# Effect of Bias Voltage on the Micro Discharge Characteristics of MgO Film prepared by Unbalanced Magnetron Sputtering

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**Abstract**

The performance of ac plasma display panels (PDP) is influenced strongly by the surface glow discharge characteristics on the MgO thin films. This paper deals with the surface glow discharge characteristics and some physical properties of MgO thin films prepared by reactive RF planar unbalanced magnetron sputtering in connection with ac PDP. The samples prepared with the dc bias voltage of −10V showed lower discharge voltage, lower erosion rate by ion bombardment, higher optic transparency and higher crack resistance in annealing process than those samples prepared by conventional magnetron sputtering or E-beam evaporation.

## 1. Introduction

Currently, the MgO thin films are fabricated by the electron beam evaporation method. However, MgO thin films prepared by e-beam evaporation have shown some weak points such as cracks in annealing process and high erosion rate as a consequence of ion bombardment in glow discharge [1,2].

One of the methods improving the characteristics of MgO thin films may be to introduce sputtering or ion assisted deposition process [3,4]. In order to decrease the erosion rate and to improve the surface discharge characteristics, we have studied the effect of bias voltage on the micro discharge characteristics of MgO film prepared by unbalanced magnetron sputtering.

## 2. Experimental

Fig. 1 shows a schematic diagram of unbalanced magnetron sputtering system (UBMS) with the target size of 3 inches used in this work.

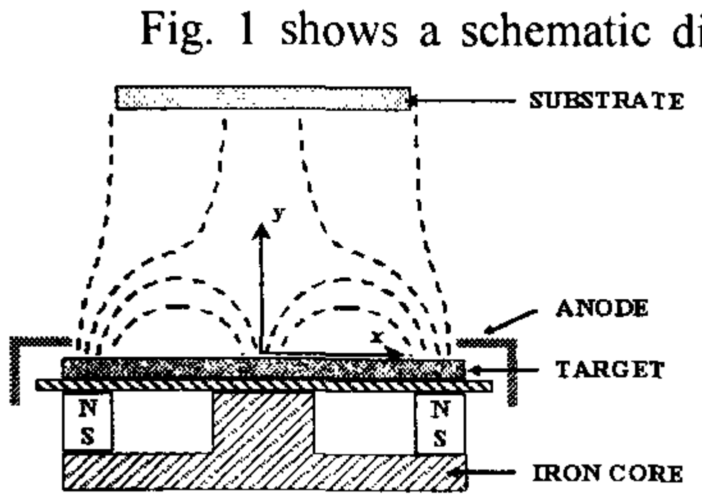



Fig. 1 The schematic diagram of Unbalanced magnetron sputtering

Fig. 2 shows the comparison of the magnetic field strength between UBMS and conventional balanced magnetron sputtering system (BMS) as parameters of positions x and y as shown in Fig. 1. From Fig. 2, it can be noticed that the vertical magnetic field strength along the target surface of UBMS is higher than BMS, whereas the parallel magnetic field strength of UBMS is lower than BMS. By controlling the relative strength of the outer and inner magnets, the ion flux can be varied over a factor of typically 300, while the deposition rate remains approximately constant [5]. Therefore, the UBMS is able to provide high ion flux to deposition atom flux ratios, and sufficient to deposit high quality thin film at low bias voltage. Furthermore, the field strength at the substrate at y=60mm is nearly uniform, that leads same ion flux density on the growing film surface.

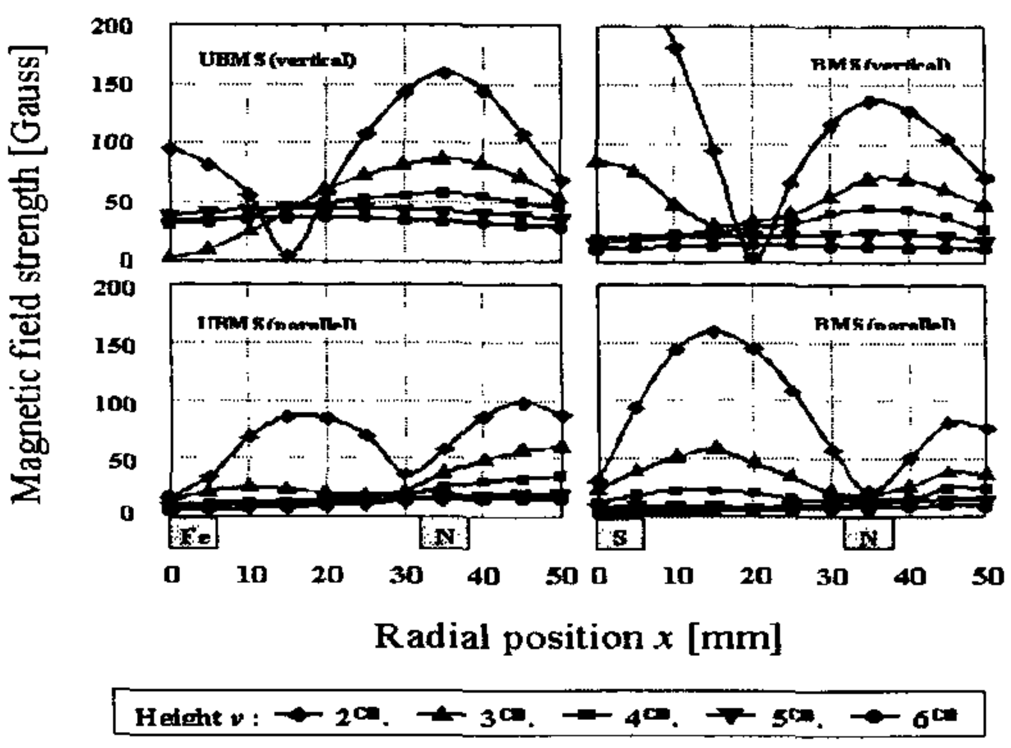



Fig. 2 The strength of vertical or parallel magnet field of UBMS and BMS along the target surface

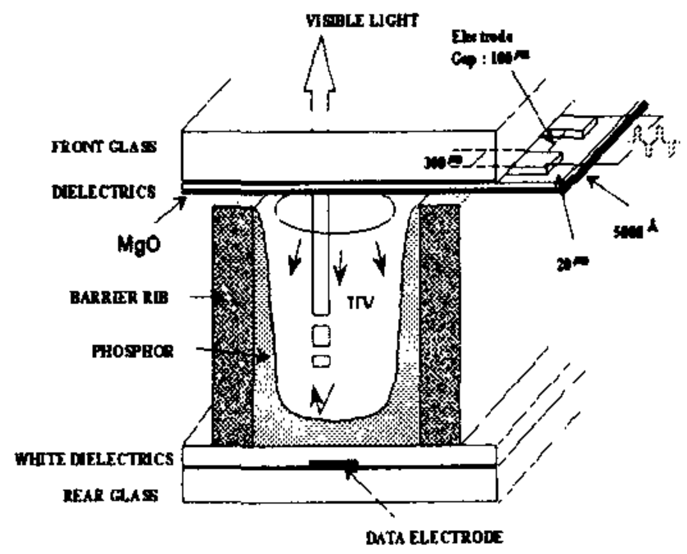



Fig. 3 The schematic diagram of a ac PDP unit cell

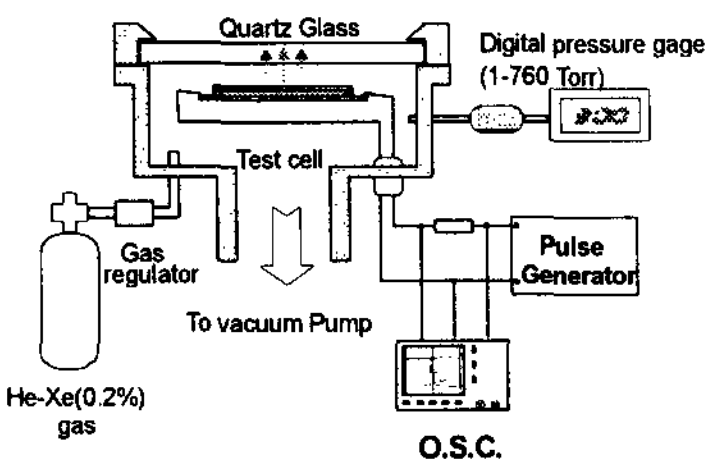



Fig.4 The schematic diagram of discharge test chamber

Fig. 3 shows a schematic diagram of unit discharge cell in ac PDP. The front panel (soda-lime) glass plate in this study has a length of 90mm, a width of 70mm, and a thickness 3mm. On the front glass, ten pairs of discharge electrodes are made by screen printing method with Ag paste. An electrode width is about 300 ㎛ and electrode gap is about 100 ㎛ which is almost the same size as the real ac PDP. On the glass substrate with ten pairs of electrodes, lead-rich glass dielectric layer is coated by screen printing method. After firing process, the thickness of the layer is about 20 ㎛ on the electrodes. The MgO thin film is deposited on the dielectric layer by UBMS. In order to apply dc bias, a substrate holder is made, which is made of stainless steel with disk type of 3 inches diameter.

After MgO deposition, the discharge characteristics of samples are tested in a small cylindrical vacuum test chamber with an inner diameter of 20 cm and height of 8 cm. The cover of the test chamber is made of quartz as a viewpoint, as shown in Fig. 4. This test chamber has a working gas feeding system, pressure controller and digital pressure display. About $10^{-6}$torr can be attained with the diffusion and rotary pump system. The working gas in the discharge test is a mixture gas of helium and xenon (0.2%) in the pressure of 300torr known as a Penning gas used in ac PDP. In this study, the discharge inception voltage ($V_f$) and discharge sustain voltage ($V_s$) are measured as a function of MgO preparation conditions.

In this work, we propose a simple relative method to test the erosion rates of many samples as follows; First, the MgO thin films are deposited on the glass substrate at a given condition. Second, the deposited glass substrate is used as a target in BMS. Third, the deposited thickness sputtered by the BMS on a new substrate is measured, whose thickness may be a indicator of a erosion rate. In this test the working gas in BMS is a mixture of helium and xenon

(0.2%) which has been used in a ac PDP as a discharge gas with 30khz ac pulse voltage. AFM, XRD, SEM, and spectroscope are used. In order to examine the cracks in annealing process, the transparency in visible light region and the grain growth of the MgO deposited by the UBMS.

### 3. Experimental results and discussion

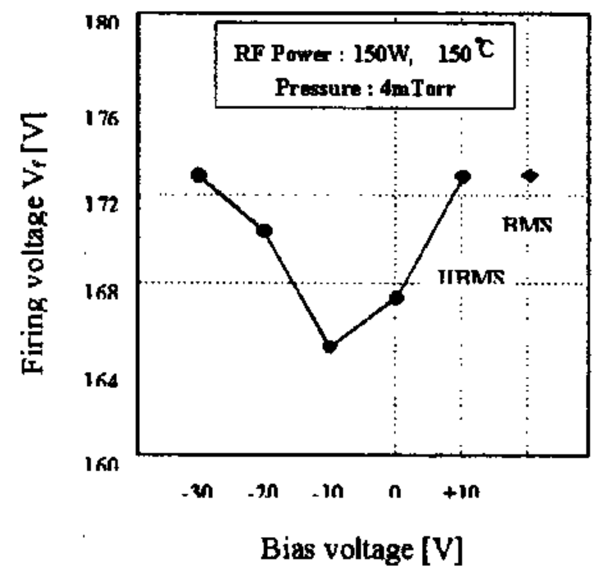



Fig. 5 Firing voltage as a parameter of bias voltage

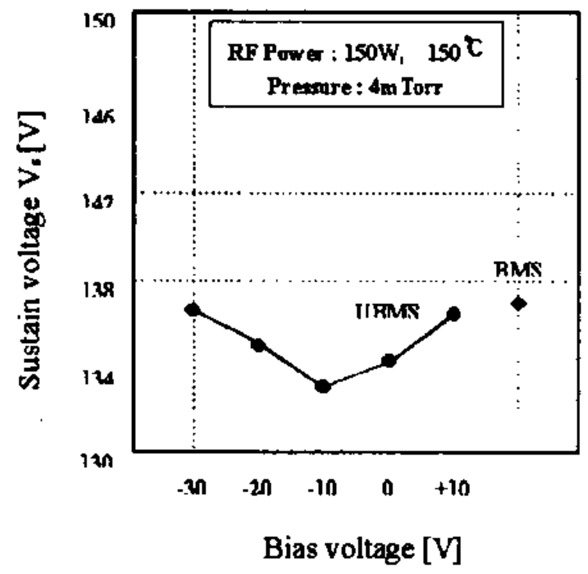
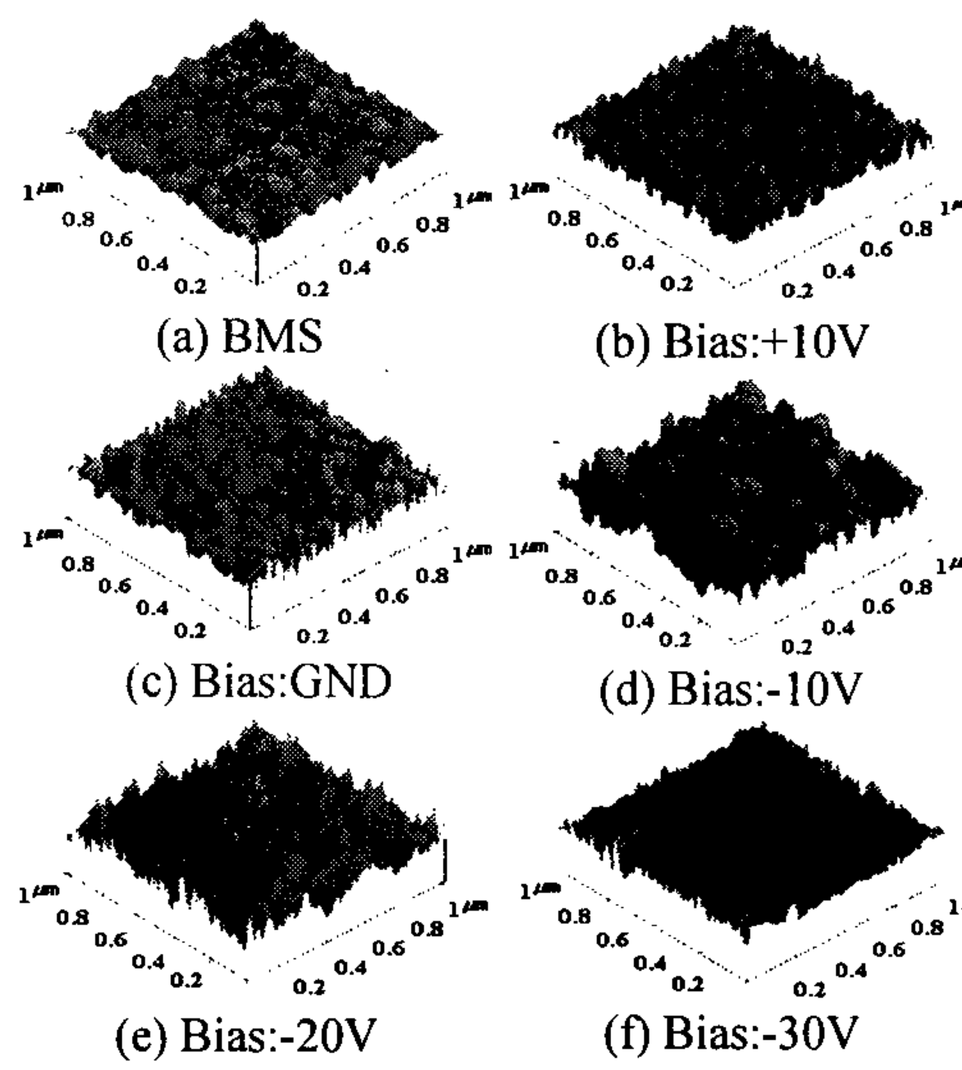



Fig. 6 Sustain voltage as a parameter of bias voltage

Figs. 5 and 6 show the surface discharge inception or firing voltage $V_f$ and the discharge sustain voltage $V_s$ characteristics of the MgO thin films, respectively as a parameter of the bias voltage applied to the substrate holder of UBMS. The minimum $V_f$ and $V_s$ are obtained for the sample prepared by the bias voltage of −10V. In comparison purpose, the $V_f$ and $V_s$ of the sample prepared by BMS also indicated in Figs. 5 and 6. The maximum difference in $V_f$ between two kind of fabrication methods is about 8V, whereas the difference in $V_s$ is about 3.5V. In order to find out the causes of difference in $V_f$ and $V_s$, the grain growth of the MgO are examined.

Fig. 7 shows atomic force microscope (AFM) photos of MgO surface prepared by UBMS as a parameter of bias voltage except for Fig. 7(a) prepared by BMS shown as a comparison purpose. From this figure the grain size of MgO is, at first, increased with increase in the negative bias voltage and shows maximum at −10V. However, the grain size decrease with increase in the negative bias voltage above −20V. The reasons for these results may be due to the severe resputtering above −20V that leads to low deposition rate [6]. From Fig. 5, 6 and 7, the strongest correlations are observed between discharge voltages and the grain morphology of the MgO surface. For the sample prepared by the bias voltage of −10V, the grain size and roughness are the largest and the minimum $V_f$ and $V_s$ are obtained.



(a) BMS (b) Bias:+10V

(c) Bias:GND (d) Bias:-10V

(e) Bias:-20V (f) Bias:-30V

Fig. 7 AFM photo of MgO surface as a parameter of bias voltage

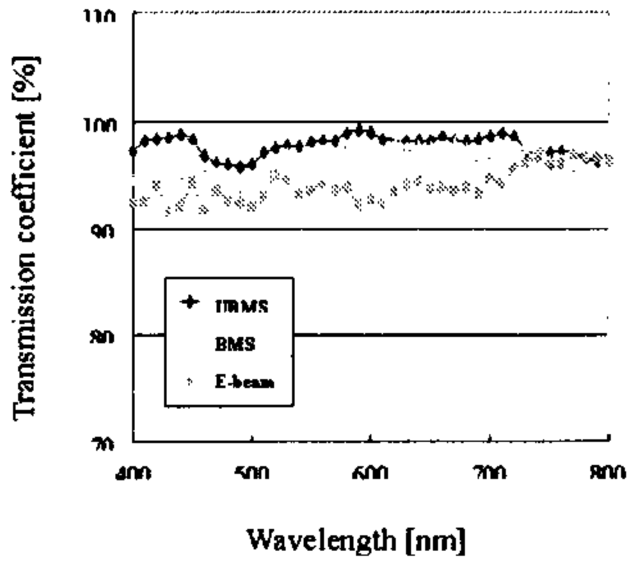



Fig. 8 Transmission coefficient as a parameter of MgO

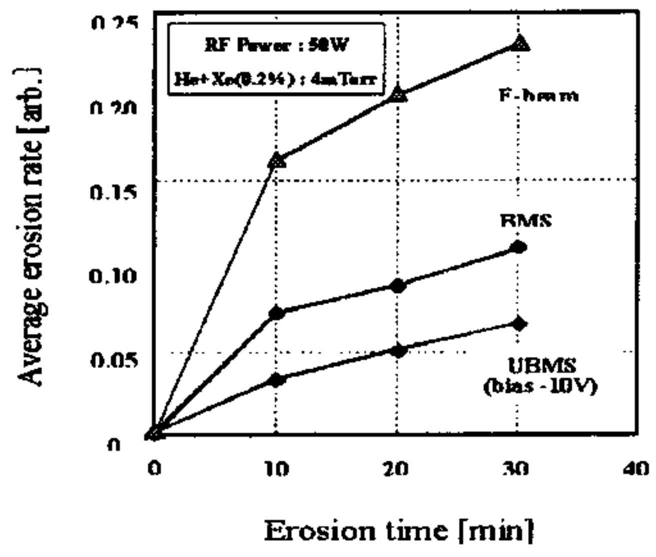



Fig. 9 Erosion characteristics as a parameter of MgO

A typical transparency of MgO thin film prepared by UBMS is shown in Fig. 8. The average transmission coefficient of the UBMS samples is above 95%.

Fig. 9 shows the average erosion rate as parameters of erosion time and MgO deposition methods. The average erosion rates of the samples prepared by UBMS shows about one half of BMS, whereas about one quarter of E-beam method.

Fig. 10 shows some cracks on the MgO surface prepared by BMS after heat-treatment at 520℃ for 30 minutes. However, no cracks are found for the sample prepared by UBMS with bias voltage of −10V at the same heat-treatment conditions.

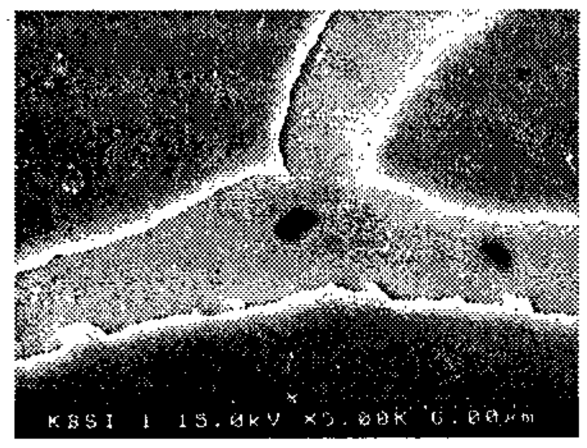


Fig. 10 SEM photo of MgO surface cracks prepared by BMS after heat-treatment at 520℃ for 30min in air

### 4. Conclusion

MgO thin films with low discharge voltage, low erosion rate, high optic transparency above 95% and crack resistance in the heat-treatment are successfully prepared on the dielectric layer by reactive RF unbalanced magnetron sputtering. The bias voltages of the substrate holder in deposition process have direct effects upon the MgO grain size and the discharge voltage on the MgO surface. The most desirable MgO properties in ac PDP is obtained for the sample deposited with the dc bias voltage of −10V.

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