*Advanced Materials Research Vols. 403-408 (2012) pp 1168-1172*
*Online available since 2011/Nov/29 at www.scientific.net*

*doi:10.4028/www.scientific.net/AMR.403-408.1168*

# Molarity Effect on the Structural Properties of Nano-MgO Thin Films

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**Keywords:**Nano-MgO; Molarity; Morphology; Structural Properties; Sol-Gel

**Abstract.** Nano-MgO thin films were grown on the cleaned glass substrate via sol-gel spin coating techniques using magnesium acetate tetrahydrate, ethanol and nitric acid. For the thin films deposition, the solutions were prepared at six different molar concentrations (0.1M, 0.2M, 0.4M, 0.6M, 0.8M and 1M). The thickness and roughness of nano-MgO films was found to be increased with an increase of molar concentration. The increment in particle size and agglomerated particles were observed from FESEM (JEOL JSM-J600F) images as the molar concentration increased from 0.1M to 1.0M. The results showed 0.4M nano-MgO films have the best properties for example it has a uniform film, non-porous structure and has nanometer dimension size which around 42.8nm.

## Introduction

Magnesium oxide, MgO is a best candidate to be used as dielectric layer due to its excellent properties such as has high dielectric constant (~ 9.8), large band gap in the range of 7.3 eV -7.8 eV [1, 2] and has higher breakdown field (12 MV/cm) compared to commonly used dielectric layer which is silicon dioxide ($SiO_2$) [3]. Due to its excellent dielectric properties, MgO has been proposed to be used for capacitor applications because MgO can improve the storage capability of a capacitor. Other characteristicsofMgOthat comparable to $SiO_2$aredue to its chemical inertness, electrical insulation, optical transparency, high temperature stability, high thermal conductivity and secondary-electron emission with a lattice constant of 4.21 Å [4]. Due to its excellent properties, MgO has been proposed to replace current dielectric material ($SiO_2$) [3, 5]. In the capacitor application, it is hypothesized that using this material will result in used of thin dielectric layer with high dielectric constant which can improve the storage capability of a capacitor.

There are several methods can be used to deposit the MgO thin films such as pulsed laser deposition, electron beam evaporation, chemical vapor deposition and sol-gel spin coating technique[6]. Compared to others, sol-gel offers several advantages, such as good film homogeneity, easy stoichiometry control, purity, ease of processing and controlling the composition, and the ability to coat at large and complex area substrates [7, 8].

In this study, nano-MgO thin films at six different molar concentrationswere prepared using sol-gel spin coating method. Structural characterizations were conducted in order to investigate the effect of molarity to the topography and morphology of nano-MgO thin films.

## Experimental Procedure

Glass substrate used were cleaned in acetone, methanol and de-inonized (DI) using ultrasonic bath for 10 minutes to remove the residual oxide on the substrate. The MgO solutions were prepared using Magnesium acetate tetrahydrate, ethanol and nitric acid as starting material, solvent and stabilizer respectively. The MgO solutions were varied at six different molar concentrationswhich are 0.1M, 0.2M, 0.4M, 0.6M, 0.8M and 1M. The solutions were then sonicated at $50^0$C for 20 minutes and stirred at $80^0$C for 3 hours.

MgO films were then deposited on the substrates by spin coating method with the speed of 3200 rpm for 30 second followed by drying at $200^0$C for 5 minutes. The deposition and drying procedure was repeated for 10 times. After multi-coating, annealing of the MgO thin films was carried out at $500^0$C for 1 hour.

The deposited films were characterized using surface profiler (Veeco) to obtain the film thickness; atomic force microscopy (AFM- XE Park System) to determine films topology and field emission scanning electron microscopy (FESEM- JEOL) for their surface morphology. The process flow of nano-MgO films has been summarized in figure 1.

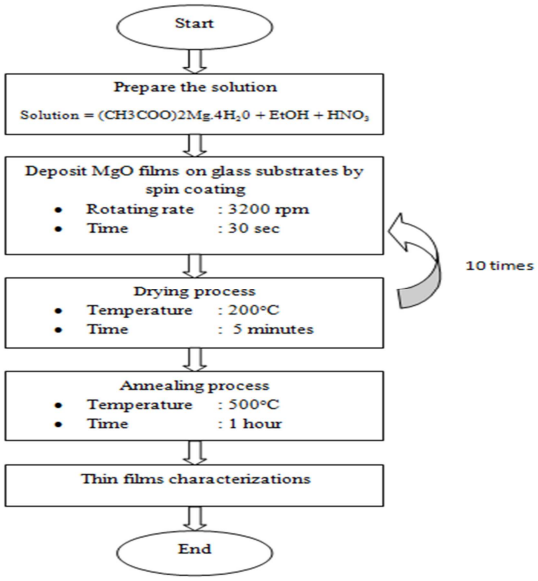


Fig. 1: Process flow of nano-MgO thin films

**Results and Discussion**

**Effect on Nano-MgoFilms Growth.**Thickness of nano-MgO thin films was measured by using surface profiler (Veeco). The thickness value and distribution of nano-MgO films are shown in table 1 and figure 2 respectively. It can be seen that the film thickness gradually increased as the molar concentration increased. The results also suggested that when the molarity above 0.6M, the films thickness was increased rapidly from 364.16nm to 1080 nm. The increment is due to rise in the amount of substance which is Mg in the solution.

TABLE 1: THICKNESS OF NANO-MgO AT DIFFERENT MOLAR CONCENTRATIONS

| MgO Molar Concentration | Thickness (nm) |
|---|---|
| 0.1M | 166.05 |
| 0.2M | 258.10 |
| 0.4M | 299.58 |
| 0.6M | 364.16 |
| 0.8M | 596.95 |
| 1.0M | 1080.00 |

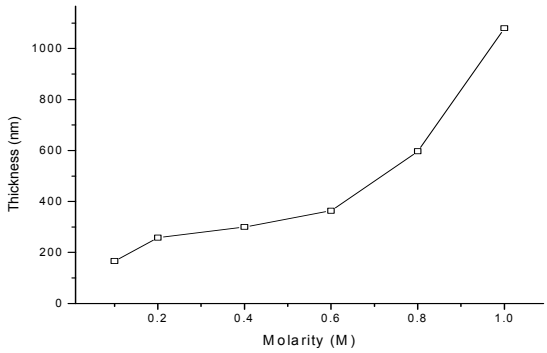


Fig.2: The thickness distribution of Nano-MgO at different molar concentrations

**Effect on Nano-MgOUniformity.**Figure 3 shows that topology of nano-MgO thin films at different molarity. As can be seen, nano-MgO films become rougher as the molarity increase from 0.1M to 1.0M where the films roughness are 1.204, 4.424, 7.280, 20.956, 38.425 and 38.456nm respectively. When the molarity reach 0.6M and above, the films has high surface roughness due to the dispersion of MgO are difficult that cause the particles to start agglomerated. On the other hand, thin films with 0.4M, is the optimum molarity to produces the most uniform film compared to other. These phenomenahas been prove by FESEM images in figure 4 where the high molarity thin films produce agglomerate particle and has porosity.

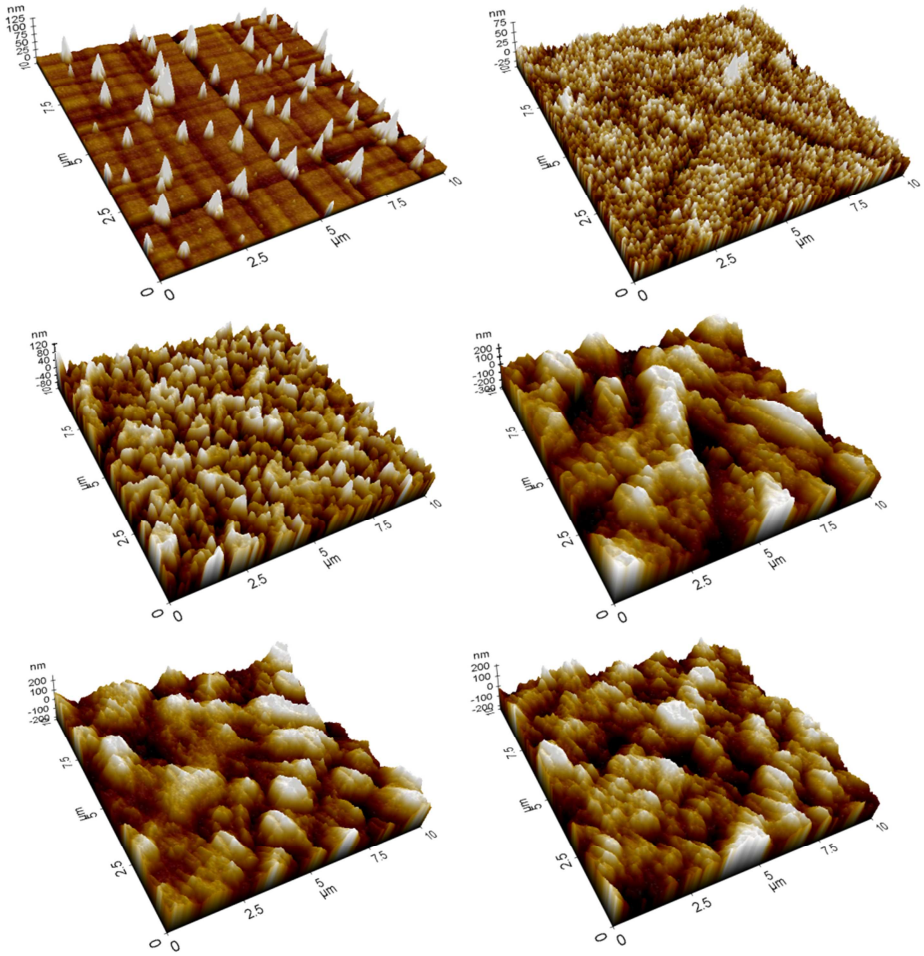

Fig. 3: AFM images of nano-MgO thin films deposited at different molarity; (a) 0.1M, (b) 0.2M, (c) 0.4M, (d) 0.6M, (e) 0.8M and (f) 1M.

**Effect on Nano-Mgo Morphology.**The morphology of prepared nano-MgO films at different molarity are shown in figure 4. FESEM images shown the particles sizes obtained from this work are in nanometer size. The MgO particles size for thin films prepared at 0.1, 0.2, 0.4, 0.6, 0.8 and 1M are 26.3, 37.5, 42.8, 58.1, 73.1, and 52.5nm respectively. The reduction of particles size is due to the sonication process thatwas performed before the solution being deposited on the cleaned glass substrate [9]. Several researches have stated that by sonication process involved commination, emulsification and stir prevent the crystal growth and aggregation. However, as can be seen in figure 4, as the molarity reach 0.6M the morphology of the films start to be rough, non-uniform and porous that due to agglomerated particle in the films.

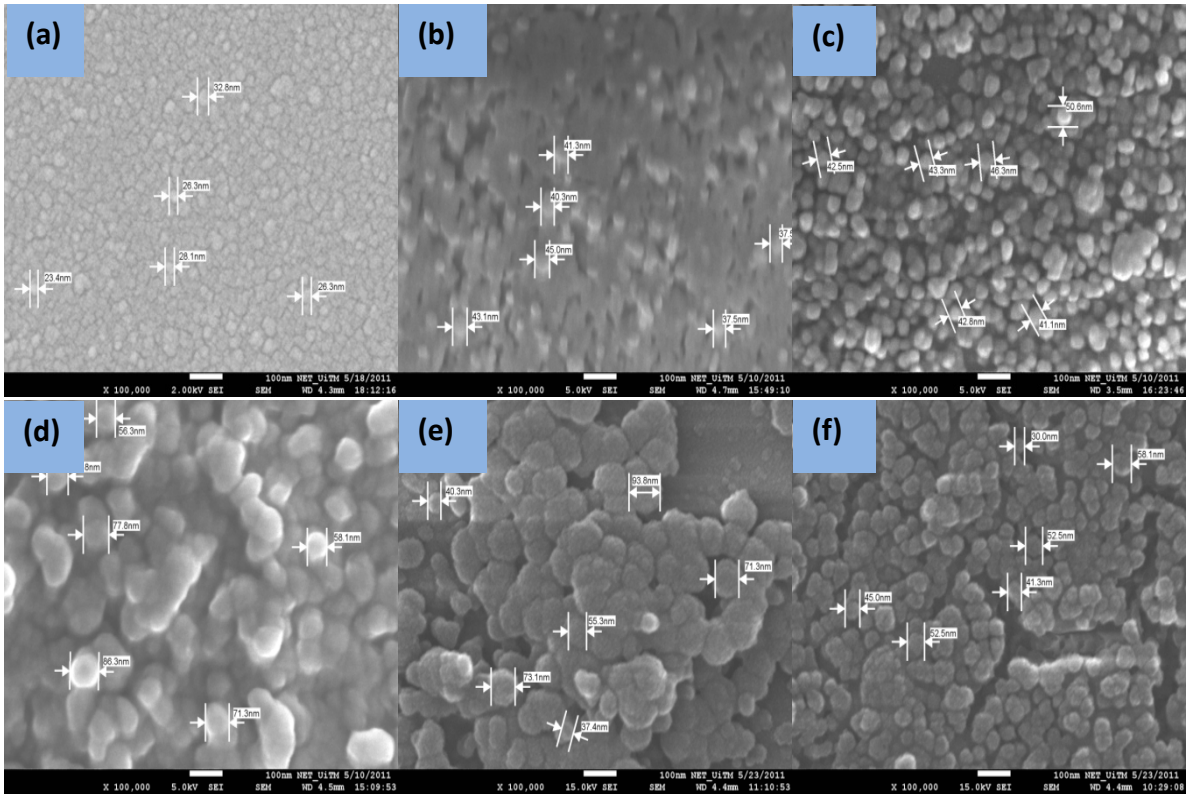


Fig.4: FESEM images for nano-MgO at different molarity; (a) 0.1M, (b) 0.2M, (c) 0.4M, (d) 0.6M, (e) 0.8M and (f) 1M.

Once the molarity increase, the amount of starting material which is magnesium being introduce to the solution increased and as the results, the particle in the solution start to aggregate when it reach certain molarity. This is because the amount of the stabilizer is not enough to break the bonding between molecules. Good in uniformity and non-porous structure, is the best criteria for a good dielectric layer. From the results obtained, 0.4M nano-MgO films is suitable to be used as dielectrics due to it uniform film with small roughness (7.280 nm), particle with nanometer dimension (42.8 nm) and also it has non-porous structure.

## Conclusion

Nano-MgO thin films were prepared at six difference molarities which are 0.1, 0.2, 0.4, 0.6, 0.8 and 1M by using sol-gel spin coating techniques. Sonication process has been performed in order to help in the formation of nano particle MgO. From the topography and morphology of the nano-MgO films that we have obtained, 0.4M is the best candidate to be used as the dielectric layer in the device fabrication such as capacitor.

**Acknowledgement**

The authors would like to thanks to UniversitiTeknologi MARA (UiTM), Research Management Institute (RMI) of UniversitiTeknologi MARA (UiTM) and Ministry of Higher Education (MOHE) for the financial support.

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10.4028/www.scientific.net/AMR.403-408

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10.4028/www.scientific.net/AMR.403-408.1168