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Structural, Morphological and Optical Characterization of Spray Deposited MgO Thin Film

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ABSTRACT

MgO thin film was deposited on a siliconglass substrate using home built spray pyrolysis method at 230°C. Aqueous solution of 50 mL containing magnesium chloride hexahydrate was sprayed as a fine mist at a pressure of 2 kg cm^{-2} with a flow rate of 3 mL min^{-1} on a preheated glass substrate. The optical property, structural property and surface morphology of the film was analyzed without any post annealing and those properties were studied by photoluminescence spectroscopy, X-ray diffraction (XRD), UV-VIS spectrophotometer, Field Emission Scanning Electron Microscopy (FESEM) and the obtained results were discussed.

Key words: MgO thin film, spray pyrolysis

INTRODUCTION

Magnesium oxide has been used in electronics applications (Kim and Kim, 1999). It is widely used as a buffer layer for high-Tc superconducting thin film (Bian *et al*., 2004) and perovskite-type ferroelectricfilms (Kim *et al*., 2000a). As MgO thin film is highly dielectric, it can be used in protecting layer of AC plasma display panel (Kim *et al*., 2000a; Kim *et al*., 2000b). In this spray pyrolysis method there is no need to create vacuum and it has an advantage of coating films in open atmosphere. It is a simple method to prepare thin films of different oxide. MgO has an advantage of wide band gap, low optical loss and heat insulation (Kurtaran *et al*., 2013). There are several methods to prepare MgO thin film such as metal organic chemical vapour deposition (MOCVD), Pulsed Laser Deposition (PLD) and spray pyrolysis method (Fu *et al*., 1999). Even in spray pyrolysis technique many types are there such as ultrasonic spray, electrostatic spray but cost wise very expensive. So this low cost home built spray pyrolysis is much better than other methods and also produces good quality film in nano meter range. The advantages of this home built spray pyrolysis are low equipment cost and good uniform thickness.

MATERIALS AND METHOD

$MgCl_2.6H_2O$ is an initial compound to produce MgO film after decomposition and dehydration. This material was purchased from Fisher Scientific. The schematic diagram of home built spray pyrolysis is show in the Fig. 1.

This spray pyrolysis set up consists of substrate heater, air compressor, temperature controller, exhaust fan and pipe, spray gun and beaker. A beaker of 80 mL was used to hold the

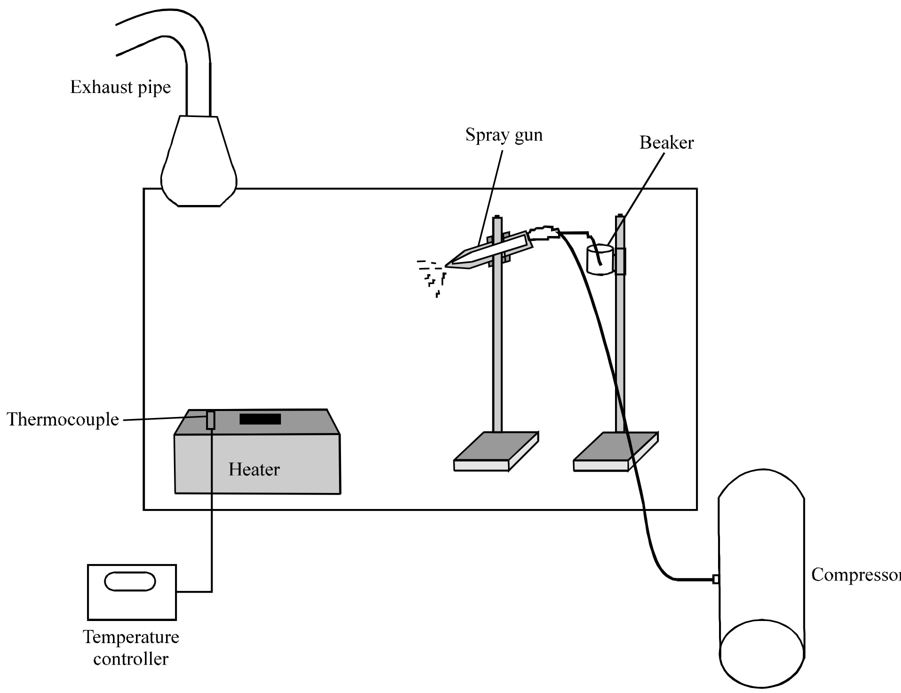

Fig. 1: Schematic diagram of home built spray pyrolysis

precursor solution. Two tubes were connected from the spray gun to beaker and air compressor. The desired temperature was set by temperature controller and purpose of thermocouple is to detect the substrate temperature.

Initially 0.05 M of magnesium chloride hexahytrate has taken as the precursor solution. It was dissolved in 50 mL deionised water and stirred for 5 min and the solution was filled in the beaker. A piece of amorphous glass substrate was cleaned and placed on the stain less steel plate and then heated at a constant temperature of 230°C. The spray gun nozzle and substrate was fixed at a distance of 40 cm with spray nozzle maintained at an angle of 45° corresponding to the substrate. The compressed air was used as a carrier gas. The beaker solution was sprayed on the glass substrate with a flow rate of 3 mL min^{-1}. The solution was sprayed on the glass substrate upto 50 mL volume. Each and every droplet comes out from the spray gun was less than micro sized particles and hence the film coated will be of uniform in thickness. Solution droplets adsorbed on the surface has undergone pyrolytic decomposition and finally MgO thin film was obtained.

The obtained MgO thin film was characterized by Field Emission Scanning Electron Microscopy (FESEM), X-ray diffraction (XRD), UV-Vis spectrophotometer, photoluminescence spectroscopy and the carrier concentration and resistivity of the film has been determined from Hall effect measurement.

RESULTS AND DISCUSSION

Figure 2 depicts the XRD pattern of deposited MgO film. The diffracted peaks were obtained at particular angle 42.67, 62.3 and 72. These are corresponding to the crystal plane (200), (220) and (311). The high preferential peak (200) accommodates more MgO atom at lower temperature. All broadening peak indicates that the particle size is smaller and film is polycrystalline in nature. The density of atom is higher in (200) plane and smooth surface obtained due to optimized condition (Patil, 1999). The mobility of magnesium and oxygen atom is higher at the substrate

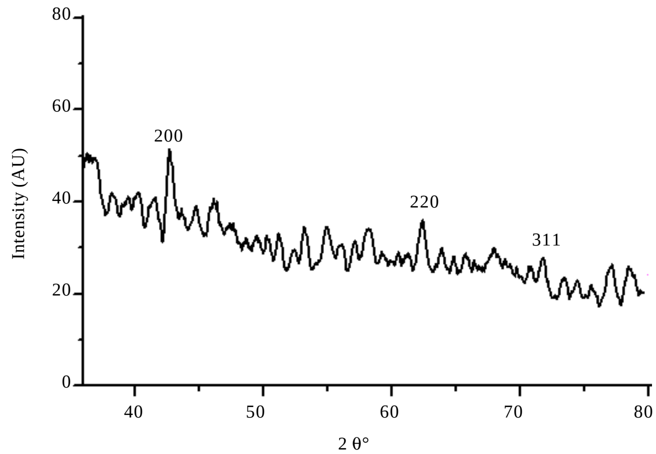

Fig. 2: XRD pattern for MgO film on glass substrate

Table 1: Crystalline size, dislocation density and strain value for the deposited MgO film

D (nm)	δ $(nm)^{-2}$	Strain
14	2.2456	0.005469

temperature of 230°C on the growing film surfaceand hence it formed crystallized grain. The water solvent did not affect the periclase phase of the film and no more phases shown in XRD pattern. It is completely dehydrated during deposition without any post annealing. The peaks obtained in the pattern are matched with standard JCPDS data (71-1176) and so it is confirmed that the coated film is MgO. Table 1 shows the average crystalline size, dislocation density and strain.

The average crystalline size were calculated using Scherrer equation:

$$D = \frac{0.9\lambda}{\beta \cos\theta} \tag{1}$$

where, λ is wavelength of X-rays (1.5418 Å).

Mechanical property of crystalline material is dislocation density. It occurrs because of strain (δ) developed during solution flow from spray gun to substrate and calculated from the relation:

$$\delta = \frac{1}{D^2} \tag{2}$$

The optical transmittance and band gap energy for MgO film is shown in the Fig. 3 and 4. The maximum transmittance of 86% attain in the higher wavelength. The maximum absorption or excitation peak obtained at 331 nm and this reveal that the film absorb UV region. The band gap of MgO has been calculated from the plot $(\alpha h\upsilon)^2$ vs. $(h\upsilon)$ and is shown in Fig. 4. The band gap was found to be 2.5 eV and semiconductor nature.

Figure 5 shows the room temperature PL spectrum of MgO film. The Photoluminescense spectrum gives the information about the film defect. It sclearly indicates that the defect in MgO film because of Mg and O elements vacancies and similar results are reported by Kim *et al.* (2000b).

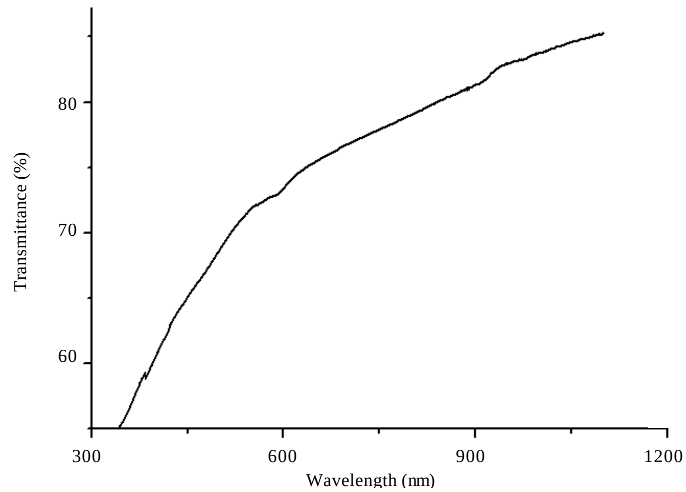

Fig. 3: UV transmittance spectrum of MgO thin film

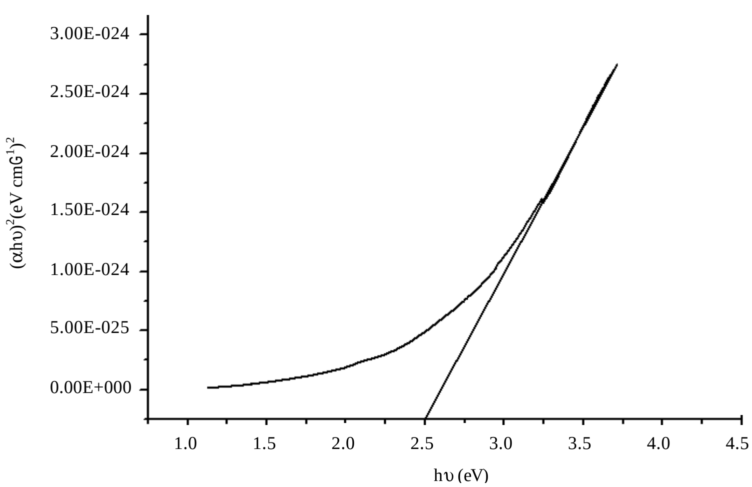

Fig. 4: Bandgap determination plot

Table 2: Bulk carrier concentration, mobility and resistivity for MgO thin film

Bulk Carrier concentration (cm^3)	Resistivity (Ωcm)	Mobility (cm^2/v.s)
3.5×10^{12}	26.2×10^{4}	55.4

The film resistivity and carrier concentration was obtained from Ecopia Hall effect measurement of values is shown in Table 2. The measured resistivity value is higher so it is a insulating material (Yi *et al.*, 1996).

Figure 6 displays the Field Emission Scanning Electron Micrograph (FESEM) images of MgO thin film. Mostly the film composed of sphere and rod like particles. Small dark area represent porous in the film and the presence of it will increase the electrical resistivity.

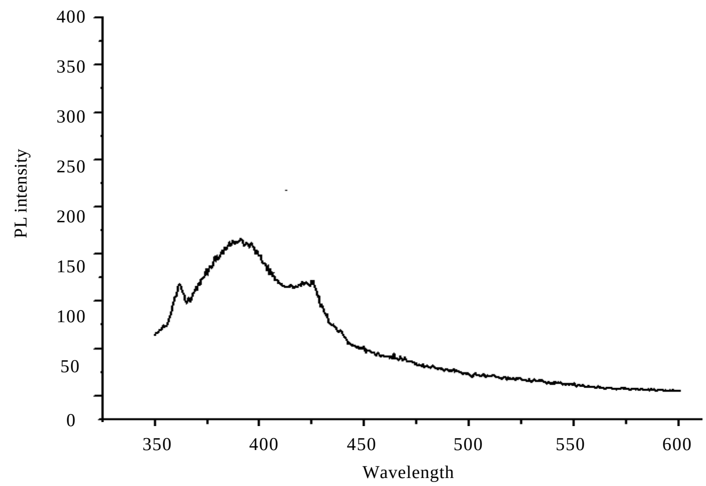

Fig. 5: PL spectrum of MgO film

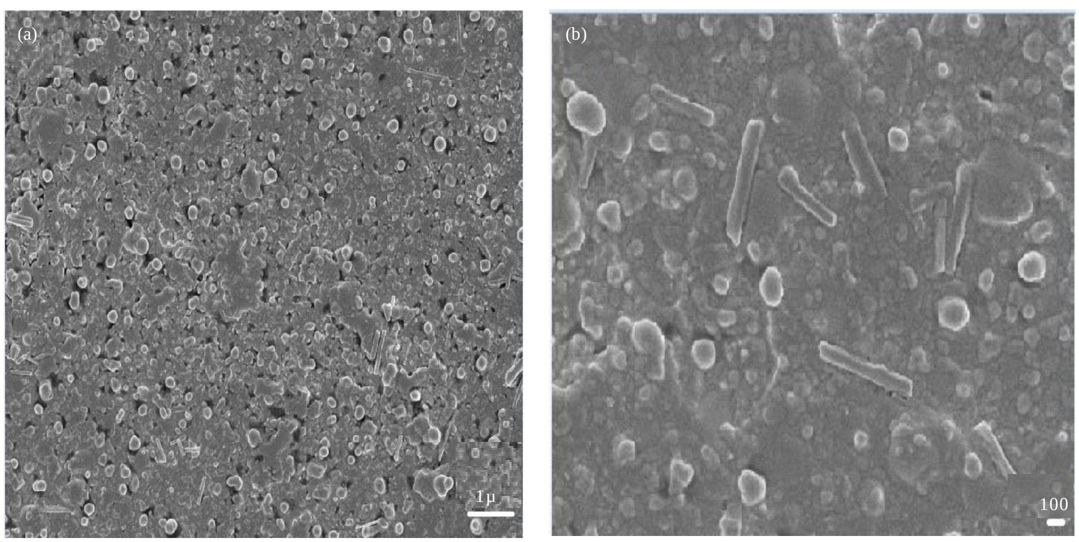

Fig. 6(a-b): FESEM image of MgO thin film at 230°C

Smooth and dense surface is observed in Fig. 6b. The obtained grain size is smaller and good agreement with X-ray diffraction pattern.

CONCLUSION

Magnesium oxide thin films were deposited on a preheated glass substrate by using home built spray pyrolysis from the precursor of magnesium chloride hexahydrate. The XRD pattern indicates polycrystalline nature and also calculated grain size was in the order of nanometer. The high optical transmittance of 86% and wide band gap 2.50 eV was observed UV-VIS spectrophotometer studies. The deposited MgO film revealed high resistivity by Hall effect measurement.

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