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The Influence of the Defect States on the Secondary Electron Emission from the Mg_{1-x} Be_xO Protective Layer of AC Plasma Display Panels

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In order to improve the material properties of the protective layer for alternating current plasma display panels, small amount such as BeO elements was added to the MgO protective layer. The electrical properties of $Mg_{1-x}Be_xO$ film deposited by an electron beam evaporation were investigated. The experimental results reveal that the discharge voltage of PDP device with the $Mg_{1-x}Be_xO$ film, when the concentration of BeO was 40 at.%, was reduced by 20 V, compared with the conventional MgO film. To elucidate the reason for increasing the secondary electron emission, the change in the energy band structure was investigated by measuring PL. The experimental results show the defect level of the $Mg_{1-x}Be_xO$ films increases to a large extent in comparison with that of the conventional MgO film. It also implies that the secondary electron emission has a strong correlation with the energy band structure, related to the defect levels originating from doping and thence resulting in changes in the associated electrical characteristics.

Keywords Plasma display panel; $Mg_{1-x}Be_xO$ thin films; defect states; photoluminescence; secondary electron emission; discharge voltage

1. Introduction

Plasma display panels (PDP) is known to be a promising flat panel display device with sizes larger than 50 inch diagonal and is under active development for its application to high-definition television including FHD TV. However, there are still many problems to improve such as the high resolution, the high efficiency, the low discharge voltage, faster address delay time, and the long lifetime. Nowadays, one of the most important issues is to realize a low voltage for high-speed performance in the PDP module. Many researches on the high-speed driving have so far been reported, including cell geometry [1,2], MgO protective layers [3], the gas composition [4] for the discharge and the driving waveform [5]. Especially, protective layers have a great influence on the high-speed and the low voltage because of their high level of secondary electron emission (γ). Amatsuchi et al. proposed

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a crystal emissive layer (CEL) structure for high-speed performance [6]. Additionally Lee et al. reported the doped MgO protective layer with higher a γ [7]. The secondary electron emission of the protective layer largely depends on film properties, such as the crystal orientation, the stoichiometry, the film density, the surface morphology, the roughness, and the defect levels. Moreover, the γ is one of the most important factors for determining the firing voltage and the address delay time [8].

In order to reduce discharge voltage in PDP, the discharge properties of the $Mg_{1-x}Be_xO$ films were investigated. The $Mg_{1-x}Be_xO$ films grown by an electron beam evaporation were studied and the energy band structure, related to the defect levels originating from doping in the $Mg_{1-x}Be_xO$ film, was evaluated by measuring the photoluminescence (PL) as a function of doping elements. Finally, we an attempt to find a correlation was made between the secondary electron emission and energy band structure, related to the defect levels originating from doping in the $Mg_{1-x}Be_xO$ film.

2. Experimental Setup

The $Mg_{1-x}Be_xO$ films were grown using an electron beam evaporation system on the bare glass substrates (Corning #7059). The MgO and BeO powders of 99.99% purity were used to prepare a powder mixture of various desired compositions. $Mg_{1-x}Be_xO$ mixed powders were used as an evaporation material. If the BeO concentration was higher than 40at.%, the image sticking or life time was deteriorated or reduced. Thus, we were measured until 40at.% with BeO concentration. The detail deposition conditions of the $Mg_{1-x}Be_xO$ films are summarized in Table 1. The crystallinity of the $Mg_{1-x}Be_xO$ films was analyzed by a X-ray diffractometer (XRD: PHILIPS, X'PERT). The surface morphology was measured by a field emission secondary electron microscopy (FE-SEM: HITACHI, S-4200). The surface roughness was analyzed using the atomic force microscope (AFM, Digital Instrument 3100). The defect levels were examined by using photoluminescence. The excitation region of wavelength 325 nm was obtained from a HeCd laser in the wavelength region of 350∼640 nm. The discharge characteristics were measured an indirect method by measuring the discharge intensity in the planar type test panels with using a photometer, placed in a discharge test chamber without sealing.

Figure 1 shows a schematic diagram of the vacuum equipment used for the plasma discharge measurement. 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 were shown in Table 2, respectively.

Table 1. Deposition conditions of $Mg_{1-x}Be_xO$ thin films.

Deposition Parameter	Value
Base Pressure	1×10^{-5} Torr
Working Pressure	5×10^{-5} Torr
Substrate Temperature	150°C
Film thickness	5500 Å
Deposition rate	$3 \sim 5$ /s

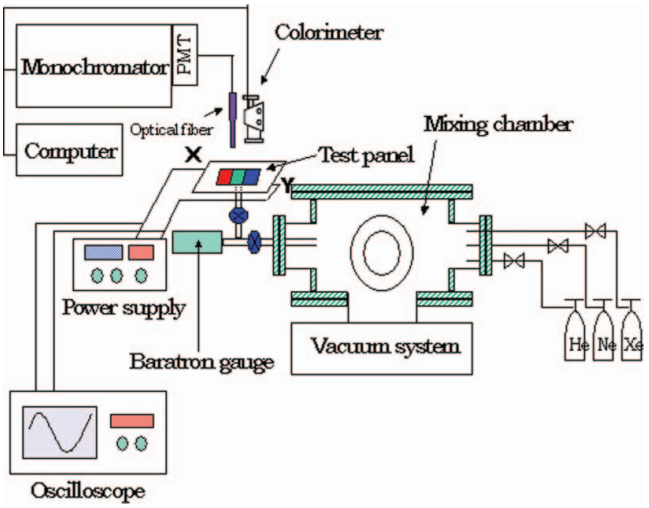

Figure 1. Schematic diagram for measuring the discharge properties.

3. Results and Discussion

Figure 2 shows the XRD patterns of the $Mg_{1-x}Be_xO$ films grown as a function of the BeO concentration levels. The (200) peak increased by adding a small amount of BeO. There were no remarkable change in (200) peak positions with increasing BeO amounts.

Figure 3 represents the surface roughness of the $Mg_{1-x}Be_xO$ films as a function of BeO concentrations. As the amount of BeO increased from 0 to 40 at.%, the surface roughness decreased from 18 Å to 8 Å. It is considered that the decrease of surface roughness is attributed to the change of grain size in films.

The photoluminescence spectra of the $Mg_{1-x}Be_xO$ films with respect to BeO concentration under 300 K was plotted in Fig. 4. PL peaks were observed at around 470 and 530 nm, as shown in Fig. 4. It is indicated that the 470 and 530 nm bands are probably due to the F^+ and F centers in the $Mg_{1-x}Be_xO$ surface, respectively. As the amount of BeO was added above 30 at.%, the PL peak intensity of F^+ and F centers increases and wavelength of F^+ and F centers slightly shifts between 470 and 530 nm. As the amount of BeO was added to 20 at.%, the PL intensities related to F^+ and F centers decrease at 300 K. The reason is supposed that the work function (ϕ) of the $Mg_{1-x}Be_xO$ films was reduced, because the Fermi level approaches the bottom of the conduction band due to an increase of the repulsive potential or the strain potential between Be ions and the oxygen vacancy (O^{-2}). Therefore,

Table 2. Driving conditions for measuring the discharge characteristics.

Parameter	Value
Base Pressure	1×10^{-5} Torr
Electrode Type	ITO electrode, Planar type
Discharge gap	0.5mm
Discharge gas	Ne 10 torr
Driving condition	25 KHz, duty 40% square pulse

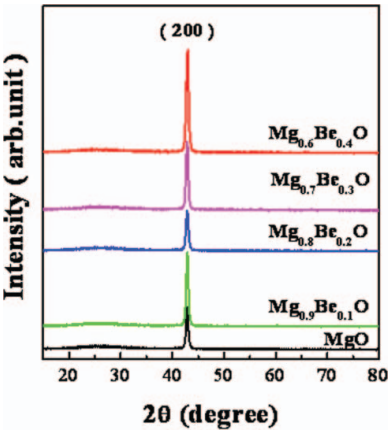

Figure 2. X-ray diffraction pattern of $Mg_{1-x}Be_xO$ films with respects to BeO concentrations.

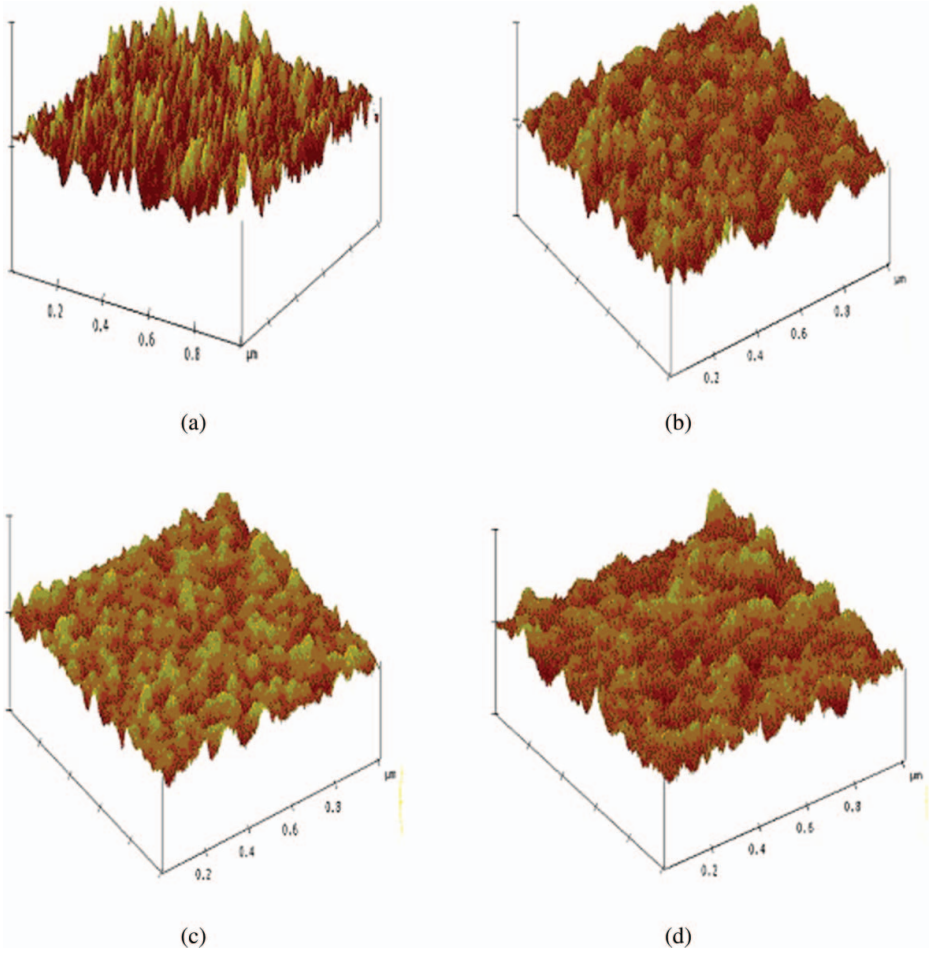

Figure 3. Surface roughness of the $Mg_{1-x}Be_xO$ films with respects to BeO concentrations. ((a) 0 at.%, (b) 20 at.%, (c) 30 at.%, (d) 40 at.%).

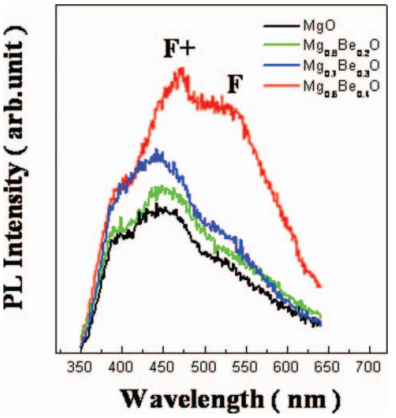

Figure 4. Photoluminescence spectra of the $Mg_{1-x}Be_xO$ films with respects to BeO concentrations at 300 K.

it is considered that the secondary electron emission of $Mg_{1-x}Be_xO$ films increases due to decreasing the work function (ϕ) [9]. This fact implies that doping elements contribute to the shift of Fermi level (E_f), resulting in shallower levels in the $Mg_{1-x}Be_xO$. From these results, it can be anticipated that more electrons can be easily ejected from the surface of the $Mg_{1-x}Be_xO$ thin film. Thus, we draw a conclusion that the secondary electron emission has a strong correlation with the work function, in turn, the energy band structure.

Figure 5 represents the dependence of the firing voltage V_f, and the sustain voltage V_s with the addition of the BeO content. V_f and V_s of the $Mg_{1-x}Be_xO$ films were reduced by about 20 V, compared with the conventional MgO film when the concentration of BeO was 40 at.%. Above 20 at.%, V_f and V_s decrease with increasing PL intensities from F^+ centers. These results suggest that the values increase with increasing numerical densities of the F^+ centers [10,11].

Figure 6 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

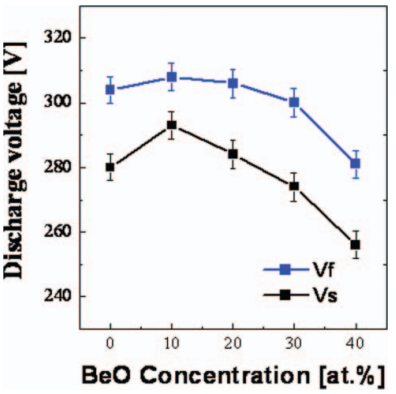

Figure 5. Discharge voltages (firing voltages Vf, sustain voltages Vs) of the $Mg_{1-x}Be_xO$ films under 10 Torr of Ne gas.

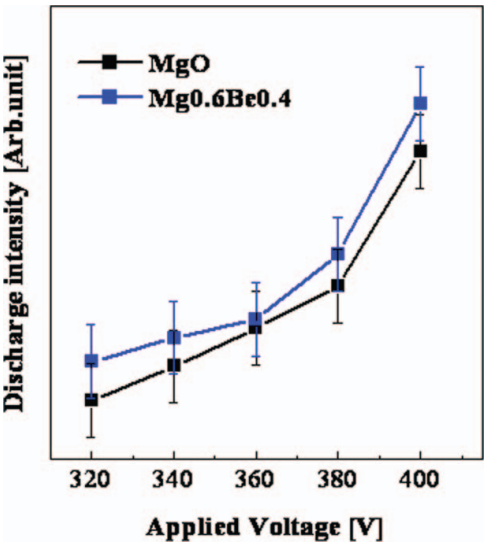

Figure 6. Discharge intensity of the $Mg_{1-x}Be_xO$ films as a function of applied voltages under 10 Torr of Ne gas.

with the increasing applied voltages. The discharge intensity of the $Mg_{1-x}Be_xO$ film with the BeO concentration of 40 at.% was relatively higher than that of the MgO film at the same voltages. These higher discharge intensities obtained from the panel with the same device structure under the same driving conditions 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 (LEED) [12], the results suggest that more secondary electrons can be emitted from the $Mg_{1-x}Be_xO$ surface with 40 at.% BeO content than from the MgO surface. It should be noted that according to Auger neutralization, secondary electron emission from the surface state depends on the energy band structure of oxides and the surface state density. If this is such 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 property originating from doping BeO into MgO. The condition for secondary electron emission form an insulator surface by Auger neutralization is

$$E_i > 2(E_g + \chi) \tag{1}$$

where E_i is the ionization energy of the incident ion and E_g and χ are the energy band gap and electron affinity of the insulator material, respectively. If E_g is about 7–8 eV and $\chi \sim 1$ eV as shown in Eq. (1), secondary electron emission by Xe ion whose ionization potential is 12.1 eV is prohibited with a MgO film. However, the positions of F and F^+ centers are known to be about 5 or 6 eV below the conduction band edge of MgO, which means that the Xe ion (12.1eV) may be able to participate in secondary electron emission of the electrons trapped by the defect levels [13]. The possibility of having secondary electron emission caused by the Xe ion may result in lowering the firing voltage and reduction of the discharge delay time in an ac PDP.

Conclusions

In conclusion, electrical properties of PDP with an $Mg_{1-x}Be_xO$ film such as Be elements were studied in order to realize a low voltage and high secondary electron emission of protective layer in the PDP device. The experiment confirms that the discharge voltage of PDP device with the $Mg_{1-x}Be_xO$ film, when the concentration of BeO was 40 at.%, was reduced by 20 V, compared with the conventional MgO film. All of these experimental results may be caused by more electron emission from surface levels due to defects because the secondary electron emission coefficient enhances due to change in the defect levels by doping Be elements into MgO films.

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