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The Discharging Characteristics of Spin-Coated MgO Thin Films with Li Dopant in a Flat Fluorescent Lamp Structure

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The physical and electronic properties of lithium ion doped MgO films formed by spin coating were investigated and characterized in a flat fluorescent lamp structure. The doped MgO films were exquisitely crystallized until the doping concentration was increased to 5%. The test panel with Li-doped MgO films showed that the initial discharge voltages were decreased with increasing the dopant concentration. In particular, the static memory margin of the test panel showed the higher value than that of pure-MgO film. The CL spectra confirmed the creation of defects energy levels in the energy band gap of MgO and showed that the main defects in the doped MgO were the F^+ center increased as the concentration of lithium ion was increased.

Keywords: F^+ center; flat fluorescent lamp; Li^+ doping; MgO

INTRODUCTION

The MgO has been known as a valuable material used as a protective layer in an AC plasma display panel (AC-PDP) and in fluorescent lamps because it has an important role in protecting the dielectric layer and in lowering the firing voltage due to its high secondary

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electron emission characteristics. In the operation of those devices, the initial firing voltage is mainly influenced by the secondary electron emission coefficient of MgO layer related to the crystalline structure as well as defect sites of the MgO [1–4]. Many reports have shown that the secondary electron coefficient could be increased by doping and thus leading to lower the firing voltages of the ac-PDP devices [5–6].

According to the report on the addition of hydrogen during an e-beam process of MgO, the hydrogen was incorporated as a dopant and thus created deep donor energy levels in the MgO band gap improving the luminance efficiency [7]. The formation of such defects in MgO during the vacuum process is hardly controlled because of differences in the evaporation rates between the doping compound and MgO. In contrast, doped MgO films are easily formed and well controlled the doping level by the sol-gel method.

From this viewpoint, spin-coated MgO films with various doping levels were prepared by sol-gel precursors and investigated the effect of dopant on the crystallization of MgO. In addition discharging properties of Li^+ ion doped MgO films were also examined in a flat lamp structure.

EXPERIMENTAL

Figure 1 shows the detailed preparation method for the spin-coating solutions of MgO. An MgO precursor, stabilized magnesium hydroxide

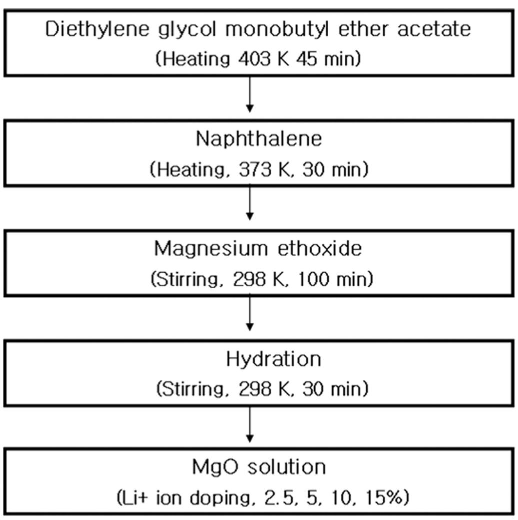

FIGURE 1 Process flow of MgO sol-gel precursor.

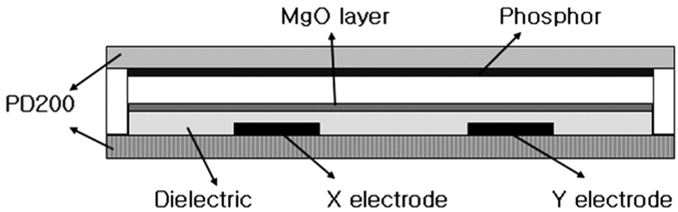

FIGURE 2 Schematic structure in flat fluorescent discharge panel with MgO solution coating.

by the stabilizer of naphthalene was prepared from the starting material of magnesium methoxide and then reacted with lithium butoxide in mole ratios of 1000 to 2.5, 5, 10, and 15 respectively. They were deposited on PD200 glasses and then fired at 823 K for 1 h. Preferred orientation and crystallinity by XRD (D/Max-220, Rigaku), SEM (S-4700, Hitachi), the defect types and binding energy in MgO films by cathodoluminescence (XL-30 FEG, FEI) and X-ray photoelectron spectroscopy (AXIS, KRATOS) were examined, respectively.

To investigate the discharge characteristics, the lithium doped MgO solutions were applied to the fluorescent discharge lamp having 200 μm gap between electrodes and 30 μm thickness of a dielectric layer formed by screen printing on a PD200 glass of 60 $\times$ 90 mm as shown in Figure 2. After spin-coatings, we calcined the MgO films at 833 K for 1 h and then, set a front plate with green phosphor and the rear plate in the vacuum chamber. The height between a front and rear plate was fixed at 0.7 mm by glass spacers. The measuring chamber was filled with Ne-Xe (5%) of discharge gas and maintained at 100 Torr, and then applied a square pulse with a frequency of 40 kHz with 20% duty ratio.

RESULTS AND DISCUSSION

The XRD patterns in Figure 3 of MgO films formed by spin coating show clearly a trend of enhanced or reduced crytallinity by the Li^+ ion content. The diffraction peaks increase with an increase in Li^+ content up to 5% and decreases with an increase in Li ion content over 5%.

The morphologies of MgO layers in Figure 4 show many small pores on the surface of MgO films, and developing micro-cracks dependent on dopant concentration.

Figure 5 is XPS spectra of the O_{1s} of Li^+ doped MgO films. The peaks of O_{1s} energy were shifted differently dependent on lithium ion content, indicating the creation of additional donor energy levels

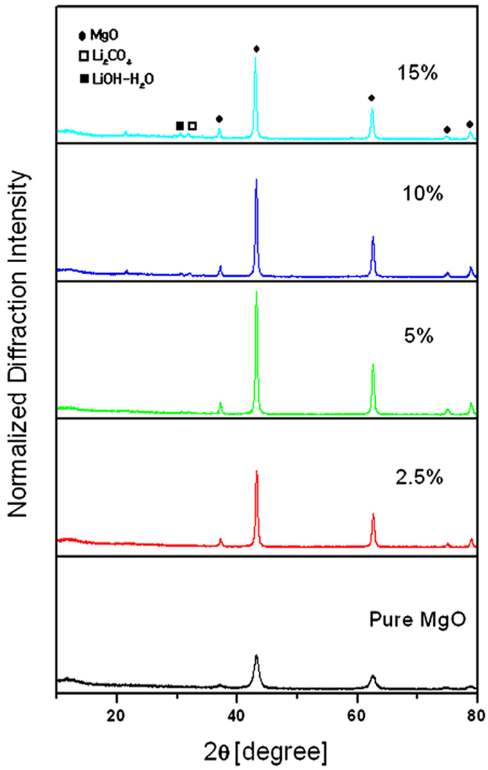

FIGURE 3 XRD analysis of MgO films deposited with various lithium dopant content.

within the band gap of pure MgO by doping. Up to 5% of Li ion contents, it seems that the dopant develops defects energy level in MgO effectively. For more than 5% doping, the excess Li ion which is not incorporated in MgO lattice is observed.

In Figure 6, the CL spectra confirming the creation of defects energy levels in the band gap of MgO, show that the F^+ center of 390 nm, one of two major point defects in MgO crystal, is the main defects in spin-coated MgO films. Based on the CL and XPS results, it seems that some excess of Li ion not only causes oxygen vacancy, but also increases the binding energy of Mg-O in well ordered MgO crystal.

In Figure 7 of the discharge test results of panels with different dopant contents show that the Li^+ doped MgO clearly reduced the firing voltages of test panels compared to the pure MgO. Interestingly, the static memory margin of doped MgO are somewhat increased owing probably to the influence of cracks and a lot of small pores.

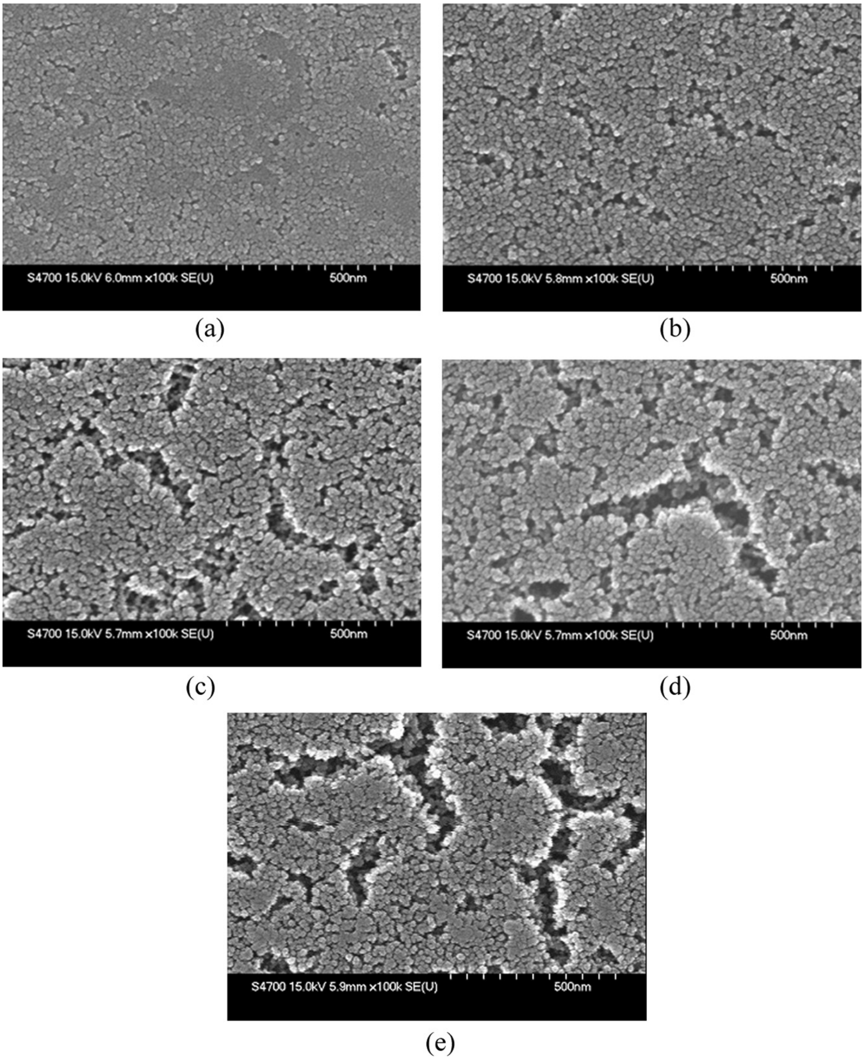

FIGURE 4 SEM image of Li doped MgO (a) Pure MgO, (b) 2.5% Li, (c) 5% Li, (d) 10% Li, (e) 15% Li.

Generally, the MgO surface is charged after the primary electron or the secondary electron emission and also, covered with charged particles during the discharging process. The surface of the doped MgO may have a larger concentration of carriers in the conduction band leading to higher conductivity and eventually causing the reduction

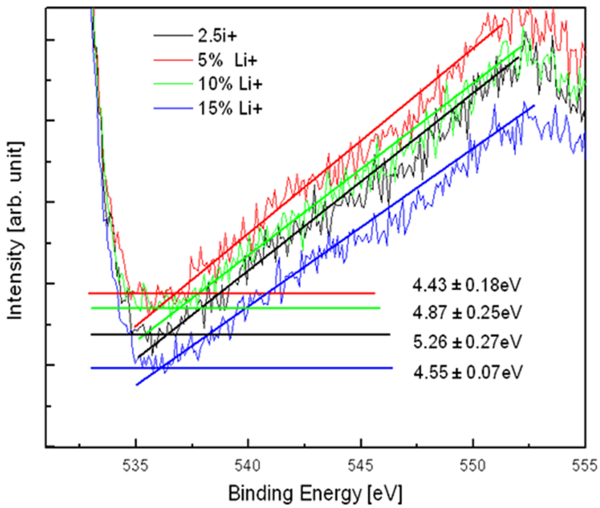

FIGURE 5 O_{1s} spectra of MgO films dependent on dopant concentration by XPS.

of the static memory margin. From our experimental results, lithium ion doping can increase the surface conductivity of MgO film; however, the cracks or pores on the MgO films increased the wall charge and leaded to large memory margins of test panels.

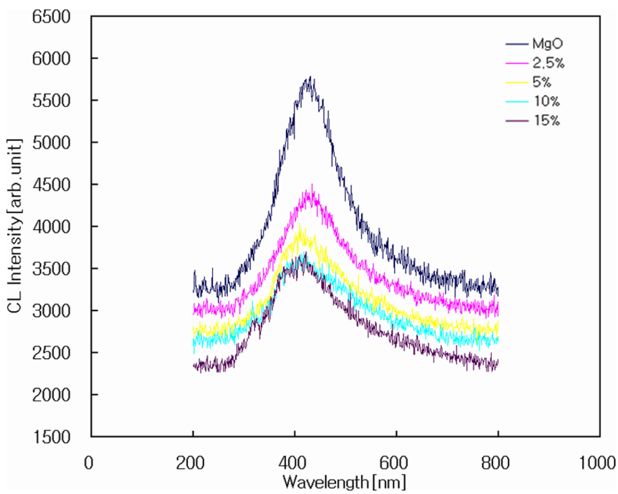

FIGURE 6 CL spectra of lithium ion doped MgO film with different dopant contents.

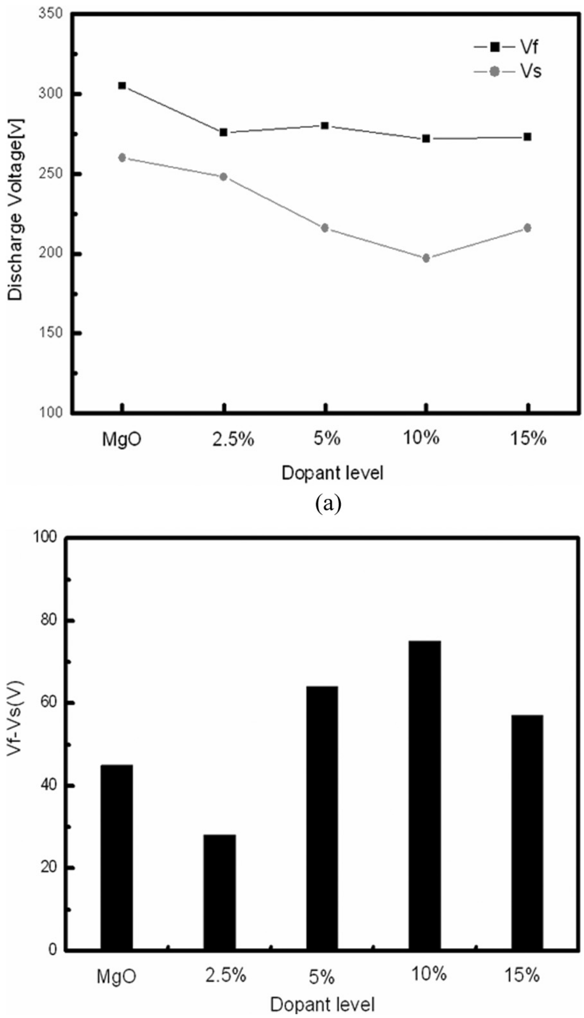

FIGURE 7 Discharge characteristics of various Li^+ doped MgO thin film on test panels at 100 Torr: (a) firing voltage and sustain voltage, and (b) static memory margin.

CONCLUSIONS

The influence of Li^+ ion on the growth of MgO crystal in a spin coated thin film was investigated. Up to around 5% of Li ion contents, the XRD showed the dopant reinforced the crystallization of MgO. For over 5%, it seems that MgO films have an excess Li ion which is not incorporated into crystal lattice. The CL spectra showed the F^+ center was remarkably developed by Li^+ ion regardless of incorporation into crystal lattice. The memory margin of test panels with doped MgO were higher than that of the panel with pure MgO film not only owing to the small pores, but also owing to the micro cracks which can act as a large storage of charged particles on the surface during the operation.

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