CHARACTERIZATION OF ZINC OXIDE (ZnO) THIN FILM COATED BY THERMAL EVAPORATION TECHNIQUE

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Thin Films of zinc oxide have been deposited by thermal evaporation of zinc metal. The annealing temperature varied from 350°C to 450°C for fixed one hour annealing time. XRD results show the presence of (100), (101) and (002) diffraction peaks for all the films of ZnO. The intensity of the diffraction peaks increase with increase in annealing temperature. The FWHM values of the peaks decrease with increase in annealing temperature showing better crystallinity of the thin films. The SEM study shows the needle like morphology of the thin films. The films are found optically transparent for visible region of the electromagnetic spectrum from the VIS-UV data. RBS study showsthe thickness of films 180nm.

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1. Introduction

The interest of researchers now-a-days is focusing on the transparent conducting oxides due to their wide range of applications in optoelectronics, photovoltaic devices, sensors, solar cells and biomedical fields. Zinc oxide with direct bandgap of 3.37eV also known as future material[1] attracting the interest of researchers due to its unique properties like biocompatibility, biosafety and piezoelectric properties and number of researchers already worked on zinc oxide. There are number of methods to prepare thin films of zinc oxide like sol gel [2], pulsed laser deposition [3], sputtering, chemical vapour deposition[4] and thermal evaporation. Among all these methods, thermal evaporation is more suitable because of its ability to deposit multiple films, friendly environment, non-pollutant, thermal temperature, easy to control the growth factors like film thickness and deposition rate [5]. Zinc oxide thin films are grown on variety of substrates like glass, silicon and sapphire. Glass substrate is suitable because of low cost and easy availability. In literature, we see that number of researchers already worked on his method but we have use this method because of non-pollutant environment, thermal temperature and good deposition rate [6-9]. In literature, we also see that number of researchers have worked on zinc oxide and also number of researchers are now working on zinc oxide [10-13] because of its wide range of applications in various fields.

In this work, the microstructures of ZnO thin film prepared by thermal evaporation technique and annealed at different temperatures are reported. The enhancing optical transmission natureand band gap variation of ZnO thin film with annealing to makes them suitable for transparent electrode.

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2. Experimental Details

Thin films of zinc oxide were grown onto glass substrate under different conditions. Substrates were cleaned ultrasonically by acetone followed by distilled water, then ultrasonically cleaned by ethanol followed by distilled water and hanged on iso-propanol 2. The cleaned substrates were placed in the vacuum chamber. The zinc powder was loaded in the boat made of tungsten and placed in the vacuum chamber.The pressure of $10^{-3}$was achieved in the vacuum chamber and maintained during the coating.The power supply was used to evaporate the material. The evaporated material was then condensed onto the glass substrate. The thickness of the films was controlled by the help of thickness monitor. The prepared films were then annealed for one hour at temperature ranges from 350-450 ˚C. By the help of JOEL JSM-6490A, surface morphology of zinc oxide thin films was studied. The optical properties of zinc oxide thin films were studied by Perkin elmer UV-Vis Spectrophotometer.Rutherford backscattering (RBS) was performed to confirm the layer structure across the thickness of the thin films. Incident particles were the He^{++} ions accelerated by 5UDH Tandem Accelerator to energy of 2.84 MeV. The scattering angle was 170^o, which is most popular for conventional RBS. However, required depth resolution was achieved by maintaining the surface normal of the sample to 0^o with respect to incident beam and 10^o with respect to the scattered beam.

3. Results and Discussion

The structure and crystallinity of the of ZnO thin films at different annealing temperature deposited by thermal evaporation was investigated by non-destructive XRD analysis performed at room temperature, shown in Figure 1-3. The XRD patterns of ZnO thin films. The peaks belonging to (100), (101) and (002) planes are observed in all the films. The intensity of all the peaks gradually increases with increasing temperature showing more ordered structure.
The average crystallite size of as deposited ZnOand annealed thin films was calculated by using scherrer formula, based on the full width half maxima of the XRD (100) peak of each sample.

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

Where θ is the Bragg angle (degree), $\lambda = 1.54056Å$ is the wavelength of Cu K_α radiation, β is the full width and half maxima (FWHM) of the Bragg peak (radian) and D is the average diameter of the Crystallite. A trend increasing of crystallanity is observed with annealing which imply that annealing improve the crystallization. The effect of Mg dopant concentration with the change of crystallite size has been observed from 72nm (for pure SnO) to 23nm (for Mg doped SnO) thin films. It has been observed that by increasing the annealing temperature the FWHM of all peak becomes slightly narrow, indicating that the crystallite size of ZnO thin films increases with increasing temperature. The variation of crystallite size of particle and FWHM size with annealing temperature are given in table 1.

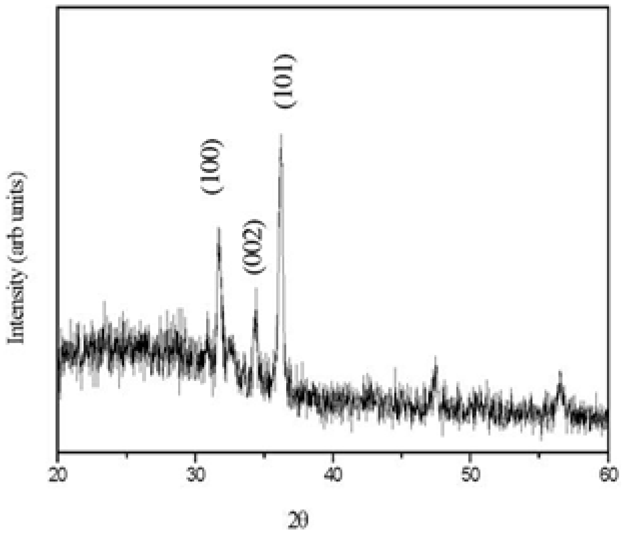


Fig.1: XRD pattern of ZnO thin film annealed at 350 °C

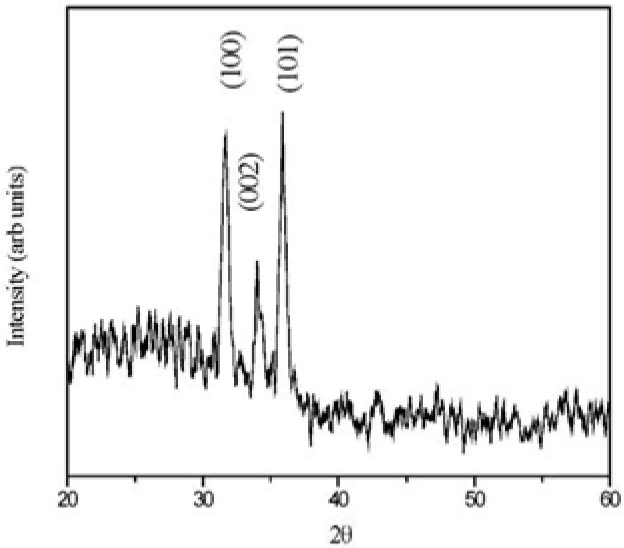


Fig.2: XRD pattern of ZnO thin film annealed at 400 °C

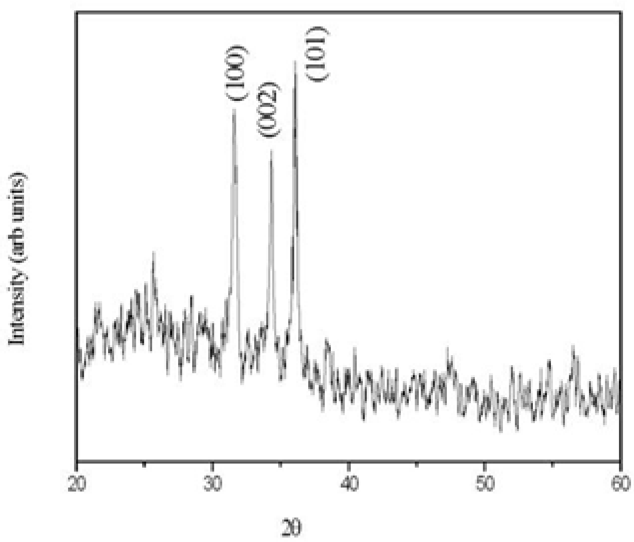
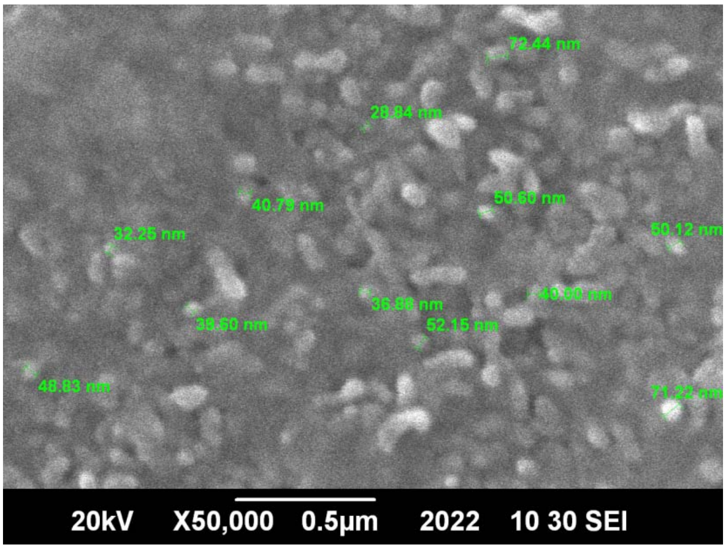


Fig.3: XRD pattern of ZnO thin film annealed at 450 °C

Morphological and surface studies of ZnO thin films at different temperature fabricated by thermal evaporation have been carried out using scanning electron microscopy (SEM) shown in Figures 4 (a &b). It is evident from the figure 4 that the grains of pure and the Mg-doped SnO thin films possess small needle-like symmetry. The length and diameter of each needle is in the range of 0.4–0.6 µm and 0.1–0.2 µm, respectively. SEM study reveal that each needle like grains has been formed as a result of incorporation and agglomeration of crystallite (~30 nm) and each needle are fused with each other forming an interconnected 3D network with electronic connections. Upon increasing the annealing temperature, the surface morphology and roughness of the thin films changes and the grains size increases. Thus SEM studies corroborate the XRD findings, where the crystallite size increases with the increase of temperature. The difference in the value of grain size in the SEM study with the XRD analyses has been revealed due to different orientations. The preferred orientation of thin films with the morphology of characteristic needle shaped grains shown along (100), (002) and (101) plane, respectively.

(a)



(b)

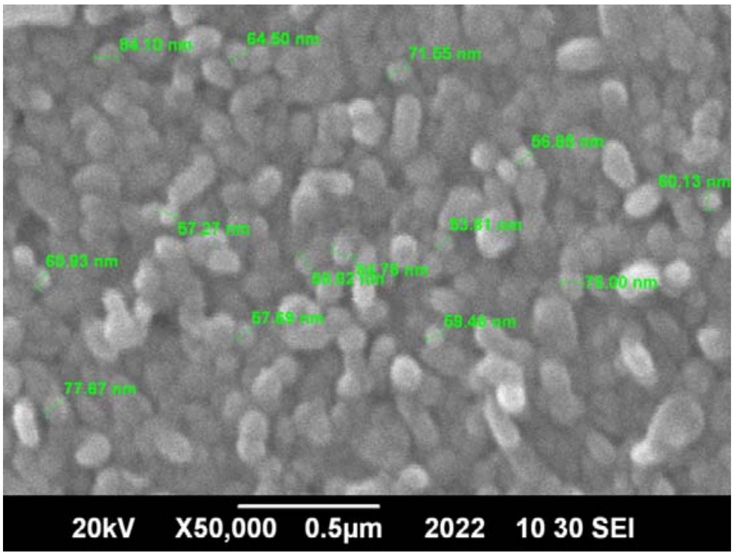


Fig.4: SEM micrographs of ZnO thin film annealed (a) at 350 °C, (b) at 450 °C

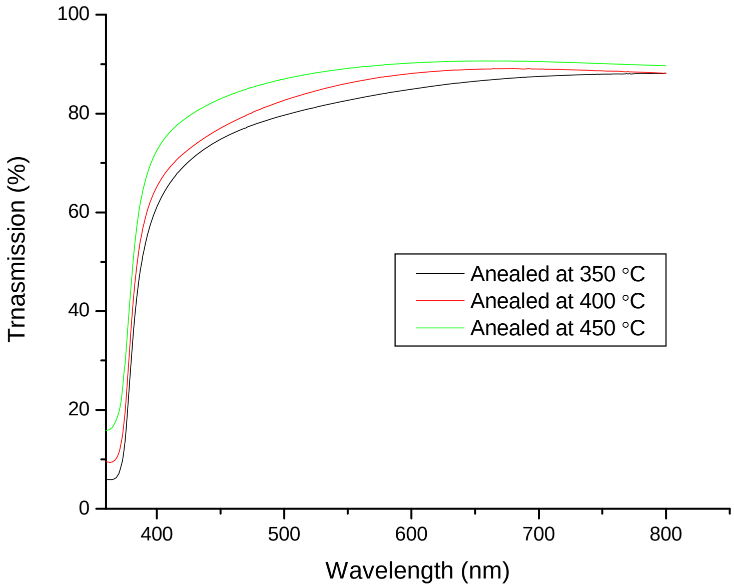


Fig. 5: Transmission spectra of ZnO thin films at different temperature.

The transmission spectra of ZnO annealed thin filmswere recorded in range of 300-800nm. Figure 5 shows the variation of transmittance with the wave length for. The average transmission in the visible region was found to be increased from 87 to 91% and it seems depending on the on the annealing temperature.

The depth profile and the elemental concentration of the deposited ZnO thin films have been examined by Rutherford Back scattering analysis. Figures 6 show the simulation and experimental data of the thin film at 450 ˚C. The O, and Zn are simulated at the channel energies corresponding to 0.82, and 1.71MeV respectively.

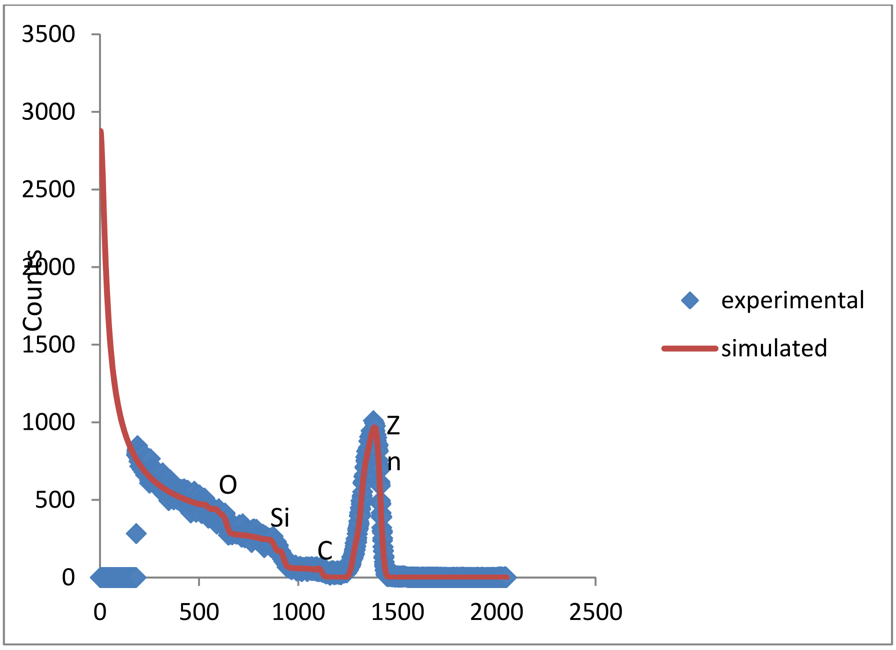


Fig. RBS spectrum for zinc oxide thin film annealed at 450 °C

Table 1 Observed structure and optical parameters of ZnO thin films.

Sample Type	Crystallite size (nm)	Grain size (nm)	Thickness (nm)	Max. Transmission (%)
At 350˚C	30	38	180	87
At 400˚C	49	55	180	89
At 450˚C	61	66	180	91

4. Conclusion

The morphology structure changes and optical properties of ZnO films were investigated by SEM, VIS-UV and XRD and RBS techniques. The temperature variation had shortly influence in surface morphology and structure changes in the ZnO films. The SEM structure shows the grain size increases with increase in temperature. The increasing temperatures also influence the crystallite size of the ZnO films. The RBS energy study revealed that the thickness of ZnO film around 180nm.

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