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Nanocrystalline Thin Film of Nickel Doped Zinc Oxide by Sol-Gel Dip Coating Technique

Barshan Saha, Md. Nazmul Ahsan and M. Moniruzzaman
Department of Materials & Metallurgical Engineering, Bangladesh University of Engineering & Technology (BUET), Dhaka-1000, Bangladesh
Corresponding e-mail and Telephone: barshantbth@gmail.com

Abstract

Nickel doped zinc oxide nanocrystalline thin film on glass substrates is prepared by Sol-Gel dip coating technique with different concentrations of Ni^{2+} (0, 5, 10, 20 & 30 wt%. The variation in the properties with the change of Ni^{2+} concentrations are compared. The presence of Zn & Ni are confirmed in the film by EDX. Reflectance and absorbance of undoped and Ni doped ZnO are measured by UV-VIS Spectroscopy. It is observed that band gap energy of ZnO is decreased with increase of %Ni doping. The film is made up of ZnO nano crystallites with hexagonal crystal structure obtained from XRD. The film surface shows the characteristics Ganglia pattern confirmed by SEM. The Ganglia pattern becomes more branched and distorted with increase of Ni content in the film.

Keywords: Nanocrystalline thin film, Sol-Gel, Ganglia pattern, Absorbance, Band gap energy

1. Introduction

In recent times, ZnO has become special interest because of its unique properties. As ZnO is a semiconductor with wide band gap, large exciton binding energy and environment friendly properties, it is used in solar cell, electrical devices, field emitters, short wave length LED and information technology. Nanocrystalline thin film of ZnO can be prepared by different methods- Chemical Vapor Deposition (CVD) [1], Sol-Gel [2], Thermal Evaporation etc. Among them, Sol- Gel method with utilization of dip coating technique is the most effective and less costly process to prepare thin films. The recent research demonstrates the scope of utilization of homogenous ZnO thin films with desired thickness and microstructures by Sol-Gel dip coating technique [3].

The objective of our research was to find the change in structural morphology & optical properties of ZnO nanocrystalline thin films with the change of Ni^{2+} concentration. We also compared crystal structure of ZnO of different Ni^{2+} compositions. Sol-Gel method is used to make the precursor solution and the film was made by dip coating technique.

2. Experimental

We prepared precursor solution adding Zinc Acetate Dihydrate [$Zn(CH_3COO)_2.2H_2O$] and 2-Methoxy Ethanol as reagent whereas Monoethanolamine (MEA) as stabilizer [4]. Then we heated that solution on hotplate at 60°C with magnetic stirring at 400 rpm for 1 hour. After that, we dipped our glass slide into the solution in order to get thin films. Finally, we dried the film on hot plate for 15 minutes and annealed it at 500 °C and performed furnace cooling.

On the other hand, for nickel doping, we added Nickel Acetate Tetrahydrate [$Ni(CH_3COO)_2.4H_2O$] in the precursor solution in calculated amounts for different concentrations of Ni as intended (5, 10, 20, 30 wt% Ni). The final solution was clear & homogenous and was ready to serve as the coating substance for film preparation. No visible changes were observed in the precursor solution at room temperature for at least 2 weeks. After preparing all samples (with and without doping), we had performed XRD to determine its crystal structure, Energy Dispersive Spectroscopy (EDS) to ensure the presence of Zn and Ni in the film. Then for surface morphology, we observed the microstructures using SEM. Moreover, we had performed UV-VIS Spectroscopy to determine its absorbance and reflectance and which eventually helped us to find out band gap energy of Ni doped and undoped ZnO. Thus we characterized the samples in order to examine the effect of nickel doping in ZnO.

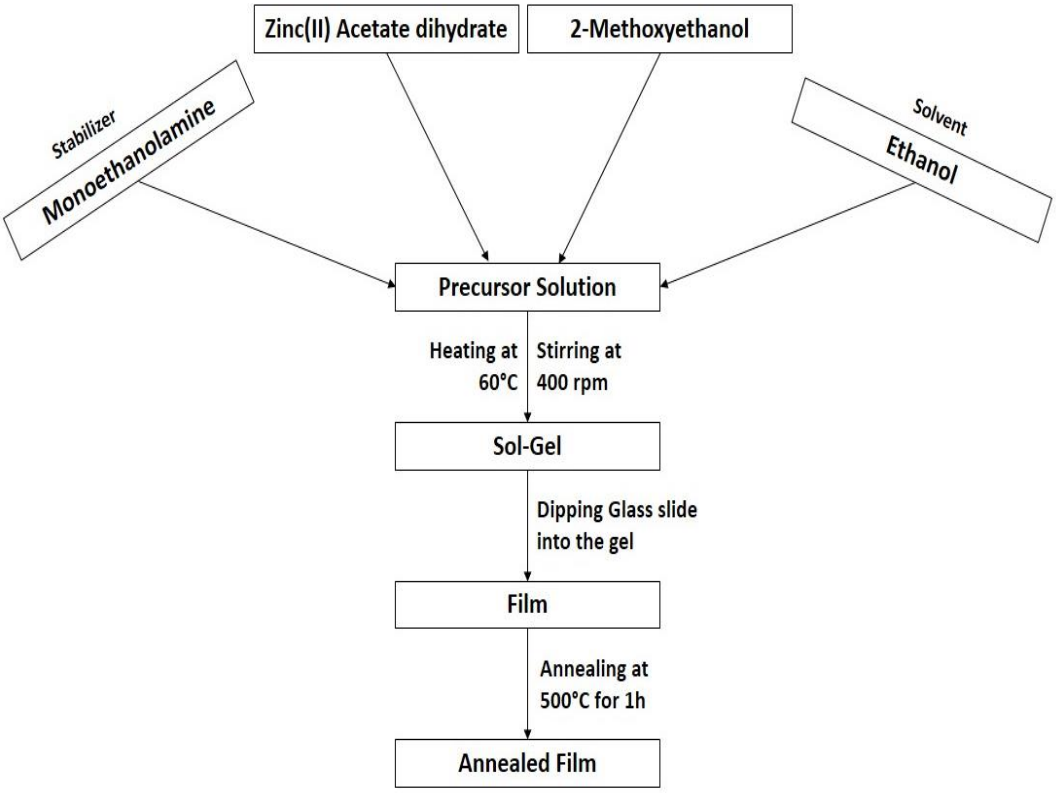


Fig. 1. Scheme of the experimental procedure for deposition of thin ZnO films by Sol-Gel dip coating

3. Results & Discussion

The plane view of SEM micrographs (Fig. 2) of 10% and 30% Ni doped ZnO show smooth Ganglia-hill in whole structure. The number of wrinkles are increased in 30% Ni doped structure. Moreover the size of wrinkles become smaller with increase of %Ni doping. So it can be stated that 30% Ni doped sample shows more branched structure than 10% Ni doped ZnO [5].

XRD patterns (Fig. 3) of Ni doped ZnO shows three main diffraction peaks of crystalline ZnO between diffraction angle of 30 and 40º. This pattern proves that prepared films which are annealed at 500ºC for 1 hour shows polycrystalline hexagonal wurtzite structure [6]. Moreover it is found that presence of Ni^{2+} ion has no notable effect on crystal structure of ZnO.

While performing EDX, some white particles are seen on the SEM which yields the result shown in figure 4. It is observed that approximate 10 wt% Ni was doped into Zinc Oxide structure and we confirm this from EDX report.

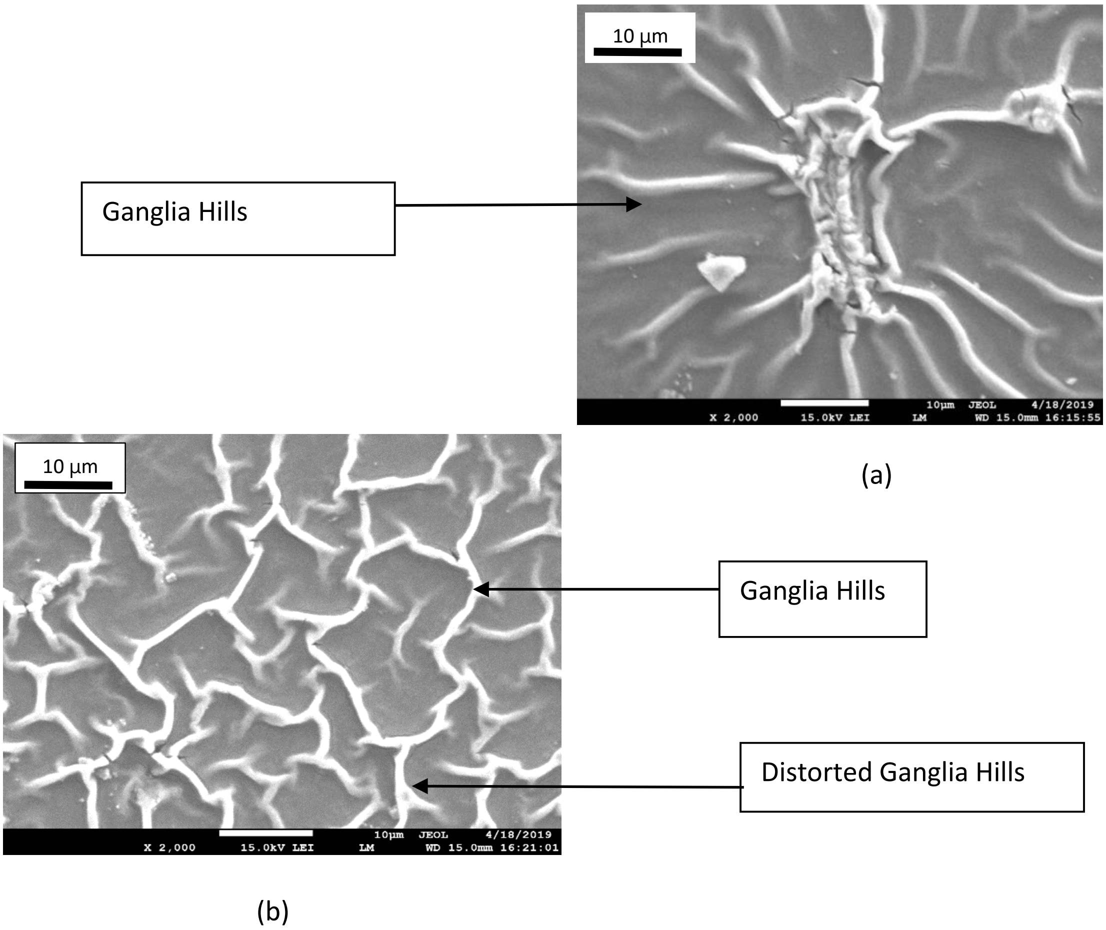


Fig. 2. SEM Micrograph of (a) 10% Ni doped and (b) 30% Ni doped ZnO

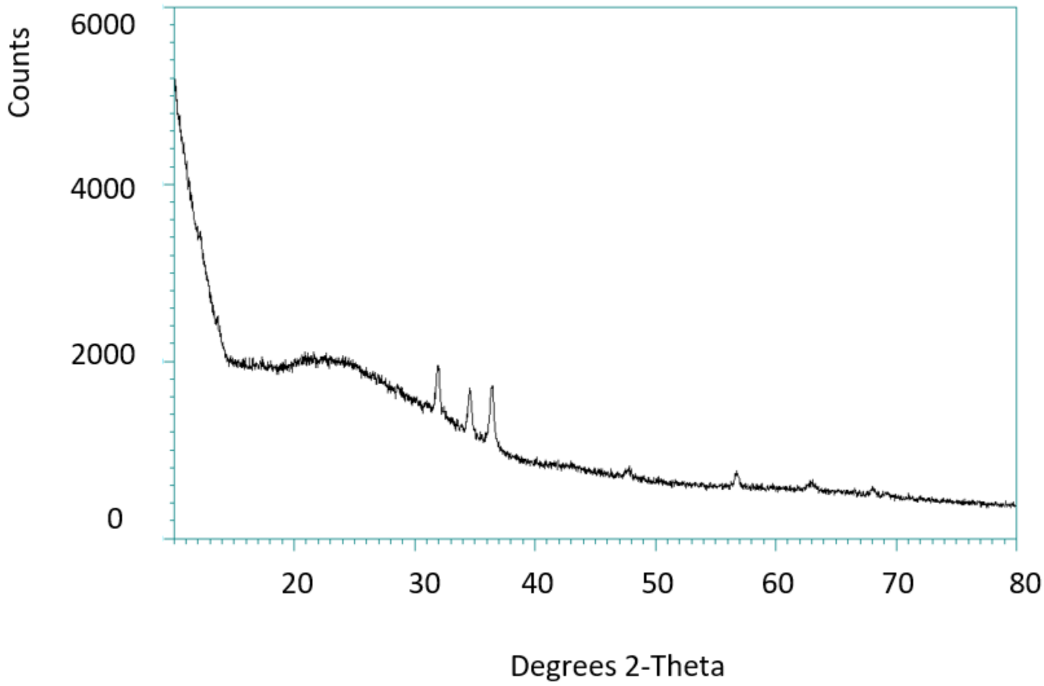
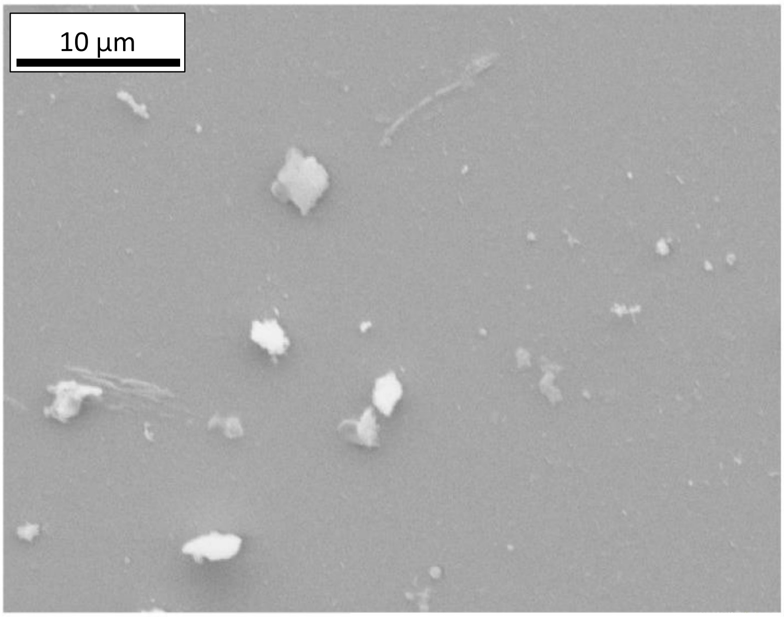
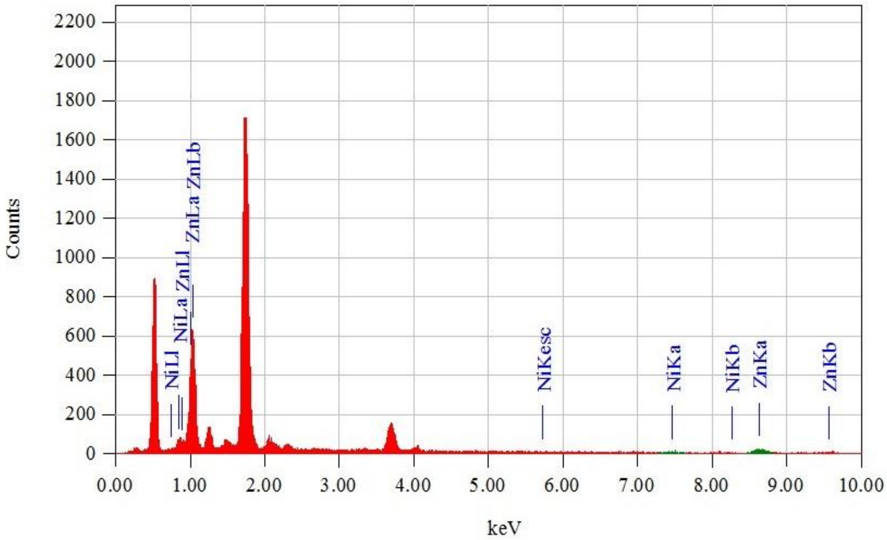


Fig. 3. XRD of 5% Ni doped ZnO





ZAF Method Standardless Quantitative Analysis
Fitting Coefficient : 0.9044

Element	(keV)	Mass%	Sigma	Atom%	Compound	Mass%	Cation	K
Ni K*	7.471	10.21	1.94	11.24				12.7655
Zn K	8.630	89.79	7.02	88.76				87.2345
Total		100.00		100.00				

Ni = 10.21 wt%

Fig. 4. EDX report of 10% Ni doped ZnO

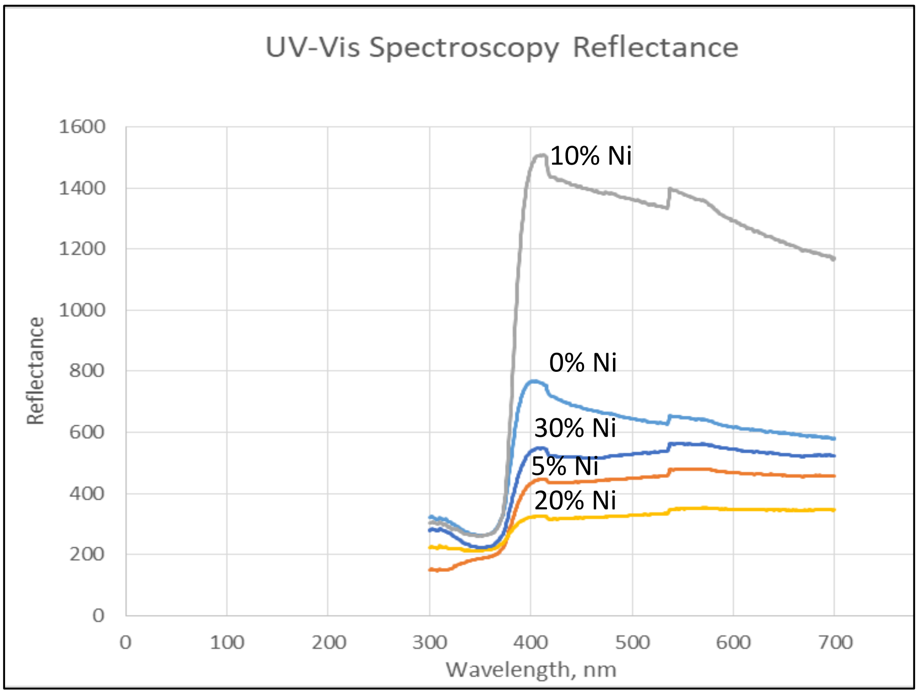


Fig. 5. UV-VIS of reflectance of undoped & Ni doped ZnO

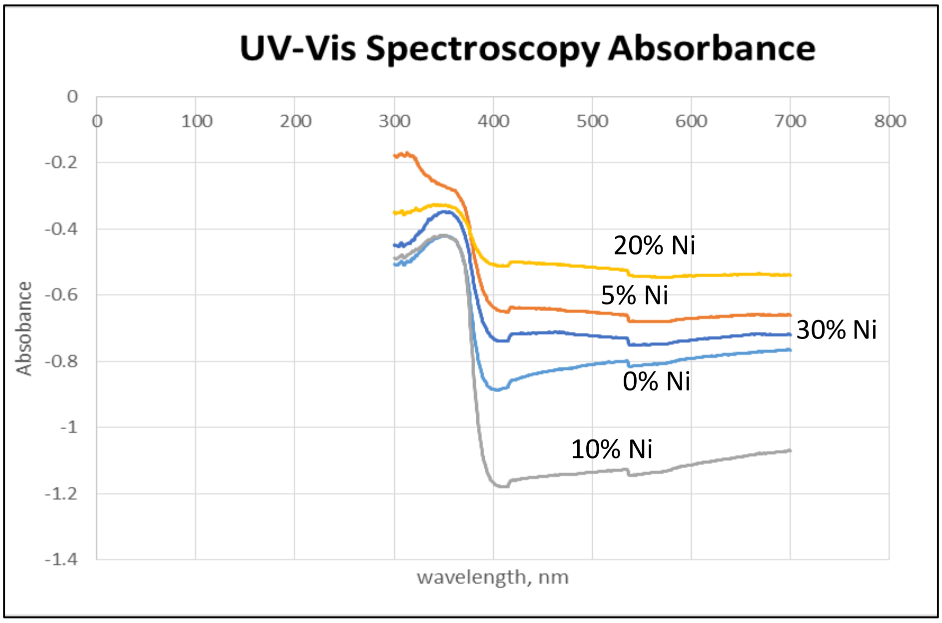


Fig. 6. UV-VIS report of absorbance of undoped & Ni doped ZnO

From Fig. 5 & 6, it is observed that reflectance & absorbance change with increase of Ni^{2+}. 10% Ni doped ZnO shows the highest reflectance and lowest absorbance. The band gap energy of the ZnO thin films with different Ni doping concentration is calculated from the UV-Vis absorbance spectroscopy by equation (1).

$$E = h\, c/\lambda \qquad (1)$$

Where, h is the Planks constant, 6.626 x 10^{-34} Joules sec, C is the Speed of light, 3.0 x 10^{8} meter/sec, λ is the Cut off wavelength (in meter) and 1eV is equivalent to 1.6 X 10^{-19} Joules (conversion factor). From the plot in Fig. 7, it is observed that the band gap energy of ZnO is decreased with increase of Ni doping [7]. So optical property of ZnO is enhanced with Ni doping.

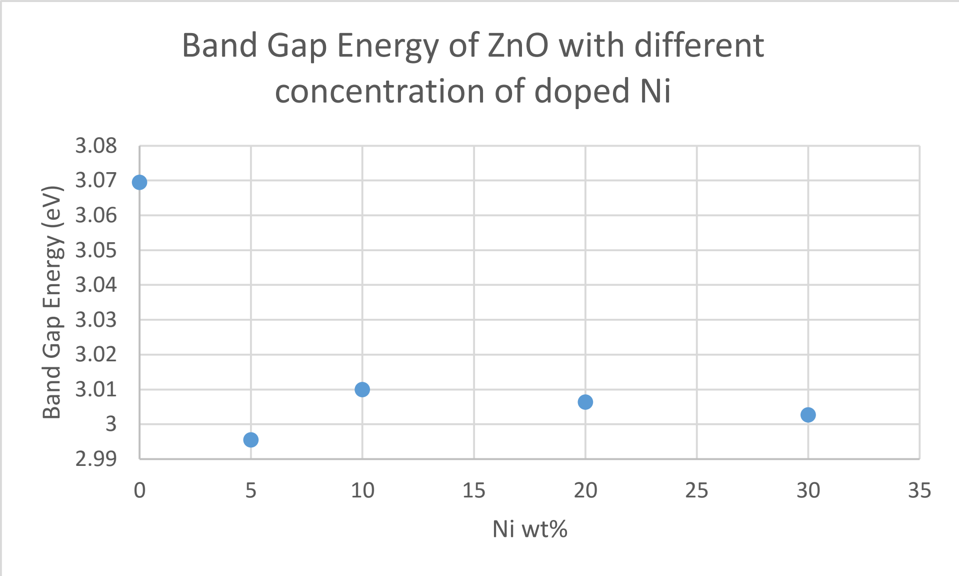


Fig. 7. Band Gap Energy of undoped & Ni doped ZnO

4. Conclusion

Nanocrystalline thin films of Ni doped ZnO are successfully prepared on glass substrates using dip coating technique. Later the films are characterized by XRD, EDX, SEM and UV-VIS. EDX confirms the trace of Ni doping on ZnO. From XRD, it is observed that the film consists of polycrystalline wurtzite structure which is unaffected by Ni doping. SEM micrographs show Ganglia hills pattern which become more branched and distorted with increase of Ni%. UV-VIS confirms that Ni doping affect the absorbance & reflectance of ZnO. 10% Ni doped ZnO shows the highest reflectance. Band gap energy is measured from absorbance graph by finding out cut off wavelength. It is obtained that band gap energy is decreased with increase of Ni%. So it can be stated that optical property of ZnO is enhanced with Nickel doping.

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