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Sputtering Technique of Magnesium Oxide Thin Film for Plasma Display Panel Applications

Young-Wook Choi† and Jeehyun Kim*

Abstract - A high rate deposition sputtering process of magnesium oxide thin film in oxide mode has been developed using a 20 kW unipolar pulsed power supply. The power supply was operated at a maximum constant voltage of 500 V and a constant current of 40 A. The pulse repetition rate and the duty were changed in the ranges of 10~50 kHz and 10~60%, respectively. The deposition rate increased with rising incident power to the target. Maximum incident power to the magnesium target was obtained by the control of frequency, duty and current. The deposition rate of a moving state was 9 nm m/min at the average power of 1.5 kW. This result shows higher deposition rate than any other previous work involving reactive sputtering in oxide mode. The thickness uniformities over the entire substrate area of 982 mm x 563 mm were observed at the processing pressure of 2.8~9.5 mTorr. The thickness distribution was improved at lower pressure. This technique is proposed for application to a high through-put sputtering system for plasma display panels.

Keywords: Sputtering, Magnesium oxide thin film, Plasma display panel

1. Introduction

The plasma display panel (PDP) is one of the most promising candidates for large area wall hanging displays because of its simple panel structure, superior display quality, and wide viewing angle. Although plasma display panels are now entering the world wide markets, further improvements in picture quality, life span, and lowering costs are still needed. Magnesium oxide thin films play a particularly important role in the high quality and long lifetime of PDPs. Magnesium oxide thin films have been used as a protective layer for dielectrics in the alternative current (AC)-PDP to improve discharge characteristics and panel lifetime because of their anti-sputtering property, high transmittance, and secondary electron emission coefficient [1-3].

The typical manufacturing methods of magnesium oxide thin films are reactive sputtering, electron beam deposition, and ion plating. Reactive magnetron sputtering for magnesium oxide thin film has been proposed by several researchers [4-6], with advantages of low temperature processing for polycrystalline materials and film uniformity over large areas. However, the sputter method has a relatively low deposition rate. To overcome this, the fundamental understanding of the reactive sputtering mechanism and the development of a new sputtering technique are required. Therefore, efforts to create a magnesium oxide thin film manufacturing system having both superior quality and high deposition rate must be pursued diligently.

The aim of this study is the development of a higher deposition sputtering process of magnesium oxide thin film at the oxide mode using a devised power supply. The size of plasma display panel is intended to be 30~100 inches and consist of the vertical In-Line type. Deposition conditions were pursued at the oxide mode to improve the characteristics of time delay of magnesium oxide thin film. This technique will be contributed to a magnesium oxide thin film manufacture system having superior quality, high deposition rate, and low cost.

2. Sputtering Equipment

Fig. 1 shows the photograph of the reactive sputtering system used in this experiment. The total length of this system is about 5 m. The purity of the used MgO target is 99.95%. The target size is a width of 3.5", a length of 25" and a thickness of 1/4". This system is designed to extend the number of the magnetron cathode parallel targets. This sputtering system is applicable to a 42 inch PDP panel (height 563 mm, width 982 mm).

3. Experiment

In this experiment, a unipolar pulsed power supply of 20 kW was used. The power supply was operated at a

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† Corresponding author; Korea Electrotechnology Research Institute, P. O. Box 20, Changwon, 641-600, KOREA.(ywchoi@keri.re.kr)

* Dept. Physics, POSTECH, San 31, Hyojadong, Namgu, Po-Hang, Gyeong-Buk, KOREA(jeehkim@postech.ac.kr)

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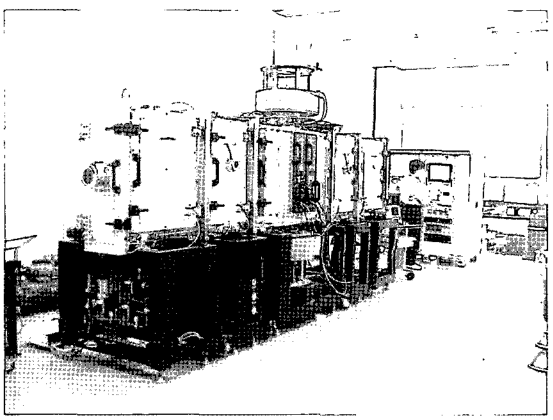

Fig. 1 Photograph of the reactive sputtering system. (Dimension of the vacuum chamber: 5000 (length) x 1000 (heigth) x 300 (width), mm)

maximum constant voltage of 500 V and a constant current of 40 A. The target voltage could not be applied between 250~300 V because of relatively low impedance (about 15 Ω) of reactive discharge. In this case, in order to increase incident power of the target, the constant current mode was used. Therefore, a maximum power density of the magnesium target was obtained by controlling a constant current mode. This function was significant for increasing the deposition rate. The deposition parameters in this experiment were as follows.

Base pressure : 1e-5 Torr
Processing pressure : 2.8~9.5 mTorr
Argon flow rate : 60 sccm
Oxygen flow rate : 40 sccm
Incident average power : 1.5 kW
Target-substrate distance : 70 mm
Substrate temperature : 200 °C
Pulse repetition rate : 25 kHz
Power duty ration : 50 %
Carrier speed : 30 mm/min
Number of targets : 1 -

4. Results and discussion

Fig. 2 presents the results of deposition rate. The deposition rates were 6 nm m/min and 9 nm m/min at the average power of 1.1 kW and 1.5 kW, respectively. Deposition rate increased with rising incident power to the target. The method that delivers maximum power to the target was pursued by adjusting frequency, duty and current at the pulsed power supply. From this, higher deposition rate was achieved. Fig. 3 shows the results of thickness uniformities at the processing pressure of 2.8~9.5 mTorr. We found that thickness uniformity was improved at the lower processing pressure. Fig. 4 depicts the measured waveforms of voltage and current at the target. Incident power to the magnesium target was calculated using these waveforms. The results of film analysis were as follows [7]. The texture of the sputtered magnesium oxide thin film was characterized by X-ray diffraction. The intensity of (111) texture was detected two times as much as the reference intensity. This means that the (111) texture has a relatively large portion in the deposited magnesium oxide film. The other peaks show the reference intensity of magnesium oxide film property. Secondary electron emission coefficient was measured to be 0.1 at 100 V of ion acceleration voltage. The transmittance was observed to be approximately 90% at the wavelength of 300 ~ 800 nm. The density and hardness were measured as 93.2%, and 800 ~ 900 kg/mm^2, respectively. When the prepared magnesium oxide film was applied to the six-inch plasma display panel, discharge phenomena of the plasma display panel occurred at 200 V. The grain size of crystal magnesium oxide had a diameter of approximately 30 ~ 60 nm. The RMS roughness of the magnesium oxide film was measured to be 1 nm at a substrate temperature of 200°C. The luminance and the luminance efficiency were 650 cd/m^2 and 1.53 lm/W, respectively. Characteristics of the time delay were measured to be about 1 μs.

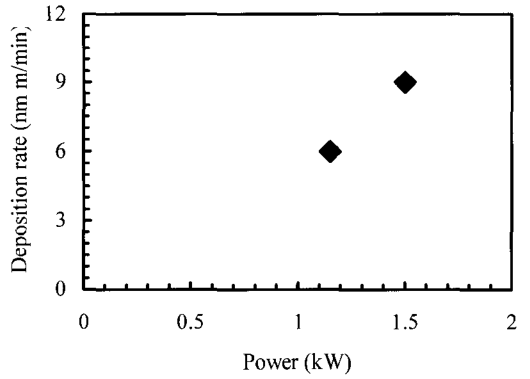

Fig. 2 Deposition rate of magnesium oxide thin film with incident power.

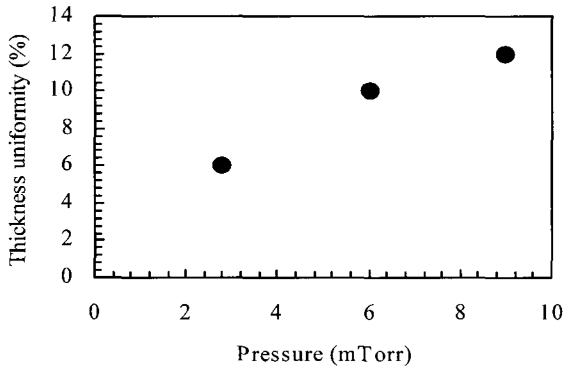

Fig. 3 Thickness uniformity over the entire substrate area of 982 mm x 563 mm.(2.8 mTorr: 6%, 6 mTorr: 10%, 9.5 mTorr: 12%)

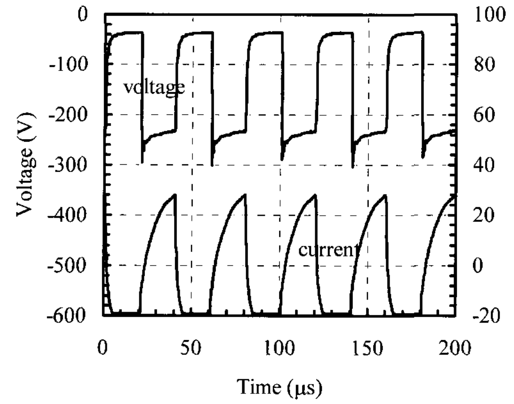

Fig. 4 Measured waveforms of voltage and current at the magnesium target(Frequency: 25 kHz, Duty: 50%, Average power: 1.5 kW)

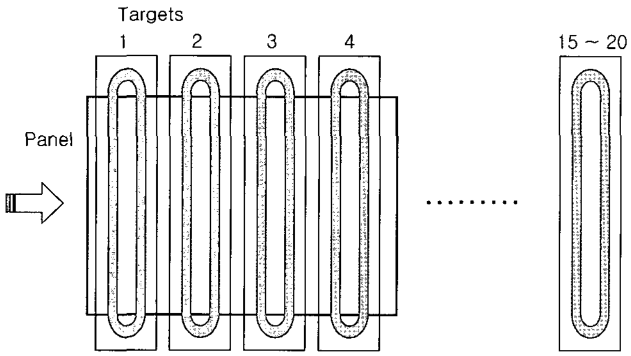

Fig. 5 Diagram for high through-put of magnesium oxide thin film.

From this work, we obtained higher deposition rate than any other previous work of reactive sputtering at the oxide mode, at which the magnesium target is covered with the oxide. The reason why we developed this technique at the oxide mode was to achieve superior quality of time delay characteristics. The way to apply this technique for high through-put is to increase the number of targets. On the basis of this work, in the case of 15~20 targets, the through-put is estimated as 2.7–3.7 minutes with a 42 inch panel and a coating thickness of 500 nm. Fig. 5 indicates the diagram of the magnesium oxide thin film sputtering system for high through-put.

5. Conclusion

The high deposition rate technique in oxide mode was developed using a devised power supply that has the function of a constant voltage and a constant current mode. This technique shows higher deposition rate than any other previous work. This fundamental technique is proposed for application to a high through-put sputtering system for plasma display panels. It requires further study to determine the greatest deposition rate and the optimal process.

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Young-Wook Choi

He was born is Seoul, Korea, on June 26, 1960. He received the B.S. degree in electrical engineering from Hanyang University, Seoul, Korea, in 1984, and the M.S. and Ph.D. degrees from the Interdisciplinary Graduate School of Engineering Sciences, at Kyushu University, Japan, in 1994 and 1997, respectiverly. In 1984, he joined the Korea Electrotechnology Research Institute (KERI), where he was engaged in high voltage engineering. From 1991 to 1997, he was involved in research of glow discharges using laser diagnostic techniques at Kyushu University in Japan. In April 1997, he returned to KERI. From March 2001, he was promoted to be a Principal Researcher at KERI. His major research interests include laser diagnostic for the plasma phenomena, power source manufacture for the versatile plasma application. Recently, he is engaged in the development of sputtering and beam source for plasma display panel applications. He is a member of the IEEE, APS, JJAP, and KIEE.

Jeehyun Kim
She was born in Daegu, Korea in 1973. She received the B.S. degree in chemistry and M.S. degree in plasma physics from POSTECH in 1996 and 1998, respectively. Since 2002, she has been in the Korea Electrotechnology Research Institute (KERI), Chang-won, Korea, as a research scientist. Her research interests include plasma ion implantation, plasma surface treatment, and plasma diagnostics and applications. She entered a doctoral program of POSTECH in 2006.