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Preparation and electric characteristics of MgO films deposited by plasma-enhanced chemical vapor deposition

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In a plasma display panel (PDP) as one very successful technology, a MgO thin film is used to protect the dielectric layer of an AC PDP due to its large secondary electron emission coefficient resulting in a lower firing voltage. In this study, we deposited an MgO film using a plasma-enhanced chemical vapor deposition method and identified the characteristics of the MgO film by observing its preferred orientation and surface shape in terms of substrate type and deposition variables. MgO films with good morphology and a (200) preferred orientation were obtained on Si(100), Pt/Ti/SiO_2/Si(100), and glass substrates when the deposition temperature is approximately 270 . Pt/MgO/ITO/glass and Pt/MgO/ITO/PET capacitors were fabricated and their electric properties were measured for a low temperature application such as in a flexible display.

Key words: MgO, PECVD, PDP, surface morphology, Si, glass, capacitance.

Introduction

Nowadays, extensive research is being done on MgO as a growth substrate or buffering layer for various materials such as metals, semiconductors, superconductors, ferroelectrics and in optoelectronic devices [1-5]. MgO has a strong ionic bond and a NaCl-type crystal structure with a lattice constant of 4.21 °C. Having a low standard free energy, dielectric constant (up to 9.8) and work function as well as a considerable band gap energy (up to 7.8 eV), it has been known as a chemically and thermally stable substance [6]. More recently, it is being used as a material for the dielectric passivation of AC-PDPs, which is one of the very successful technologies for large-format displays.

An MgO thin film can be produced in various ways: sputtering, e-beam evaporation, ion plating and chemical vapor deposition etc [6-8]. Among them, this study applied plasma-enhanced chemical vapor deposition (PECVD) to deposit MgO films. This technique enabled deposition over a large area, easy adjustment of the deposition rate and modification of the substrate temperature within a wide range. Therefore, the technique could be used with almost all materials including highly bonded oxides, and it successfully produced a thin film with a high bond strength with the substrate.

This study describes the results of research on the deposition process of MgO films generated using the PECVD method. The growth characteristics of the film in terms of the substrate type and change in deposition temperature, the surface orientation of the films, and the resulting electric properties were observed.

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Experimental

The PECVD technique was applied for the deposition of MgO films, and the equipment consisted of a reaction chamber for deposition and a load/unload chamber where test samples were taken. An RF power source of 13.56 MHz was used; for the film to grow evenly in a plane-parallel electron structure, carrier and reaction gases were sprayed from the opposite electrode. Also, substrates of Si(100), Pt/Ti/SiO2/Si(100), ITO/glass, and ITO/PET were used for the depositions, and a N_2 plasma pretreatment was made before the deposition. Solid 2,2,6,6-tetramethylheptanedionato-3,5-magnesium(II) (Mg(thd)2) was used as a precursor for the depositions. In the deposition process the temperature of the substrate ranged from 150 °C to 400 °C, and the process took 10 minutes. The base pressure was maintained below 0.93 mPa using turbo and rotary pumps, and a mass flow meter(MFC) and an air operating valve were utilized to control the flow of gas and open/close the pipe. Ar and O_2 gases were kept at 5 sccm and 10 sccm, respectively; the deposition pressure was around 13.3 Pa and the RF power at 100 W. The structural and chemical properties of the deposited MgO films were observed and analyzed using X-ray photoelectron spectroscopy (XPS), scanning electron microscope (SEM), and atomic force microscope (AFM). The electric properties were analyzed using the capacitance-frequency curve.

Results and Discussion

Fig. 1 illustrates the results of the XPS analysis for identifying the composition of the MgO film deposited on Si(100) at an RF power of 100-W. The substrate temperature here was below 400 because of a consideration

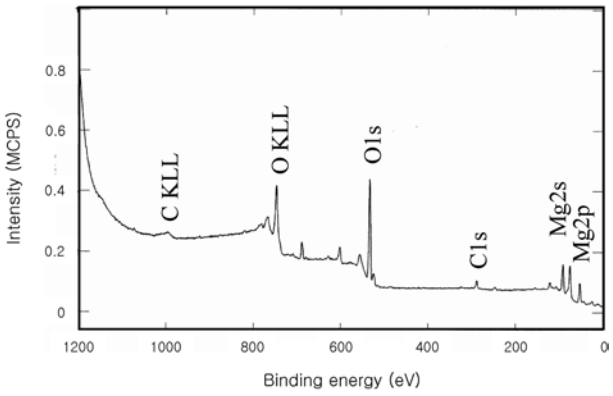

Fig. 1. XPS result of a MgO film deposited on a Si(100) substrate at 360 °C.

of low temperature fabrication. Prior to the analysis, the Ar ion sputtering was used for 20 minutes to remove the oxide film. In all samples, magnesium (Mg_{2s}) and oxygen (O_{1s}) peaks were clearly distinguished, and the ratio of Mg : O : C in the MgO sample was found to be 5.2 : 5.3 : 1.

Figs. 2(a) and 2(b) show the X-ray diffraction (XRD) patterns, measured in the θ/2θ mode, as a function of the deposition temperature of MgO films deposited on the Si(100) and Pt/Ti/SiO2/Si(100) substrates. The figures

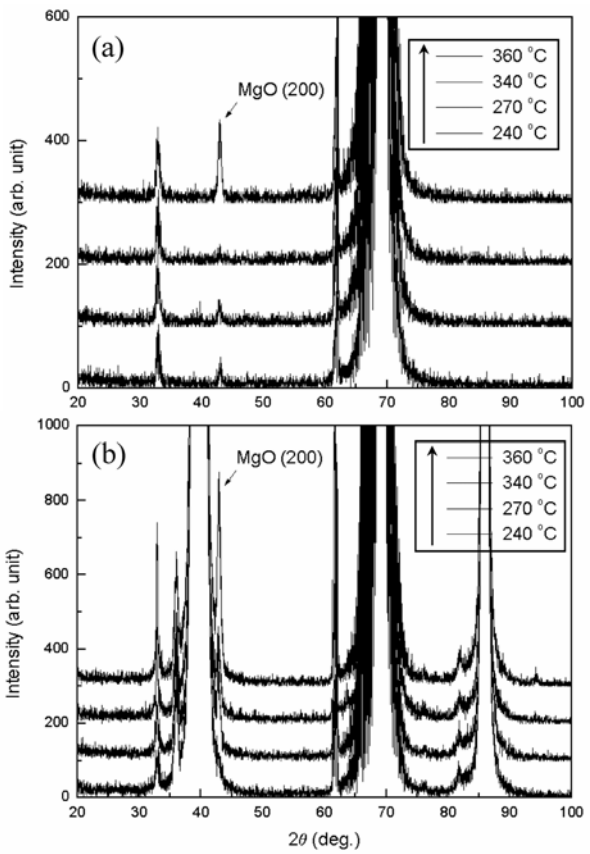

Fig. 2. XRD patterns of MgO films deposited on (a) Si(100) and (b) Pt/Ti/SiO_2/Si(100) substrates at the temperature ranges between 240 °C and 360 °C.

indicate that the relative strength of the diffraction peak from the (200) plane increases as the deposition temperature rises from 240 °C to 360 °C. This had to do with the preferred orientation of films; when the deposition temperature increased, their mobility and level of crystallization rose, thereby increasing the relative strength of the diffraction peak from the (200) plane. Fig. 3 gives the XRD patterns when ITO/glass substrates are used. As the substrate temperature rose from 240 °C to 360 °C, their crystallinity increased from the amorphous state.

Fig. 4 gives AFM and SEM images of an MgO film deposited on a Si(100) substrate at a temperature of 270 °C to observe its fine structure. In the AFM image, the root-mean-square (RMS) roughness of the MgO film is approximately 18.2 mm. Figs. 5(a) and 5(b) show AFM images of films deposited on ITO/glass substrates at temperatures of 270 °C and 400 °C. When deposited at 400 °C, the surface of the film becomes as rough at

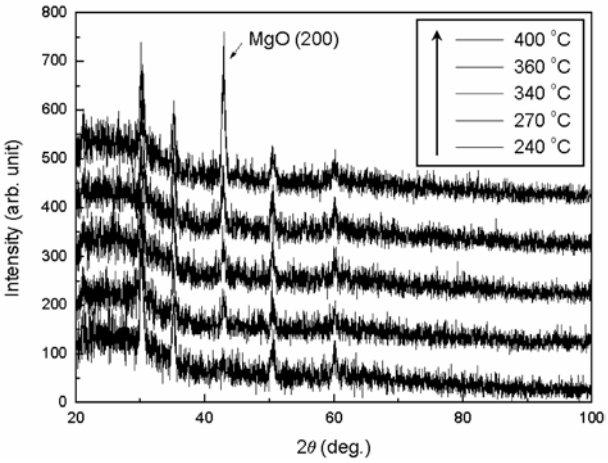

Fig. 3. XRD patterns of MgO films deposited on ITO/glass substrate at the temperature ranges between 240 °C and 400 °C.

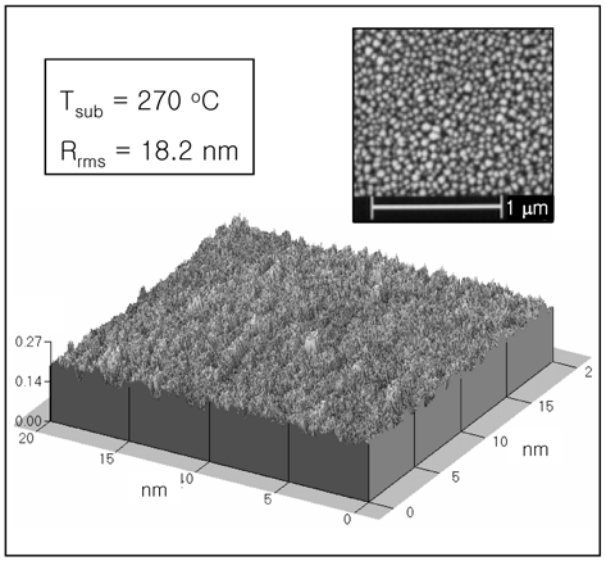

Fig. 4. AFM and SEM images of a MgO film. The thin film was deposited on Si(100) substrate at 270 °C.

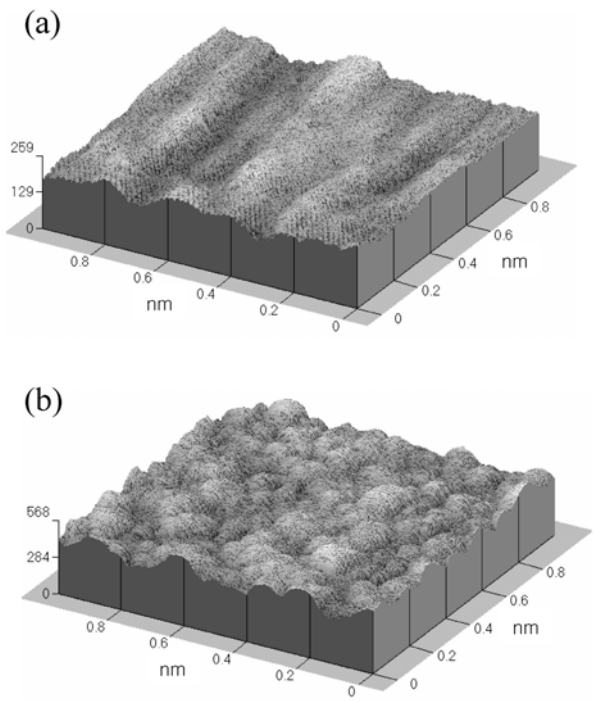

Fig. 5. AFM images of MgO films deposited on ITO/glass substrates at temperatures of (a) 270 °C and (b) 400 °C.

around 38.9 nm in the RMS surface roughness value. Meanwhile, the film deposited at 270 °C had a smooth surface with an RMS value of approximately 15.5 nm. The profile of the AFM data verified that MgO formed the most uniform and homogenous oxide films at a deposition temperature of around 270 °C.

To examine the electrical properties of MgO films, a Pt top electrode was manufactured using the RF sputtering method, and a metal-insulator-metal capacitor was made in the form of Pt/MgO/ITO/glass. Figs. 6(a) and 6(b) show the capacitance-frequency and tan δ-frequency characteristics, respectively. As the substrate temperature changes from 150 °C to 400 °C, the electric capacity at 10^5 Hz increases from 55 pF up to 160 pF, owing to the crystallization of MgO films. The electrical capacity does not change dramatically with frequency from the low-frequency through to the high-frequency range, but it shows a decline little by little. The sample deposited at 150 °C demonstrated a low dielectric loss of 0.02 at 10^5 Hz, while the sample deposited at 400 °C showed a high dielectric loss of over 0.2. Such a dielectric loss is caused by the generation and increase of grain boundary area as the films become more crystallized.

Figs. 7(a) and 7(b) respectively represent the capacitance-frequency and tan δ-frequency characteristics of MgO

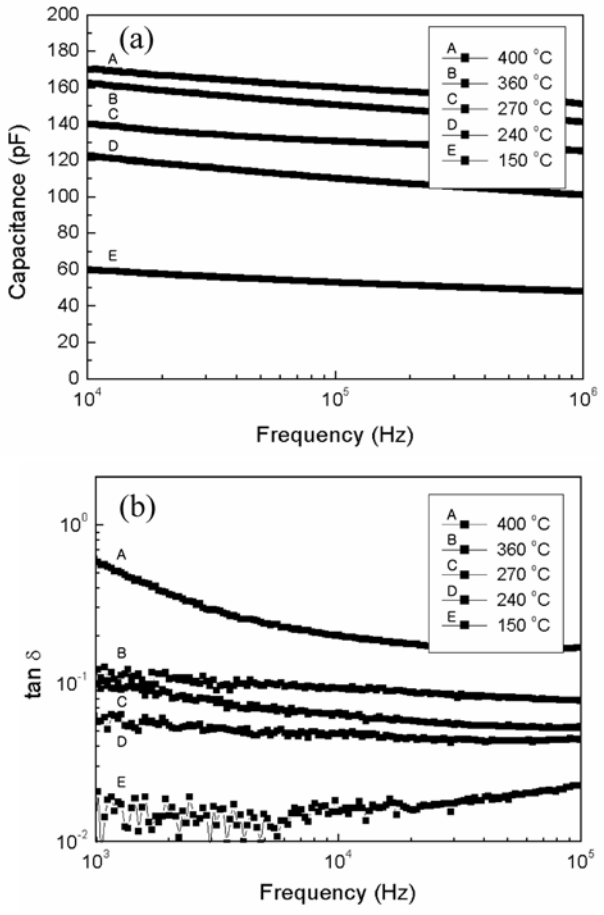

Fig. 6. Capacitance-frequency and tan δ-frequency plots of Pt/MgO/ITO/glass capacitors fabricated at various temperatures. The deposition temperatures were from 150 °C to 400 °C.

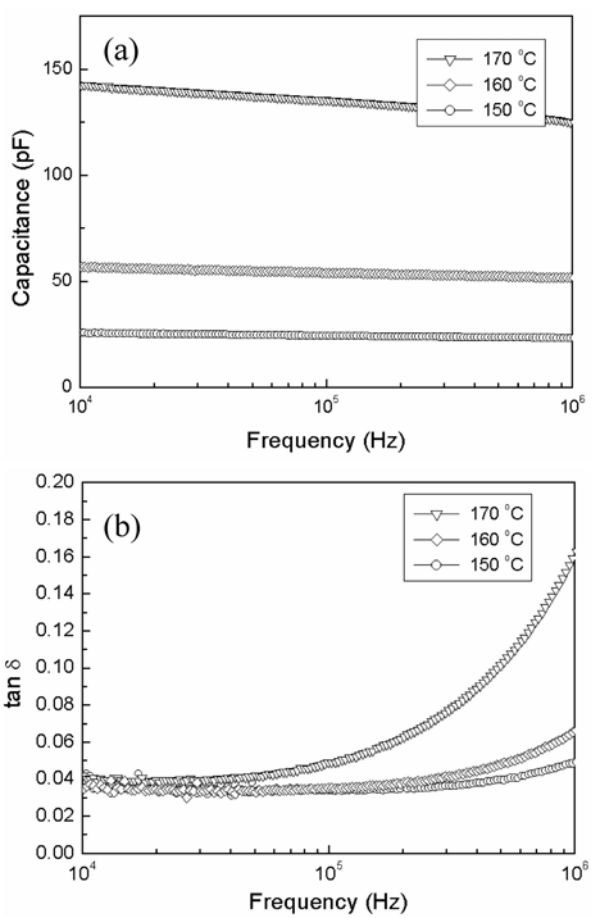

Fig. 7. Capacitance-frequency and tan δ-frequency plots of Pt/MgO/ITO/PET capacitors fabricated at various temperatures. The deposition temperatures were from 150 °C to 170 °C.

capacitors, as a function of frequency, manufactured on plastic PET substrates at low temperature for a low temperature application such as in a flexible display. The substrate temperature ranged from 150 °C to 170 °C. As the temperature of substrate increased, the electrical capacity at 10^5 Hz rose from 25 pF to 130 pF. From the low-frequency range through the high-frequency range, a change as a function of frequency was rarely observed.

Conclusions

This study has manufactured MgO films with a (100)-orientation perpendicular to the substrate, using the PECVD technique, on the Si(100), glass, and plastic substrates. The preferred orientation and surface shape of MgO films were observed at different substrate temperatures and on different substrate types; these properties were shown to be affected significantly by atomic mobility and other factors. AFM and SEM were applied to observe the fine structure of MgO films as a function of substrate temperature and type, and the electrical properties of these films were observed using capacitance-frequency curves. MgO films with good morphology and a (100) preferred orientation were obtained on the Si and glass substrates when the deposition temperature is approximately 270 °C. For an MgO film deposited on a plastic substrate at the low temperature of 170 °C, the capacitance and dielectric loss were approximately 130 pF and 0.05, respectively.

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