13-3: Effect of various MgO E-beam evaporation sources on the characteristics of MgO protecting layer of AC-PDP

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Abstract
MgO thin films were deposited by e-beam evaporation on SiO_2/Si wafers for the application of a protective layer in alternating current plasma display panels (AC-PDPs). Three different MgO sources, single crystal, melted polycrystal and sintered polycrystal, were used to find out the change of the properties of MgO protective layer depending on the source type. The properties of MgO thin films such as density, orientation and surface morphology were influenced by the source type. MgO thin films deposited with the melted polycrystal source had the highest density with the highest (100) preferred orientation, whereas the films deposited with the sintered polycrystal source had the lowest density with less preferred orientation. Such a result seems to be originated from the different mobility of adatoms on the surface of the deposited MgO thin films. Different microstructures of MgO thin films deposited even in the same deposition condition were observed depending on the MgO source type, resulting in different discharge characteristics.

1. Introduction
MgO thin film is widely used as a protective layer on the dielectric layer for alternating current plasma display panels (AC-PDPs) due to low sputtering yield, high secondary electron coefficient and good optical transparency [1-2]. In the actual operation of AC-PDPs, the discharge characteristics are critically dependent on the physical properties of MgO films; crystalline structure, surface morphology, and so on [3-4]. Many researches of diverse directions have been conducted, but the growth mechanism and the relationship between microstructure and discharge characteristics have not been reported clearly because the properties of MgO thin films are significantly sensitive to the evaporation condition and post-treatment of evaporated MgO layer. Therefore, it is too difficult to consider separately the factors influenced the discharge characteristics.
To explain the relationship between microstructure and discharge characteristics, in this study, MgO thin film was deposited with three E-beam evaporation sources; single crystal, melted polycrystal, and sintered polycrystal. The basic properties of the deposited MgO thin films were characterized by ellipsometer, X-ray Diffractometer (XRD), Scanning Electron Microscope (SEM) and Atomic Force Microscopy (AFM). And the discharge characteristics were also measured using the unsealed 2" test panels in a vacuum chamber filled with Ne-4%Xe mixture.

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2. Experimental
MgO thin films were deposited by e-beam evaporation method with three MgO sources; single crystal, melted polycrystal, and sintered polycrystal. To observe the basic properties of MgO films, the 50 nm-thick thermal-oxidized SiO_2/Si wafers were used as substrates, while the 2" test glass panels were used as substrates for the measurement of the discharge characteristics. The chamber base pressure was kept at 10^{-7} Torr and the substrate temperatures were fixed at room temperature during the deposition. Acceleration voltage was fixed at 10 kV and electron beam current was in the range of 9~20 mA. Deposition rate of MgO was 0.1 nm/sec and thickness of MgO film was about 500 nm for all samples.
Film density was calculated by means of two methods; gravimetric measurement and ellipsometer. In the first method weight and volume of the films were directly measured and then the density was calculated by dividing the weight of film by the volume. So we measured the weight of the substrate before and after deposition. And MgO film was deposited using the 6×4 cm^2 mask to keep a constant MgO deposited area for all samples. Thickness of film was measured by thickness profiler and was confirmed by cross-sectional images of SEM. The second method is done by measuring the refractive index of film using ellipsometer and then by calculating the density using Lorentz-Lorenz equation [5];

$$\rho = K(n^2-1)/(n^2+1)$$

where, ρ, K, and n are film density, Lorentz constant, and refractive index, respectively. Film density was acquired using 9.078 of Lorentz constant, K. For the identification of the crystallinity and preferred orientation of MgO thin films, XRD in θ-2θ mode was used. In order to observe the surface morphology and microstructure of MgO films, SEM and AFM were used.
Discharge characteristics, firing voltage (V_f) and sustaining

voltage (V_s), were measured using the unsealed 2" test panel in the chamber filled with Ne-4%Xe mixture gas at 300 Torr. The discharge between sustaining electrodes was generated and the sustaining pulses of 10 kHz of the panel were alternatively applied to each sustaining electrode. It is generally known that MgO has a strong tendency to form $Mg(OH)_2$ and $MgCO_3$ in exposure to air [6]. Hence, in order to prevent such tendency, discharge characteristic was immediately measured after the deposition of MgO films on the test panels.

3. Results and discussion

Figure 1 shows SEM micrographs of MgO films deposited with three sources. Films were deposited in the same condition; deposition rate was 0.1nm/sec and film thickness was 500 nm. But surface morphology was very different depending on the source type. In case of single crystal source, grains of MgO film were spherical and its grain boundaries were very loose. Grains of films deposited with melted polycrystal and sintered polycrystal sources were smaller than that with single crystal source and had a sharp triangle shape. But SEM cross-sectional images of these two films were different from each other. In case of melted polycrystal, grains were columnar and dense, whereas those of sintered polycrystal were loose and voided.

Figure 2 compares the density of MgO thin films deposited with three sources. As shown in Figure 1 (b), (d), and (f), density of MgO thin film deposited with the melted polycrystal source was the highest. The reason for the difference in surface morphology and density of film was due to the difference of filament emission current even in the same deposition rate, as shown in Table 1. The difference is caused by the energy requirement for evaporating each source, and the evaporated atoms' mobility is influenced by the filament emission current. In case of the melted polycrystal source, its emission current was so as high as 17 ~ 19 mA that its grain was dense. Whereas MgO film deposited with the sintered polycrystal source had the lowest density, because of 9 mA of emission current which was lower than that of the melted polycrystal source. Finally, it can be concluded that the emission current might control the density of the films deposited in the same deposition condition like deposition rate.

Figure 3 shows XRD patterns of MgO films deposited with three sources. Films deposited with the single crystal and melted polycrystal sources have (100) preferred orientation, but (100) peak intensity of the film deposited with the sintered polycrystal source was equal to that of (111) peak. It was also due to the mobility of the adatom on surface of deposited MgO film. Aboelfotoh et al. [7] suggested that (100) preferred orientation, which minimizes the interfacial and surface free energies, appeared when interfacial interaction between the deposited species and the substrate atoms is weak. As a result of the weak interfacial interaction between the deposited species and substrate, the mobility of the deposited species on the substrate surface was increased. So adatom having high mobility can easily move on (100) plane. In this study, the same phenomenon was observed. Atoms evaporated by higher emission current had higher mobility so they easily moved on stable (100) plane. In cases of the single crystal and sintered polycrystal sources, degree of orientation to (100) plane was less than that of the melted polycrystal source. Therefore, the degree of orientation to (100) plane was corresponded to the tendency of the filament emission current.

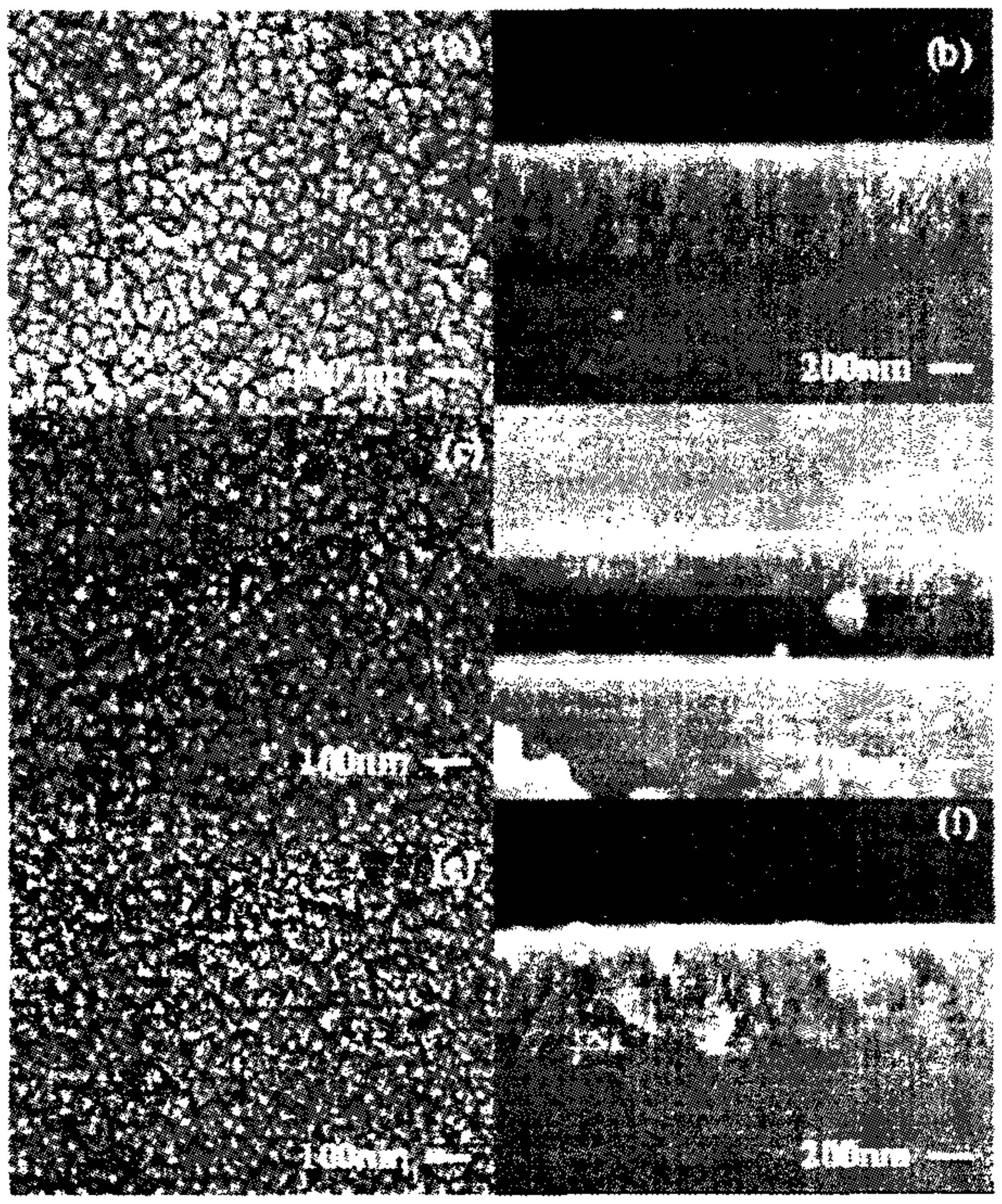

Figure 1. SEM images of MgO films deposited with (a), (b) single crystal, (c), (d) melted polycrystal, and (e), (f) sintered polycrystal source.

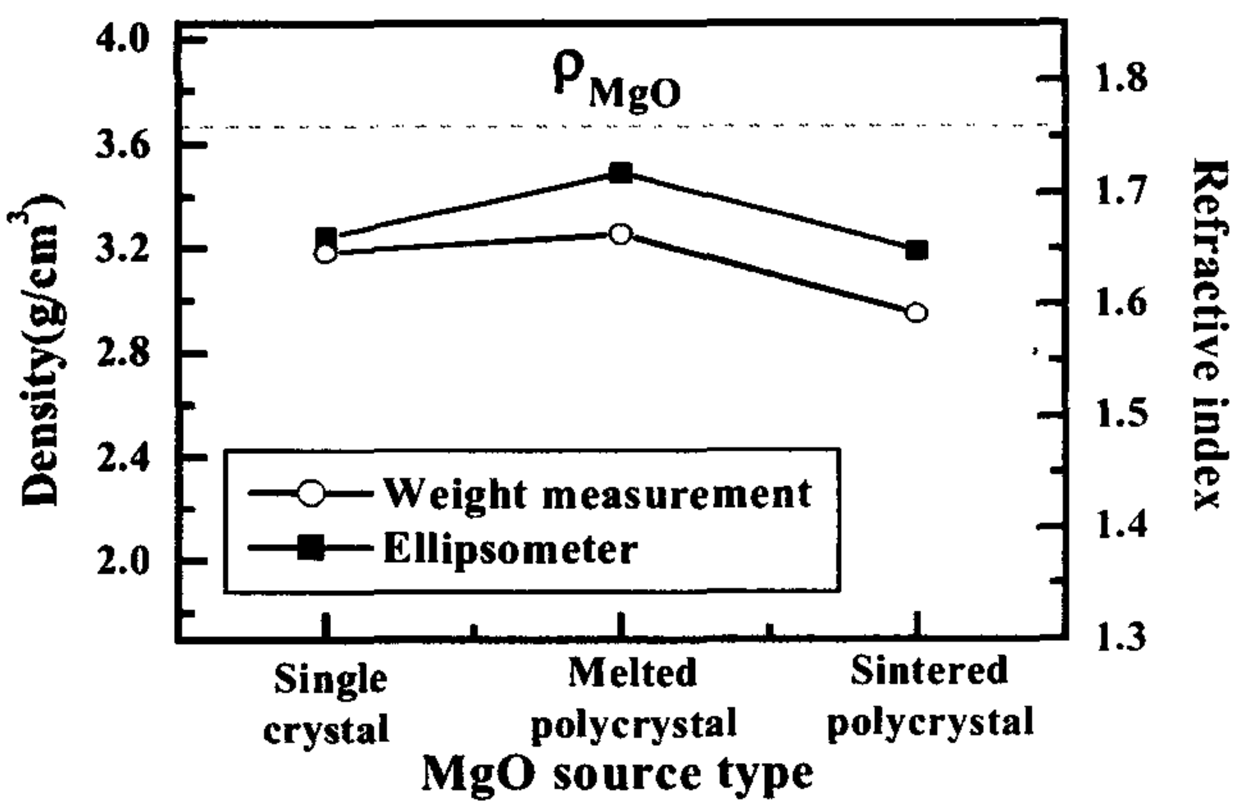

Figure 2. Density of MgO films deposited with various sources.

Table 1. Filament emission current during E-beam evaporation with various MgO source at same condition, 0.1 nm/sec.

	Single crystal	Melted polycrystal	Sintered polycrystal
Filament emission current	14~16 mA	17~19 mA	9 mA

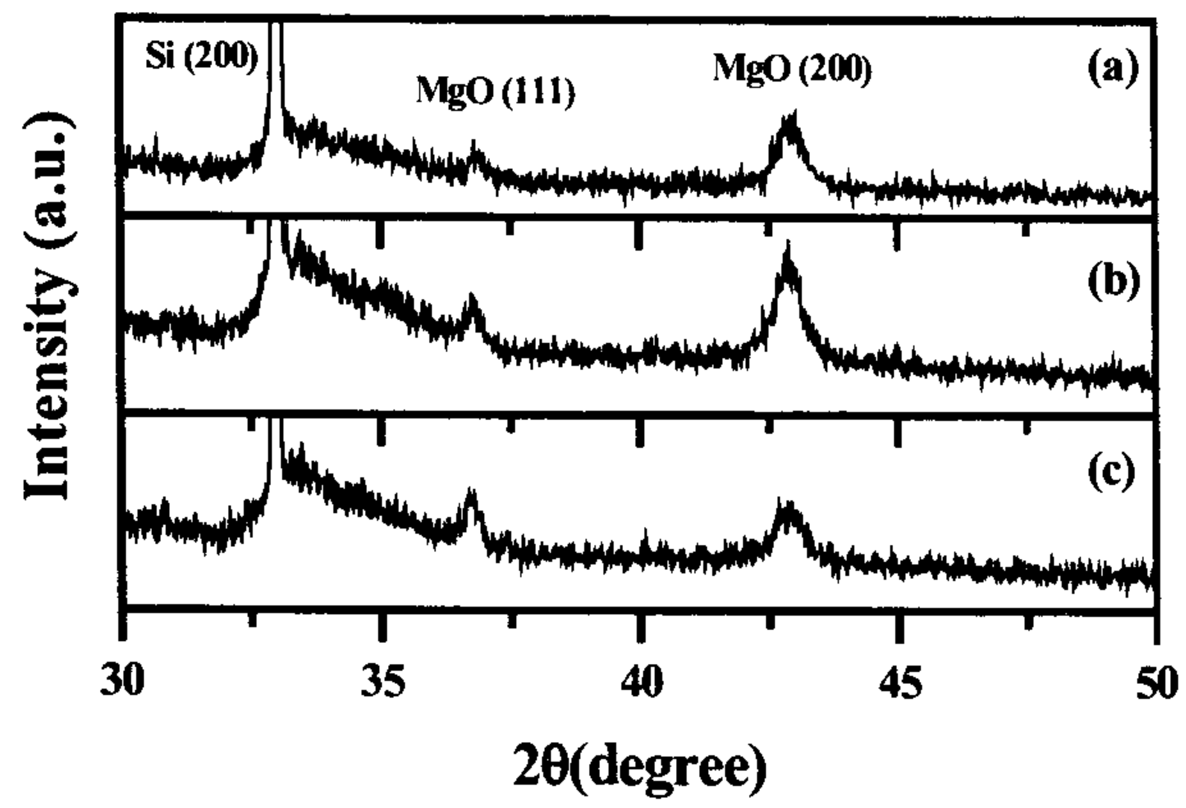

Figure 3. XRD patterns of MgO films deposited with (a) single crystal, (b) melted polycrystal, and (c) sintered polycrystal source.

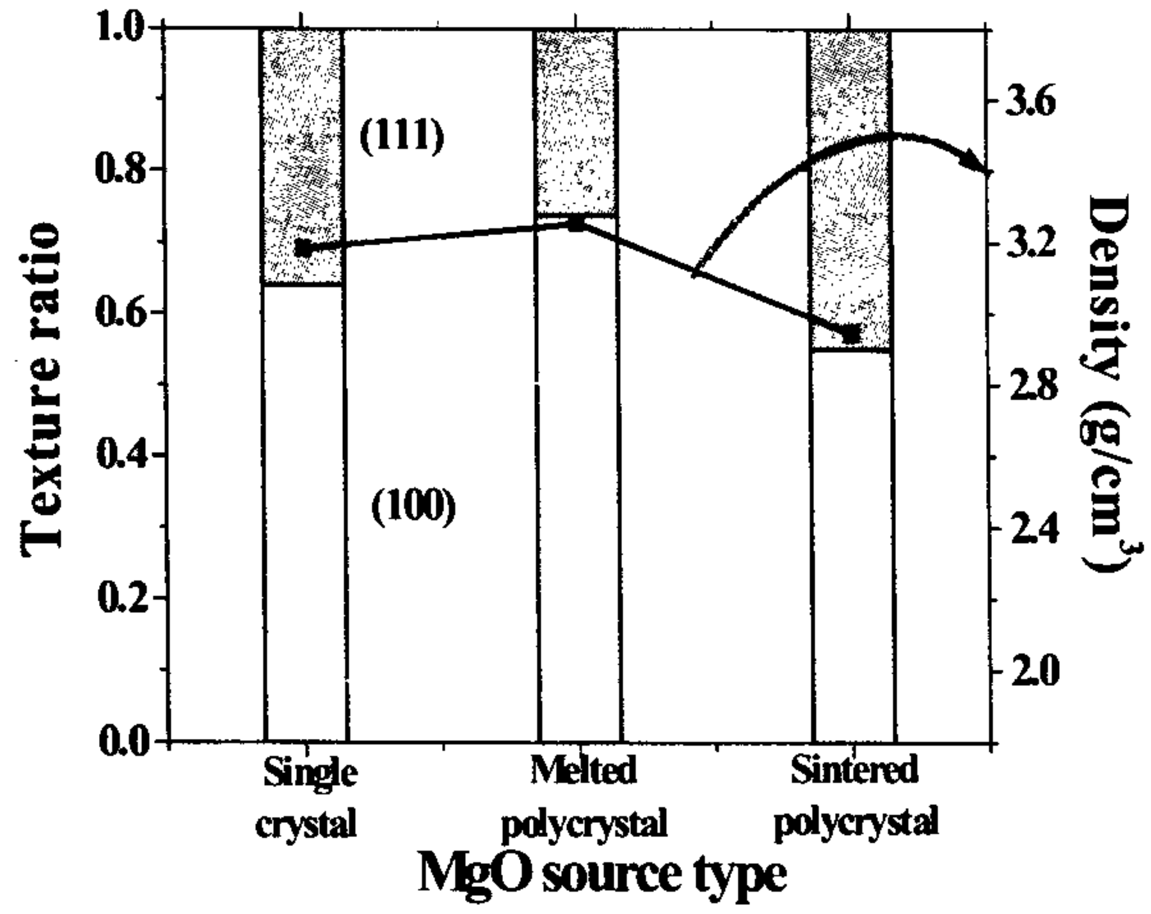

Figure 4. Relationship between texture ratio and density of MgO films deposited with various sources at same deposition rate, 0.1 nm/sec.

Figure 4 represents that adatom's mobility affected the film's density and preferred orientation, and the tendency of both was similar. To observe the dependency of the properties of MgO films on filament emission current, MgO films were deposited with various sources in 19 mA of the same emission current, and the result is shown in Figure 5. In cases of the single crystal and melted polycrystal sources, deposition rate was 0.2 ~ 0.25 nm/sec. And the deposition rate of MgO film deposited with the sintered polycrystal source was 0.5 ~ 0.6 nm/sec. On the contrary, the density of MgO films deposited with the single crystal, melted polycrystal, and sintered polycrystal sources were quite similar. From the result it can be inferred that atoms evaporated at the same emission current had the same mobility and the current was a key factor to change the density. MgO films deposited with the single crystal and melted polycrystal sources were oriented to (100) plane and the degree of texture ratio was similar to each other. But in case of the sintered polycrystal source, it was oriented to (111) plane. Although the evaporated atoms had high

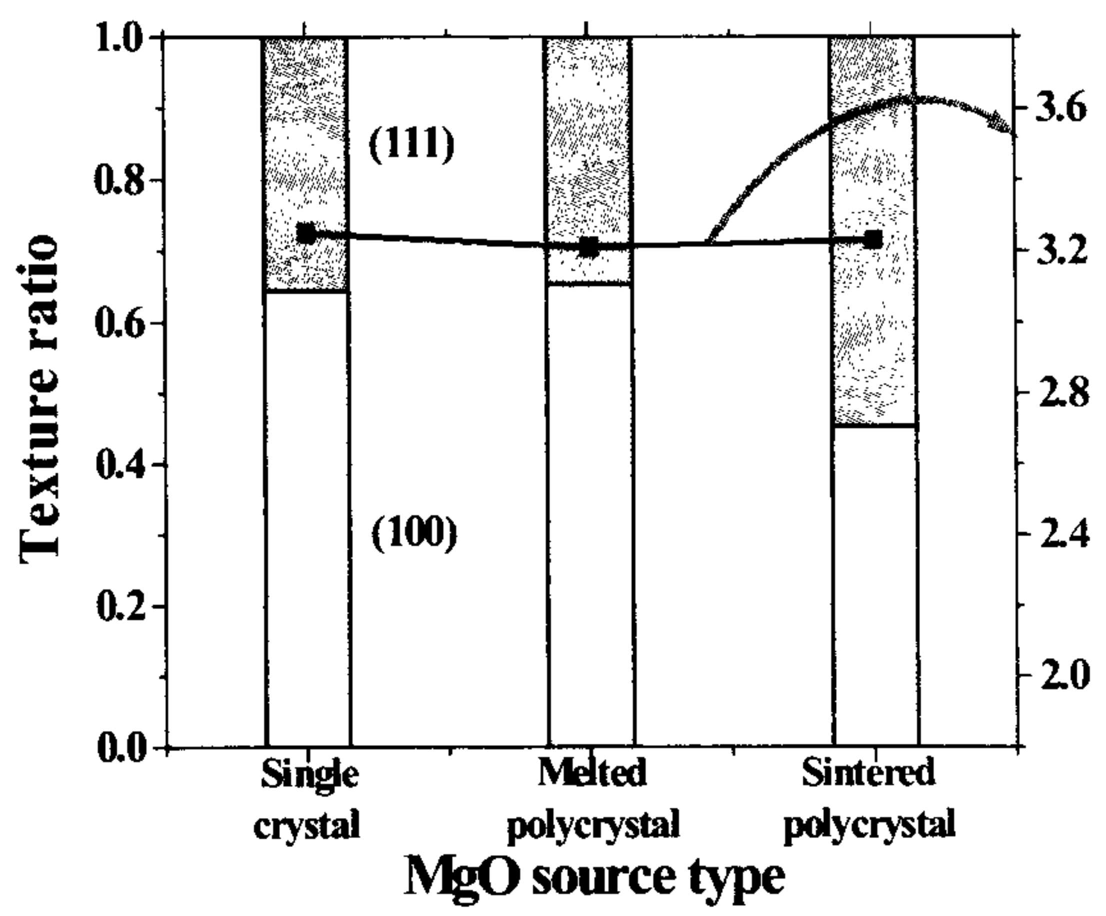

Figure 5. Relationship between texture ratio and density of MgO films deposited with various source at same emission current, 19 mA.

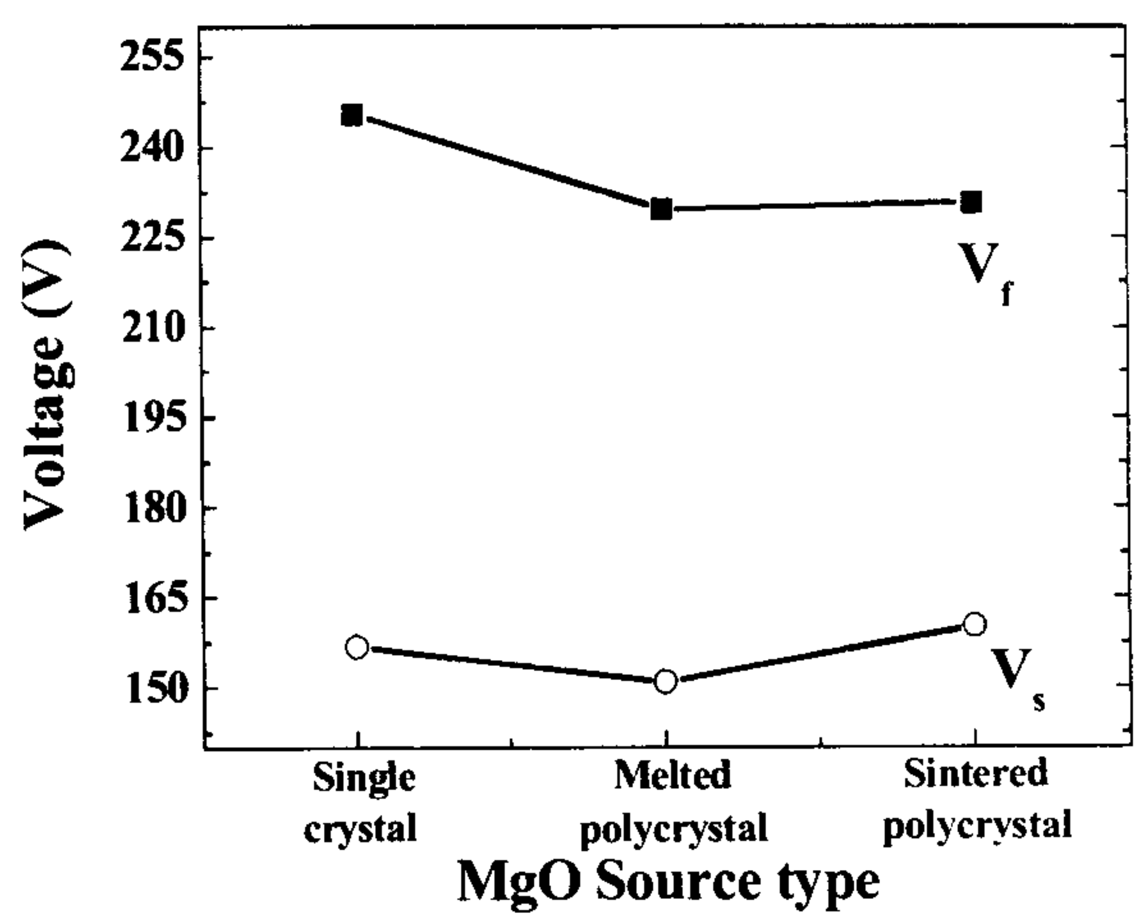

Figure 6. Discharge characteristics of MgO films deposited with various sources at same deposition rate, 0.1 nm/sec.

mobility, other adatoms arriving later could disturb the atoms in their settling down on the stable atomic sites because of high deposition rate. The result was different from that of Aboelfotoh et al. [7]. In case of the sintered polycrystal sources, mobility of the film was high but it was oriented to (111) plane.

As a result of deposition with three sources, it is sure that adatoms' mobility is an important factor to change the microstructure of MgO films.

Figure 6 shows the discharge voltages of test panels with MgO films deposited at the same deposition rate. Firing voltages of MgO films deposited with the melted polycrystal and sintered polycrystal sources were similar to each other, whereas firing voltage of the single crystal source was higher than those of others. In case of the single crystal source, density and preferred orientation were similar to the melted polycrystal source. But its surface morphology was different from those of other sources. It seems that a spherical-shaped grain and a loose grain boundary had a bad influence on firing voltage and surface morphology was an important factor to firing voltage. Sustaining voltage of MgO film deposited with the sintered polycrystal source had highest. The tendency of sustaining voltage was in good agreement with that of density. High density of MgO film deposited with the melted polycrystal source had the lowest sustaining voltage. In case of the melted polycrystal sources, firing and sustaining voltage were lowest.

4. Conclusion

From this study it was found that microstructure of MgO films deposited with three sources was different. In case of the single crystal source, its grains were spherical and grain boundaries were loose. Grains of MgO film having the highest density deposited with the melted polycrystal sources were small and sharp. And grains of film deposited with the sintered polycrystal source were similar to those with the melted polycrystal source but its density was lowest. It was due to a difference of the atoms' mobility. High-mobility atoms developed the dense and (100) preferred oriented film. But when diffusion time was not long enough to move, film was oriented to (111) plane.
According to the discharge characteristics of the unsealed 2" test panels, it is confirmed that firing and sustaining voltages were affected by surface morphology and density of MgO films, respectively. In this study, MgO film deposited with the melted polycrystal source showed the best discharge characteristics.
In conclusion, denser MgO film with the sharp and small grains could be led to better discharge characteristics.

5. Acknowledgements

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6. References

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