Influence of Solution Concentration Towards Electrical Properties of ZnO/MgO Films using Immersion Method

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Abstract— **ZnO/MgO thin films were deposited on a glass substrate. In ZnO solution, zinc acetate dehydrate was used as the precursor while 2-methoxylethanol and mono-ethanolamine were used as the solvent and stabilizer respectively. The magnesium oxide solution was prepared using sodium chloride, magnesium nitrate and de-ionized water. The molarities of this solution were 0.2 M, 0.4 M, 0.6 M, 0.8 M and 1.0 M. The electrical property of multilayer ZnO/MgO thin films prepared by immersion method was investigated using two point probe I-V measurement (Bukoh Keiki) while the structural behavior was examined using surface profiler (KL-Tenco) and Atomic Force Microscopy (AFM). The electrical measurement shows that the resistivity increases, while the conductivity decreases as the molarity concentration increases. The highest resistivity at 6.67873 x 10^5 Ω.cm and the lowest conductivity about 1.49729 µS/cm have been obtained for 1.0M solution.**

Keywords- solution concentration; electrical properties; ZnO/MgO; immersion;

I. INTRODUCTION

MgO with the NaCl- type cubic structure has unique properties such as high dielectric constant (9.8), wide band gap (7.8 eV) and higher breakdown field (12 MV/cm) [1] while Zinc Oxide (ZnO) is one of the II-IV group compound semiconductors and it is composed of hexagonal wurtzite crystal structure. ZnO is naturally n-type direct band gap semiconductor materials that have some great characteristic which are wide energy band gap is 3.37 eV at room temperature and large free excite binding energy (60 mV) [2]. Furthermore, ZnO has been used in electronic applications such as light-emitting diode (LED), UV photoconductive sensor, chemical sensors and solar cell [3].

The multilayers of ZnO/MgO can improve the electrical and optical properties compared to single layer thin films [4]. Multilayer ZnO/MgO has widely used in tuning the bandgap either by varying the ZnO or MgO content. For the composite of Mg_xZnO_{1-x}, the thermodynamic solubility of MgO in ZnO is less than 4 mol% [5]. ZnO crystal structure which is in hexagonal form is different from cubic structure of MgO, however their ionic radius for both material is quite similar and can be replaced in matrix [6].

There are several deposition techniques to fabricate thin film. Each technique will produce different or similar performance, quality, quantity, size and also production cost [7]. Compared to other methods, immersion method has its own advantages which are simplicity, low equipment cost, high deposition rate and easy preparation of large films using stable liquid precursors [8].

ZnO has wide practical applications as transparent conducting oxides for flat panel display and solar cell [9], so it is important to study the electrical behavior of ZnO/MgO thin films. Therefore, the objectives of this research are to deposit multilayer ZnO/MgO and investigate the electrical behavior of deposited thin films.

II. METHODOLOGY

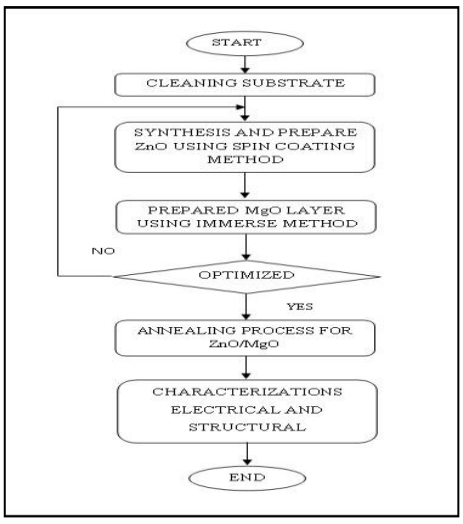

Figure 1: The flow chart

A. *Cleaning Substrate*

Firstly, the glass substrate was cleaned ultrasonically using acetone, methanol and deionized (DI) water as the clening agent to remove all the contaminations. The parameter was set up to 50°C for 10 minutes for each cleaning agent. Finally, the substrate was dried using nitrogen gas.

B. *ZnO Solution and Thin Film Preparation*

To prepare ZnO solution zinc acetate dehydrate was used as precursor, 2-methoxylethanol as solvent and mono-ethanolamine as stabilizer. The prepared ZnO solution was sonicated for 30 minutes at the temperature of 50°C. After that, solution was stir-heated for 3 hours. The stirring process was continued for 24 hour at room temperature environment. The ZnO thin films were deposited using spin coating method using the spin speed and time of 3000 rpm for 60 s followed by drying process in the furnace at 150°C for 10 minutes. The deposition and drying process was repeated for 10 times. Finally, the film was annealed at 500°C for 1 hour.

C. *MgO Solution and Thin Film Preparation*

The MgO solution was prepared at different molarities 0.2M, 0.4M, 0.6M, 0.8M and 1M. The materials used during MgO solution preparation were magnesium nitrate (MgN), sodium chloride, NaOH and deionized water. Firstly, MgN and NaOH solution separately sonicated within 10 minutes for 50°C. Then, MgN and NaOH were mixed and stirred at 50°C for 30 minutes. After that, the MgO layer was deposited on the ZnO using immersion method. Figure 2 shows the immersion method. The temperature was set to be 95°C. The immersion process was carried out for 1 hour. Finally, the film was annealed at 500°C for 1 hour.

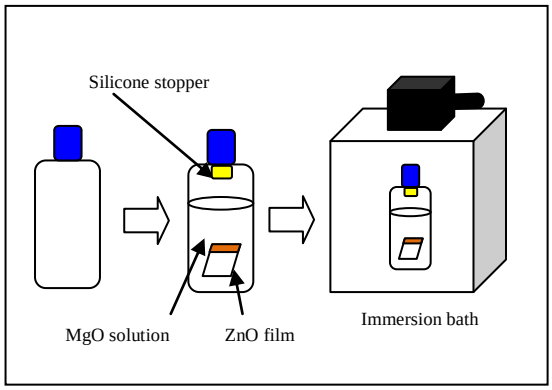

Figure 2: Immersion method

D. *Thin Film Characterizations*

Figure 3 shows the test structure of deposited ZnO/MgO films using platinum as the electrode. The electrical properties were investigated using two point probe I-V measurement (Bukoh Keiki). The thin film thickness and structural behavior was examined by using surface profiler (KL-Tenco) and Atomic Force Microscopy (AFM) respectively.

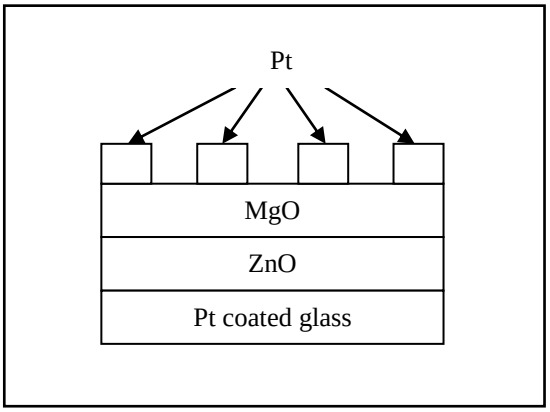

Figure 3: Multilayer structure for electrical characterization

III. RESULTS AND DISCUSSION

A. *Electrical Properties*

Figure 4 shows the I-V measurement of ZnO/MgO multilayer films at different MgO concentrations measured using two point probe I-V measurement (Bukoh Keiki). The voltage was ramped up to 10 V. From the measurement, the resistivity of multilayer films was calculated by using the following equation:

$$\rho = \frac{wt}{l}\mathrm{R}$$

ρ = resistivity (Ω.cm)
w = width of metal contact
l = length of metal contact
t = thickness of the film
R = resistance of the film

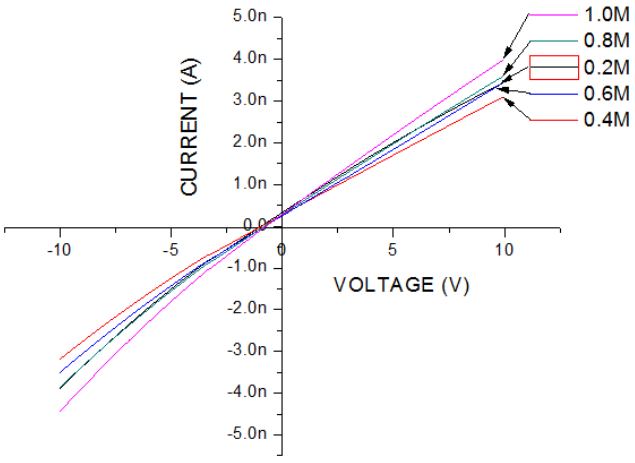

Figure 4: The electrical behavior of multilayer films in term of I-V characteristic.

Figure 5 shows that the resistivity of ZnO/MgO multilayer films increased as the concentration increased. The resistivity values of 0.2M, 0.4M, 0.6M, 0.8M and 1.0M films are 146 kΩcm, 279 kΩcm, 313 kΩcm, 480 kΩcm and 668 kΩcm respectively. Furthermore, Z. Habibah et al. reported that the resistivity increased as the molar concentration increased [10].

The conductivity of the film was decreased as shown in Figure 6. The conductance is the inverse of the resistivity and calculated as the following equation:

$$\sigma = \frac{1}{\rho}$$

σ = conductivity (S/cm)
ρ = resistivity (Ω.cm

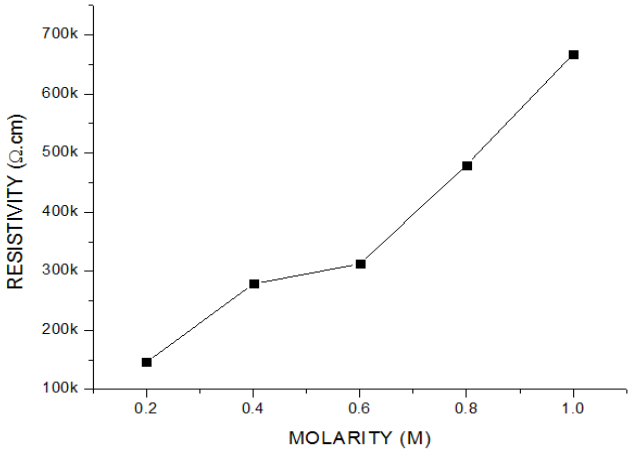

Figure 5: Variation of resistivity at different concentration for ZnO/MgO multilayer films.

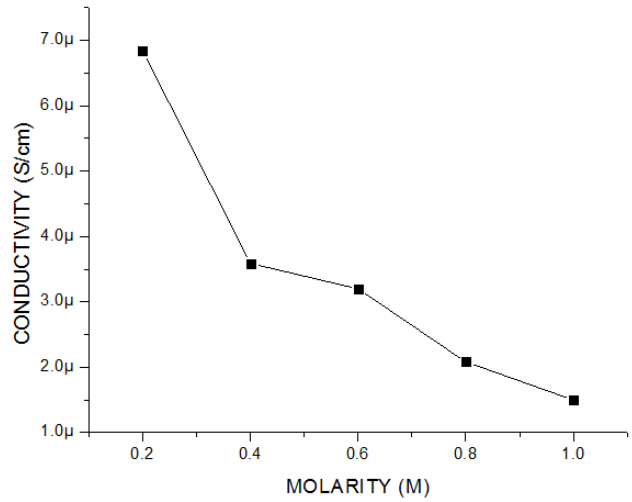

Figure 6: The conductivity of ZnO/MgO multilayer film at different concentration.

B. Structural Properties

The Table 1 below showed the measured thickness was increased as the molarity increased. Previous researcher, Z.Habibah et al. reported that the thickness was increased as the molarity of MgO increased [6].

TABLE 1: THICKNESS OF ZNO/MGO MULTILAYER

Molarity (M)	Thickness (nm)
0.2	238
0.4	274
0.6	297
0.8	272
1.0	355

The roughness of the film has been observed by atomic force microscopy (AFM). Figure 7 below show the surface become rougher when the molarities of solution increased because the particles become larger. As can be seen, ZnO/MgO films become rougher as the molarity increase from 0.2M to 1M where the films roughness are 38.992, 58.170, 83.352, 117.098 and 55.708 nm respectively.

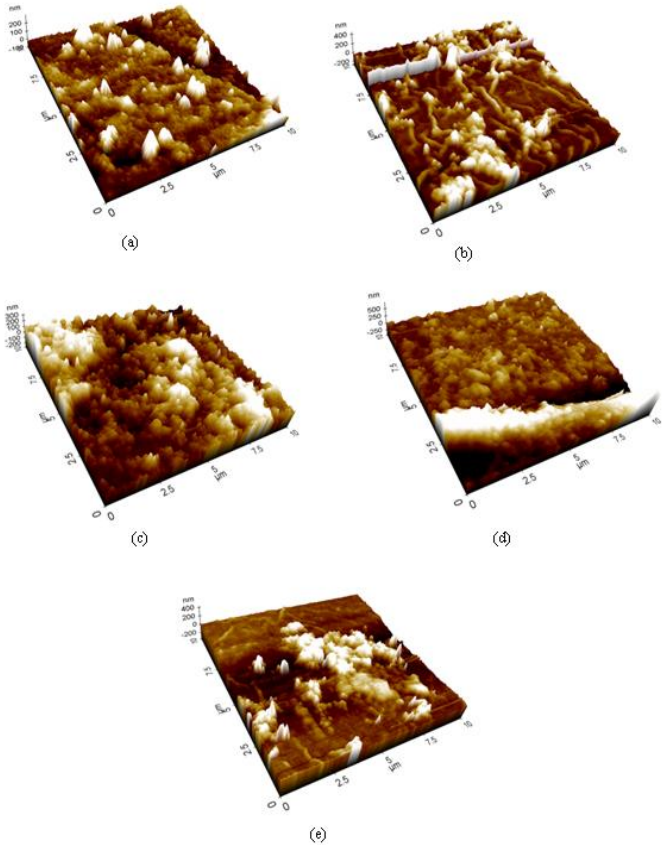

Figure 7: Surface topology of ZnO/MgO at (a) 0.2M, (b) 0.4M, (c) 0.6M, (d) 0.8M and (e) 1.0M

IV. CONCLUSION

As a conclusion, multilayer ZnO/MgO was successfully deposited at different molarities from 0.2M to 1.0M using immersion method. The electrical behavior has been investigated. The highest resistivity is 6.67873 x 10^5 Ωcm while the lowest conductivity about 1.49729 μS/cm has been obtained for 1.0M solution. Lastly, the roughness of the film was influenced by the molarities of solutions concentration.

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REFERENCES

[1] Z.Habibah, L. N. Ismail, R. A. Bakar, M. Rusop, "Influence of Heat Treatment on the Properties of MgO Thin Films as Dielectric Layer", IEEE Student Conference on Research and Development, 2011, pp 16-19.

[2] Nur Sa'adah Muhamad Sauki, Muhammad Hazman Rafie Abdul Rahim , Sukreen Hana Herman , and Mohamad Rusop Mahmood, "Physical and Electrical Characteristics of Low-temperature Annealed Spin Coated Zinc Oxide Thin Films on Teflon Substrates," Journal of IEEE Symposium on Humanities, Science and Engineering Research,2012, pp.497-500,.

[3] A.Azlinda, Z. Khusaimi, M. Rusop , "Controlled Growth of ZnO Nanostructures Prepared by Catalytic-Immersion Method", 2012, pp214-218.

[4] Ian W.Clelland and Rick A. Price, "Polymer Film Capacitors", 2011, pp 1-14.

[5] G. N. Panin, A. N. Baranov, Y. J. Oh, T. W. Kang, and T. W. Kim,"Effect of thermal annealing on the structural and the optical properties of ZnO/MgO nanostructures," Journal of Crystal Growth, vol. 279, 2005, pp. 494-500.

[6] Habibah Zulkefle, Lyly Nyl Ismail, Raudah Abu Bakar, Mohamad Hafiz Mamat, and Mohamad Rusop, "Enhancement in Dielectric Constant and Structural Properties of Sol-Gel Derived MgO Thin Film", International Journal of Applied Physics and Mathematics, Vol. 2, No. 1, January 2012, pp 38-43.

[7] M. F. Malek1, N. Zakaria1, M. Z. Sahdan1, M.H. Mamat1, Z. Khusaimi2 and M.Rusop1, "Electrical Properties of ZnO Thin Films Prepared by Sol-gel Technique", 2010, pp 384-387.

[8] Dae-Yong Shina and Kyung-Nam Kim, "Electrical and optical properties of MgO films deposited on soda lime glass by a sol-gel process using magnesium acetate", Journal of Ceramic Processing Research. Vol. 10, No. 4,2009, pp. 536-540.

[9] P.Numpud, T.Charinpanitkul and W.Tanthapanichakoon, Journal of the Ceramic Society of Japan, 116, 2008,pp 414-417

[10] Zulkefle, H.,Ismail, L.N. , Abu Bakar, R. , Mahmood, M.R., "Molar concentration effect on MgO thin films properties",Industrial Electronics and Applications (ISIEA), 2011 IEEE Symposium on,2011, pp: 468- 471.