



Electrical properties of plasma display panel with Mg $1 - x$ Zn x O protecting thin films deposited by a radio frequency magnetron sputtering method

E. Y. Jung, S. G. Lee, S. H. Sohn, D. K. Lee, and H. K. Kim

Citation: [Applied Physics Letters](#) **86**, 153503 (2005); doi: 10.1063/1.1899238

View online: <http://dx.doi.org/10.1063/1.1899238>

View Table of Contents: <http://scitation.aip.org/content/aip/journal/apl/86/15?ver=pdfcov>

Published by the [AIP Publishing](#)

Articles you may be interested in

[Lowering of the firing voltage and reducing of the discharge delay time in alternating current plasma display panels by a discontinuous spin-coated LaB6 film on the MgO protective layer](#)

[AIP Advances](#) **4**, 037109 (2014); 10.1063/1.4869021

[Electronic structure variation during aging for Mg–Zr–O protective films in alternating current plasma display panel](#)

[J. Appl. Phys.](#) **108**, 014502 (2010); 10.1063/1.3456493

[Influence of oxygen partial pressure on microstructure and discharge properties of Mg–Zr–O protective films deposited by magnetron sputtering](#)

[J. Vac. Sci. Technol. A](#) **28**, 88 (2010); 10.1116/1.3259879

[Influence of Zr O₂ addition on the microstructure and discharge properties of Mg–Zr–O protective layers in alternating current plasma display panels](#)

[J. Appl. Phys.](#) **98**, 043304 (2005); 10.1063/1.2009077

[Stoichiometry dependency of the firing and sustain voltage properties of MgO thin films for alternating current plasma display panels](#)

[J. Vac. Sci. Technol. A](#) **17**, 2619 (1999); 10.1116/1.581920

The image shows the cover of the journal 'Applied Physics Reviews' (AIP). It features a blue and orange color scheme with a molecular structure background. The text 'NEW Special Topic Sections' is prominently displayed in white. Below it, 'NOW ONLINE' is written in orange, followed by 'Lithium Niobate Properties and Applications: Reviews of Emerging Trends' in white. The AIP logo and 'Applied Physics Reviews' text are in the bottom right corner.

NEW Special Topic Sections

NOW ONLINE
Lithium Niobate Properties and Applications:
Reviews of Emerging Trends

AIP Applied Physics Reviews

Electrical properties of plasma display panel with $\text{Mg}_{1-x}\text{Zn}_x\text{O}$ protecting thin films deposited by a radio frequency magnetron sputtering method

E. Y. Jung, S. G. Lee, and S. H. Sohn^{a)}

Department of Physics, Kyungpook National University, Daegu 702-701, Korea

D. K. Lee

R&D Affairs Department, Gumi Institute of Electronics Technology, Gumi, Gyeongsangbukdo 730-030, Korea

H. K. Kim

Samsung Advanced Institute of Technology, Suwon 440-600, Korea

(Received 8 September 2004; accepted 22 February 2005; published online 6 April 2005)

In order to improve the material properties of the protective layer for alternating current plasma display panels, a small amount of ZnO was added to the MgO protective layer. The electrical properties and the surface characteristics of the $\text{Mg}_{1-x}\text{Zn}_x\text{O}$ films, deposited by a radio frequency magnetron sputtering method, were investigated. As the concentration of ZnO increases, the crystallinity of $\text{Mg}_{1-x}\text{Zn}_x\text{O}$ thin films improves and the grain size becomes larger. The firing and the sustaining voltages of panels with the $\text{Mg}_{1-x}\text{Zn}_x\text{O}$ protective layers, when the concentration of ZnO was 0.5 at. %, was reduced by 20 V, compared with the conventional panels with the MgO protective layers. It was also found that the panels with $\text{Mg}_{1-x}\text{Zn}_x\text{O}$ protective layers show the higher discharge intensity as the ZnO content increases at the same applied voltages, compared with panels with the conventional MgO protective layers. © 2005 American Institute of Physics. [DOI: 10.1063/1.1899238]

Alternating current plasma display panels (AC-PDPs) have been already available for commercial sales and are expected to be one of the leading flat-panel display systems in the future. AC-PDPs, however, still have many problems, such as a high driving voltage, low luminous efficiency, and a short lifetime. In order to solve these problems, research into the development of cell structures,^{1,2} discharge gases,³ and protective layers⁴ has been conducted. In particular, the protective layer plays an important role in preventing AC-PDP from sputtering by the ions. The endurance of the protective layer against sputtering is one of the determining factors of the life span of the PDP. At present, MgO films are widely used as a protective layer for AC-PDPs. The MgO film has high durability and good protection characteristics against ion bombardment. In addition, the driving voltage of AC-PDP is largely affected because the MgO layer has a high secondary-electron emission coefficient (γ). These are the reasons that a great deal of research has taken place regarding new protective layer materials such as La_2O_3 , CeO_2 ,⁵ the mixtures of CaO and SrO, the mixtures of TiO_2 , and MgO doped with ZrO_2 .⁶ The development of protective materials with good characteristics is needed in order to improve the overall electrical characteristics of AC-PDP.

In this letter, in order to make a possible substitute for the conventional MgO protective layer, the electrical characteristics of the $\text{Mg}_{1-x}\text{Zn}_x\text{O}$ thin films, deposited by a radio frequency magnetron sputtering method, were investigated. $\text{Mg}_{1-x}\text{Zn}_x\text{O}$ ($x=0-1$ at. %) mixed powders were used as a sputtering target material. The sputtering conditions of the $\text{Mg}_{1-x}\text{Zn}_x\text{O}$ thin films are summarized in Table I. The crystallinity of the $\text{Mg}_{1-x}\text{Zn}_x\text{O}$ thin films was analyzed by an

x-ray diffractometer (XRD: PHILIPS, X'PERT). The surface morphology of the $\text{Mg}_{1-x}\text{Zn}_x\text{O}$ thin films was measured by field-emission scanning electron microscopy (SEM: HITACHI, S-4200). The gas discharge characteristics were measured via an indirect method by measuring the discharge intensity in the planar-type test panels using a photometer, placed in a discharge test chamber without sealing. Although noble gas mixtures containing Xe have been used in AC-PDP, the Ne gas chosen as the filling gas in the experiments because the secondary-electron emission from the surface of the protective layer by the Ne ions was known to be higher than that of the Xe ions for a given ion energy.⁷ The test panel structure and the driving conditions are shown in Fig. 1 and Table II, respectively. On the other hand, not all of the protective layers carried out annealing or activation processes. As a result, the effects of contamination, such as dehydration of the hydroxyl groups on the discharge characteristics, were not considered in this study.

Figure 2 shows the XRD patterns of the $\text{Mg}_{1-x}\text{Zn}_x\text{O}$ thin films grown at different substrate temperatures. As the substrate temperatures (T_s) increased to 450 °C, the (200) peak intensity gradually increased, while it decreased at 500 °C. As a result, the films show the best crystallinity at 450 °C.

TABLE I. Deposition conditions of $\text{Mg}_{1-x}\text{Zn}_x\text{O}$ thin films.

Ar pressure	16 mTorr
O ₂ pressure	6 mTorr
Distance between substrate and target	50 mm
Rf power density	1.26 W/cm ²
Substrate temperature	450 °C
$\text{Mg}_{1-x}\text{Zn}_x\text{O}$ thin films	2000 Å

^{a)}Electronic mail: shsohn@mail.knu.ac.kr

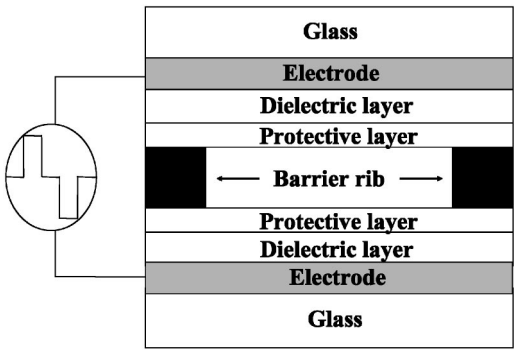


FIG. 1. Structure of the test panels.

Depending on the crystallinity of the $Mg_{1-x}Zn_xO$ thin films, substrate temperature may change in the activation energy of components, which is known to be dependent on the substrate temperatures.^{8,9}

Figure 3 shows the XRD patterns of the $Mg_{1-x}Zn_xO$ thin films grown as a function of the ZnO concentration levels. The (200) peak increased by adding a small amount ($x=0.5$ at. %) of ZnO. The addition of extra ZnO ($x=1$ at. %), however, leads to bad crystallinity. There were no remarkable changes in peak positions, and thence lattice parameters with the increase in ZnO concentration amounts.

Figure 4 shows the SEM images of the $Mg_{1-x}Zn_xO$ thin films grown at 450 °C. It is easily found that the grain size of the $Mg_{1-x}Zn_xO$ thin films becomes larger than that of the MgO thin films by the addition of ZnO.

Figure 5(a) represents the dependence of the firing voltage V_f , the sustaining voltage V_s , and the memory coefficient M_c [$=(V_f - V_s)/V_f$] with the addition of the ZnO content. Both V_f and V_s of the $Mg_{1-x}Zn_xO$ thin films, when the concentration of ZnO was 0.5 at. %, were reduced by about

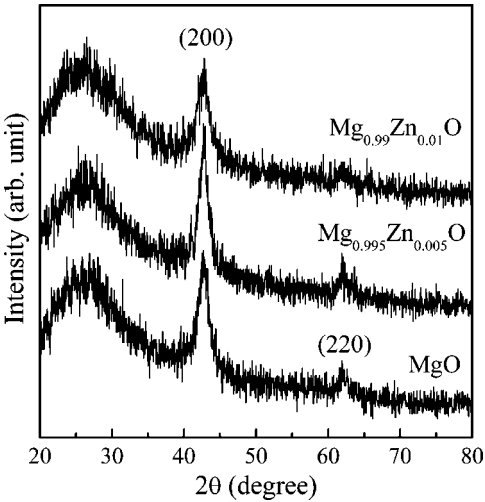


FIG. 3. The XRD patterns of the $Mg_{1-x}Zn_xO$ thin films grown as a function of the ZnO concentration levels.

20 V, compared with the conventional MgO film. As a result, these facts yield the increase of M_c . Figure 5(b) represents the Ne gas discharge intensity measured in the test panel as a function of the applied voltages. The discharge intensity increased linearly with the applied voltages. This is attributed to the increasing electric fields in the discharge cell with the increasing applied voltages. The discharge intensity of the $Mg_{1-x}Zn_xO$ thin film with the ZnO concentration of

TABLE II. Driving conditions for measuring the discharge characteristics.

Electrode	ITO electrode
Dielectric layer	BaTiO ₃ (4000 Å)
Barrier rib height	150 μm
Discharge gas	Ne gas, 200 Torr
Driving condition	10 KHz square pulse

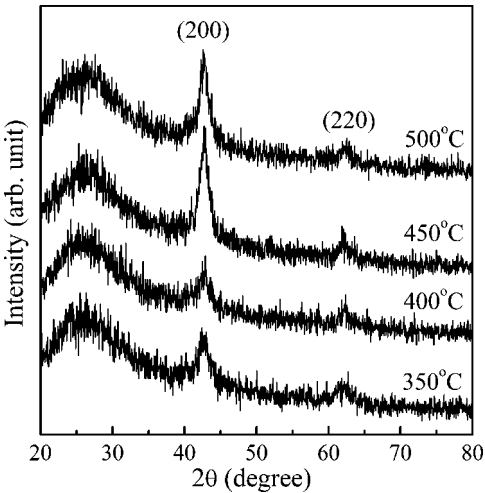


FIG. 2. The XRD patterns of the $Mg_{1-x}Zn_xO$ thin films ($x=0.5$ and 1 at. %) grown at different substrate temperatures.

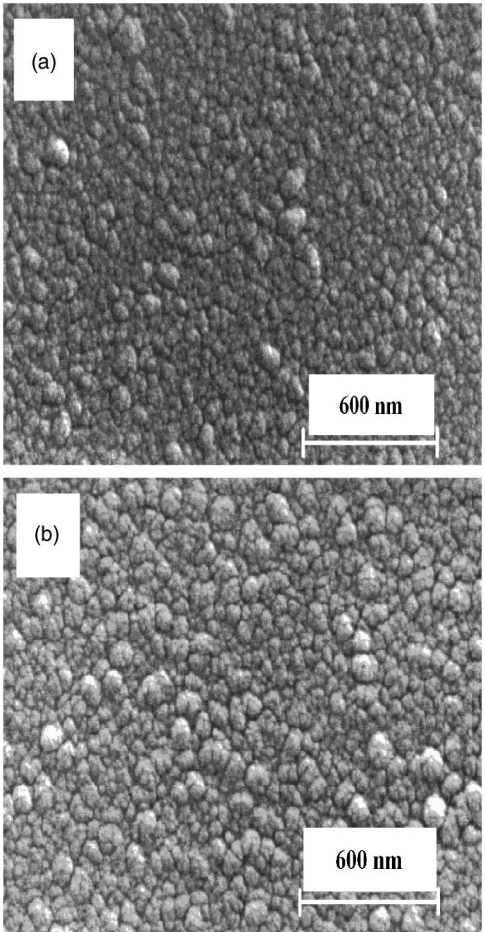


FIG. 4. SEM images of the $Mg_{1-x}Zn_xO$ thin films (a) $x=0$ at. %, (b) $x=0.5$ at. %. In both cases, $T_s=450$ C.

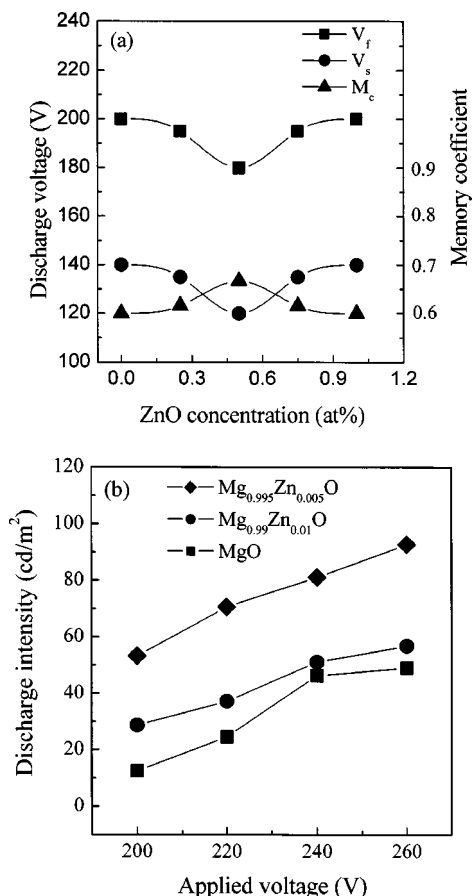


FIG. 5. (a) Discharge voltages (firing voltages V_f , sustain voltages V_s) and the memory coefficient M_c of the $\text{Mg}_{1-x}\text{Zn}_x\text{O}$ thin films. In all cases, $T_s = 450$ C. (b) The discharge intensity as a function of applied voltages under 200 Torr of Ne gas.

0.5 at. % was relatively higher than that of the MgO thin film at the same voltages. These higher discharge intensities obtained under the same driving conditions in the panel, with the same device structure except for the protective layer, seem to have a relation with the secondary-electron emission from the protective layer. Although measuring the discharge density cannot be the direct method for determining the secondary-electron emission such as a low-energy-electron diffractometer,¹⁰ the results suggest that more secondary electrons can be emitted from the $\text{Mg}_{1-x}\text{Zn}_x\text{O}$ surface with 0.5 at. % ZnO content than from the MgO surface. This increase in the levels of secondary-electron emission cannot be

explained by only the work function theory because effective electron emission cannot be expected when Zn^{2+} ions, with a work function of 4.33 eV, were substituted for the Mg^{2+} ions with a work function of 3.66 eV.¹¹ It is known that according to Auger neutralization,¹² secondary-electron emission from the surface state depends on the energy band structure of oxides and the surface state density. If this is the case, an increase in secondary-electron emission seen in the experiment may be explained by a change in the energy band structure and the surface property¹³ originating from doping ZnO into MgO .

In our experiment, the electrical properties of AC-PDPs with the $\text{Mg}_{1-x}\text{Zn}_x\text{O}$ thin films grown by a rf magnetron sputtering method have been investigated.

In summarizing the results, the crystallinity of the $\text{Mg}_{1-x}\text{Zn}_x\text{O}$ thin films depends strongly on the substrate temperatures and on the concentration levels of ZnO. The firing and the sustaining voltage of the panels with $\text{Mg}_{1-x}\text{Zn}_x\text{O}$ thin films, when the concentration of ZnO was 0.5 at. %, was reduced by about 20 V, compared with the conventional panels with the MgO films. The discharge intensity increased by adding ZnO to the MgO films, probably due to an increase in the secondary-electron emission which might have originated from changes in physical properties such as energy band structure and surface properties. The effect of adding ZnO to the sputtering yield of the newly developed $\text{Mg}_{1-x}\text{Zn}_x\text{O}$ protective layer is now being investigated.

This research was supported by the Kyungpook National University Research Team Fund, 2003.

¹M. H. Nam, J. M. Kim, S. Y. Choi, S. H. Son, and Y. M. Kim, J. Appl. Phys. **96**, 993 (2004).

²G. Veronis and U. S. Inan, J. Appl. Phys. **92**, 4897 (2002).

³D. Hayashi, G. Heusler, G. Hagelaar, and G. Kroesen, J. Appl. Phys. **95**, 1656 (2004).

⁴K. H. Nam and J. G. Han, Surf. Coat. Technol. **174–175**, 212 (2003).

⁵T. Urade, IEEE Trans. Electron Devices **ED-23**, 313 (1976).

⁶R. W. Kim, Y. H. Kim, and J. H. Park, Vacuum **61**, 37 (2001).

⁷K. S. Moon, J. Lee, and K. W. Whang, J. Appl. Phys. **86**, 4049 (1999).

⁸M. Ohring, *The Materials Science of Thin Films* (Academic, New York, 1992).

⁹E. H. Jung and S. H. Sohn, Ungyong Mulli **12**, 256 (1999).

¹⁰E. N. Sickafus, Phys. Rev. B **16**, 1448 (1977).

¹¹H. B. Michaelson, J. Appl. Phys. **48**, 4729 (1977).

¹²Y. Motoyama, Y. Hirano, K. Ishii, Y. Murakami, and F. Sato, J. Appl. Phys. **95**, 8419 (2004).

¹³M. Ishimoto, R. A. Baragiola, and T. Shinoda, *Proceedings of the 7th International Display Workshop* (Society for Information Display, Japan, 2000), p. 683.