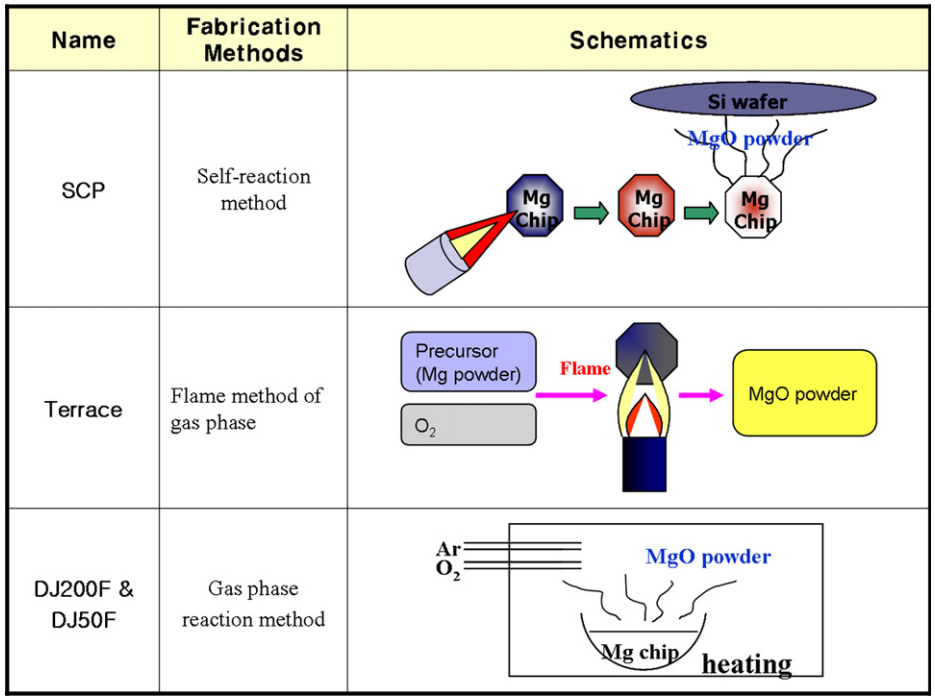

Fig. 1. Schematics of fabrication method of MgO powders.

3. Results and discussion

The sizes and shapes of the fabricated powders were evaluated by SEM. As shown in Fig. 2(a), the shape of the MgO powders made by the self-reaction method was a cube with one very sharp edge. In contrast, the shapes of MgO powders made using the flame method of the gas phase showed several line edges resembling terraces, as shown in Fig. 2(b). In the case of MgO powders made using the gas phase reaction method, the shapes were a mixed type with cubes, terraces, and irregular shapes, as shown in Fig. 2(c) and (d). All of the MgO powders were mixtures of small-sized particles of about 100 nm and large-sized particles of about several hundred nanometers.

To investigate crystallographic orientations, four types of MgO were analyzed using XRD. Fig. 3(a) shows the result from the SCP powders, and Fig. 3(b)–(d) show the results of Terrace, DJ50F, and

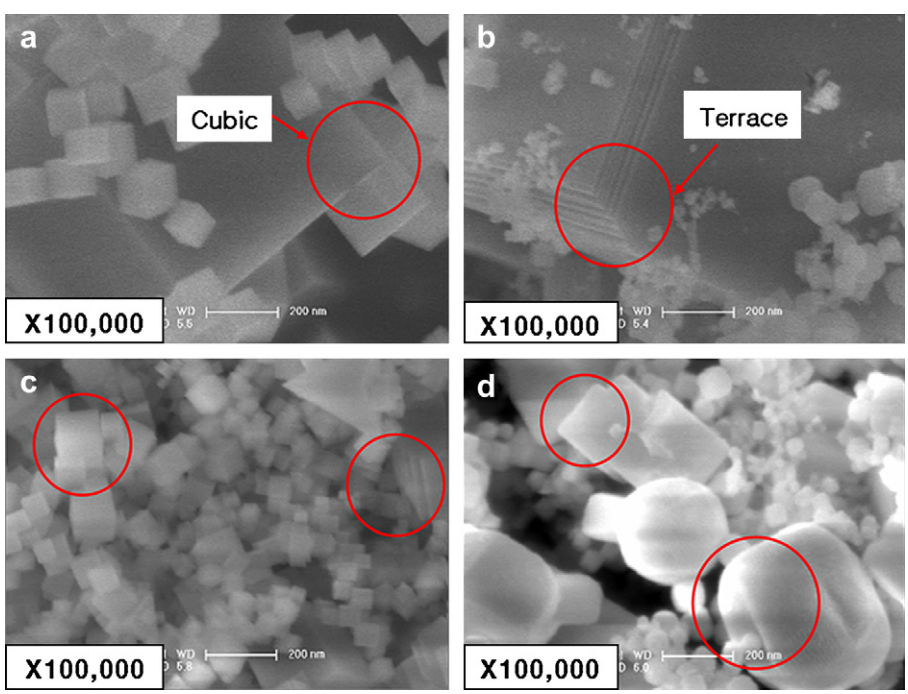

Fig. 2. SEM images of four types of MgO powders: (a) SCP powders, (b) Terrace powders, (c) DJ50F, and (d) DJ200F.

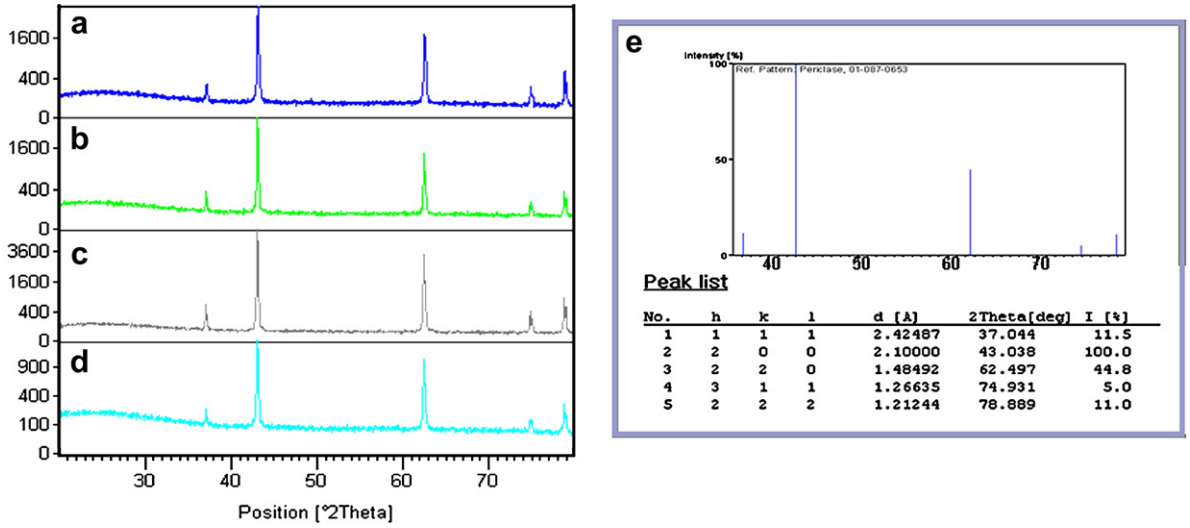

Fig. 3. XRD patterns of MgO powders: (a) SCP powders, (b) Terrace powders, (c) DJ50F, (d) DJ200F, and (e) standard MgO powders.

DJ200F, respectively. Standard peak positions and height ratios of the MgO powders are shown in Fig. 3(e) for comparison. All four types of powders showed similar peak positions and height ratios, as was the case with standard MgO powders. This means that all of the fabricated powders were randomly distributed and have similar crystal structure.

ICP-MS was used to evaluate the impurities in the four types of MgO powders. Impurities were not detected in SCP powders. However, in the Terrace and DJ-series powders, several impurities were detected such as Fe, Si, Ca, Mn, and Al. From the aforementioned results, it is clear that the SCP powders made by the self-reaction method are very pure.

Generally, MgO films used in PDPs have oxygen defects such as F centers and F^+ centers, and Mg defects such as V centers. To evaluate the oxygen and Mg defects for four types of MgO powders, cathodoluminescence was measured. The results are shown in Fig. 4. Peak points in the 250 nm and 470 nm regions are V centers and F centers, respectively. The peak point in the 700 nm region is known as a defect center of Cr. As shown in Fig. 4, the Terrace, DJ50F, and DJ200F powders have very high intensities at 250 nm, 470 nm, and 700 nm, respectively. On the contrary, the intensities for SCP powders are very low. Comparing the peaks of the SCP powders with the same peaks of the other powders on the same plot with a linear scale, we cannot see any peaks of the SCP powders. The intensity of the SCP powder peaks is several hundred times lower than those of the other powders. The peak point of the SCP powders is 370 nm for F^+ center defects. These results show that the SCP powders have very high purity.

To understand the electron emission properties of MgO powders, photoemission and exo-emission were evaluated. As shown in Fig. 5, the intensity of photoemission of the SCP powders was two to three times higher than that of the other powders. These results imply that the electron emission property of SCP powders is very good. Exo-emission properties are shown in Fig. 6. Exo-emission is a delayed electron emission after the input photon energy is stopped. The exo-emission intensity of the SCP powders was ten to one thousand times higher than that of the other powders. It is well known that impurities and defect centers create electron trap sites. Therefore, we considered that the electron emission properties of SCP powders were good because of their high purity.

MgO powders have serious problems such as chemical instability. They can be easily hydrated to $Mg(OH)_2$ under atmospheric

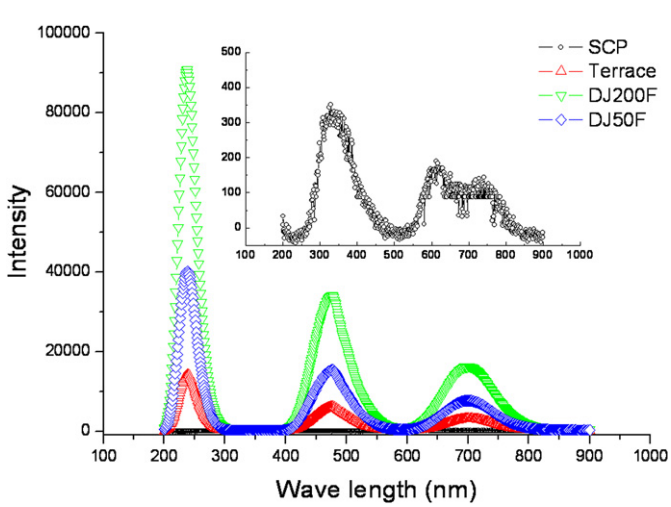

Fig. 4. Cathodoluminescence of SCP powders, Terrace powders, DJ50F, and DJ200F.

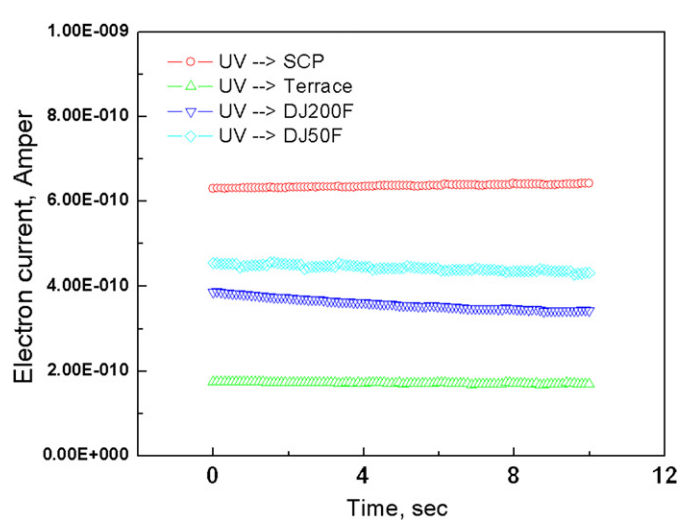

Fig. 5. Photoemission properties of SCP powders, Terrace powders, DJ50F, and DJ200F.

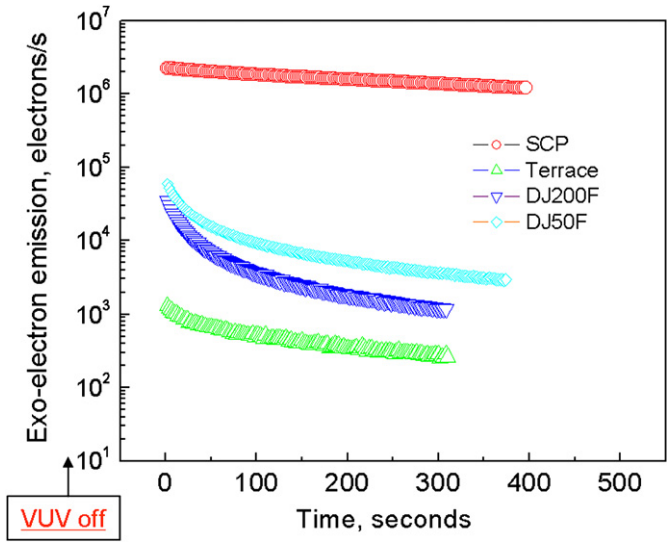

Fig. 6. Exo-electron emission properties of SCP powders, Terrace powders, DJ50F, and DJ200F.

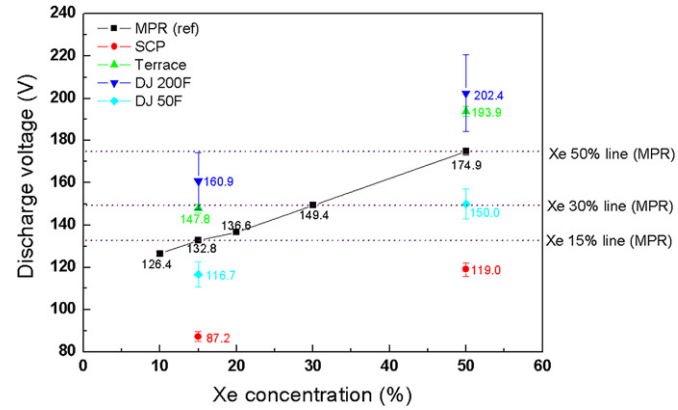

Fig. 8. Discharge properties of four types of MgO powders.

conditions. It is well known that the hydration of MgO films in AC-PDPs degrades their electrical properties: it increases the discharge voltage and sputtering yield [10–14]. Hence, the power consumption and cost of the PDP increases, and its lifetime decreases. Heat treatment has been adopted in the PDP industry to dehydrate MgO thin films and to remove residual gases. As a result, the discharge voltage has been decreased and the electrical properties have been improved.

To evaluate hydration properties, the SCP powders, Terrace powders, and DJ50F powders were kept in alcohol and water. After seven days, the morphology of the powders was evaluated. Fig. 7 shows the results. Fig. 7(a) and (b) are SEM images of SCP powders kept in alcohol and water, respectively. The MgO powders in water are hydrated more severely. Terrace powders and DJ50F powders show the same behavior. On the other hand, SCP powders are less hydrated compared with Terrace powders and DJ50F powders, as shown in Fig. 7(a), (c), and (e). This may be related to higher purity of the SCP powders.

To evaluate the discharge properties of the four types of MgO powders, disk-type PDP cells were fabricated and the discharge voltages were measured for different levels of Xe content. Fig. 8 shows the results. MPR means MgO films that were conventionally used in PDP fabrication.

As shown in the figure, the discharge voltages for the conventional MgO films were 126.4 V, 132.8 V, 136.6 V, 149.4 V, and 174.9 V at Xe concentrations of 10%, 15%, 20%, 30%, and 50%, respectively. Discharge voltage increased linearly with increasing Xe concentration. Discharge voltages of SCP powders, Terrace powders, DJ50F, and DJ200F were compared at 15% Xe and 50% Xe concentrations.

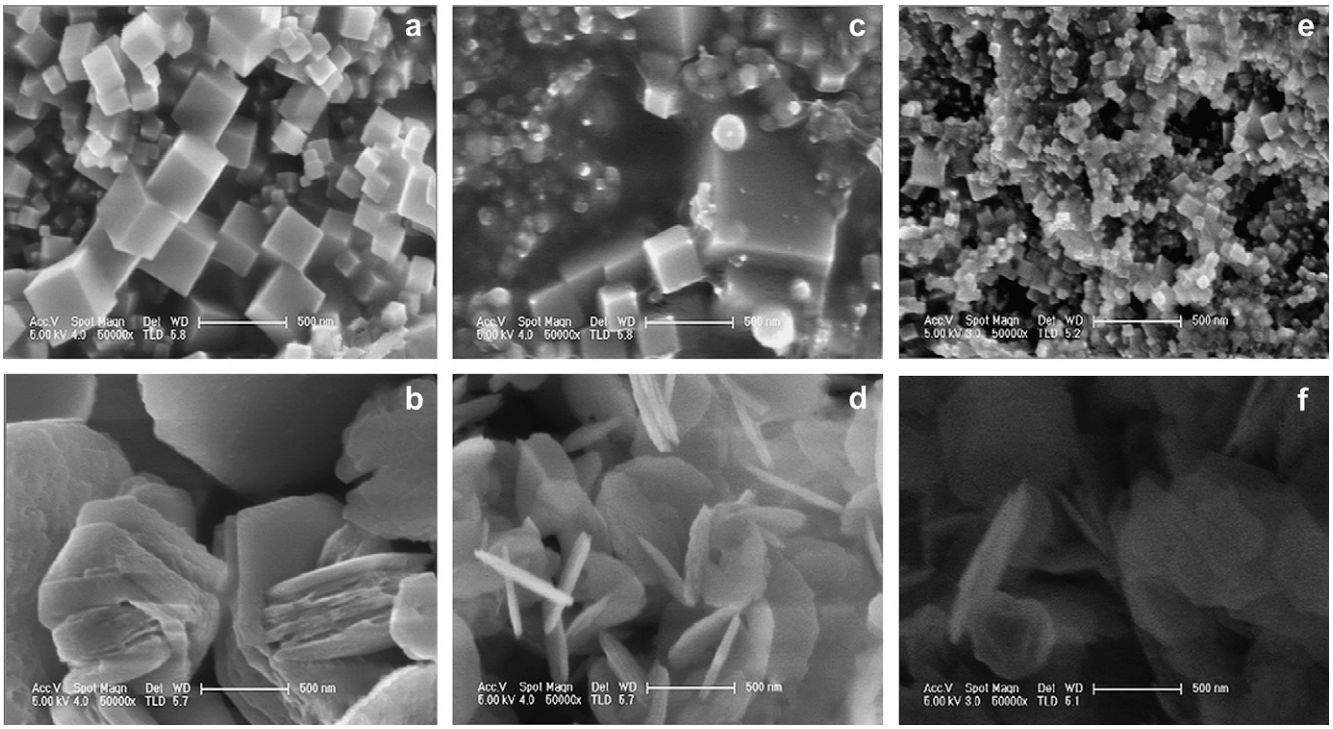

Fig. 7. Hydration properties of MgO powders, 7 days later. (a) SCP powders in alcohol, (b) SCP powders in water, (c) Terrace powders in alcohol, (d) Terrace powders in water, (e) DJ50F powders in alcohol, and (f) DJ50F powders in water.

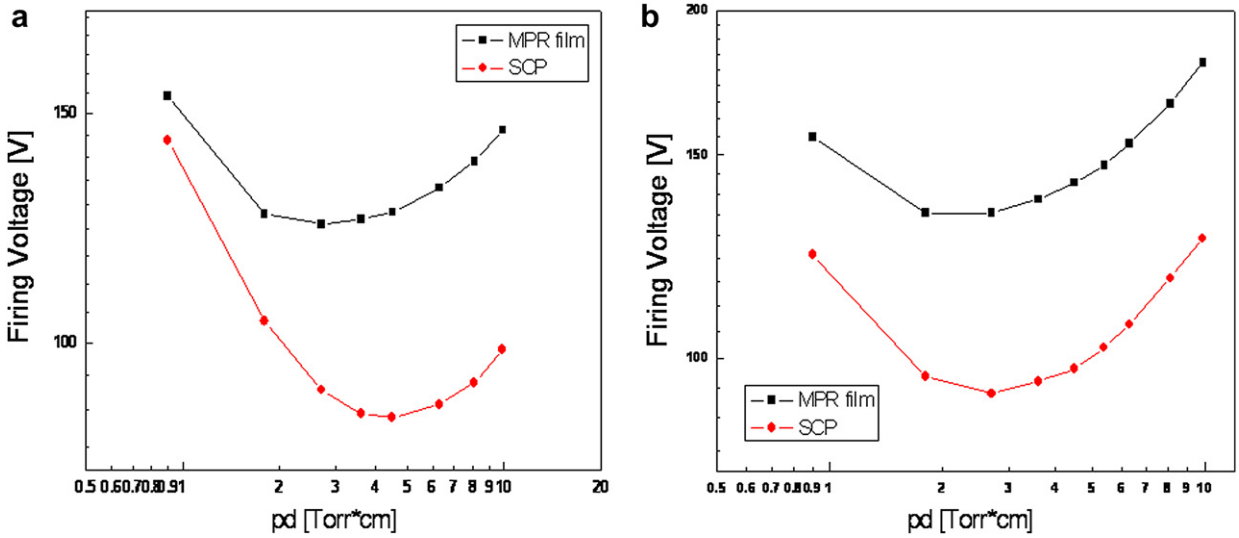

Fig. 9. Paschen curves of SCP powders and MPR films at (a) 15% Xe concentration, and (b) 30% Xe concentration.

As shown in Fig. 8, discharge voltages of the DJ200F and Terrace powders were higher than that of conventional MPR films. However, the discharge voltage of SCP powders was lower than that of the MPR films by about 45 V at 15% Xe concentration. Moreover, it was very noticeable that the discharge voltage of the SCP powders at 50% Xe concentration was 119 V, which was lower than the discharge voltage of the MPR films at 15% Xe content.

To compare the Paschen curves of SCP powders with conventional MPR films, dependence of the discharge voltage on the product of discharge pressure and electrode distance (p*d) was measured. The results are shown in Fig. 9. Fig. 9(a) shows the Paschen curve at a 15% Xe concentration, and Fig. 9(b) shows the Paschen curve at 30% Xe concentration. As shown in the figures, the discharge voltages of SCP powders were lower than those of the MPR films for all p*d values. These results also imply that the optimum p*d point of SCP-adopted PDPs might be changed to another point. More studies are needed on this subject. In summary, SCP powders made by the self-reaction method showed excellent discharge properties due to fewer defects and higher purity characteristics.

4. Conclusion

To reduce the discharge voltage of AC-PDPs, four types of MgO powders were fabricated and their properties were compared to one another. SCP powders made by the self-reaction method showed the best results. They were cubic shaped with a sharp edge, and had a low impurity content. Moreover, the SCP powders showed very high electron emission properties. Consequently, the discharge voltage of SCP powder-adopted films was reduced by about 34% compared to that of conventional films.

Acknowledgment

This work was supported by a Korea Research Foundation Grant funded by the Korean Government (KRF-2008-314-D00251 and R0A-2007-000-10032-0).

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