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Influence of Film Thickness on Surface Morphology of Nanostructured Azo Thin Films Deposited by Rf Magnetron Sputtering

Pathan Parhana[1,2,*], L. Lakshmi Devi[3], Shaik Allahudheen [1,4,*] B.Yugandhar[1,5], M.V.Lakshmaiah[1]

[1]Department of Physics, Sri Krishnadevaraya University, Anantapuramu-515003, A.P, India.
[2]Department of Physics, S.V.R. Engineering College (Autonomous), Nandyal-518501, A,P, India
[3]Department of Physics, Annamacharya University, Rajampet- 516126, A.P., India
[4]Department of Physics, Santhiram Engineering College (Autonomous), Nandyal-518501, A, P, India
[5]Junior Lecturer in Physics, SSBN Aided Junior College, Anantapuramu-515003, A.P., India.

Corresponding author: udheen786@gmail.com,farakhadar@gmail.com

Abstract:-

Nanostructured Aluminum doped Zinc Oxide thin films were deposited on glass substrates by RF magnetron sputtering in an Ar + O2 gas mixture using commercially available Zn metal (99.999% purity) and Al (99.99% purity) targets. Scanning Electron Microscope (SEM) images of AZO thin films reveal that the optical transmittance depends on the thickness of the film, whereas the grain sizes are between 20 and 44 nm.

Keywords AZO Thin films; RF magnetron sputtering; structural properties.

1. Introduction

Impurity doped ZnO semiconductor materials have attractive properties due to their large direct band gap (3.37eV), abundance of raw materials, environmental friendliness, and strong radiation resistance. At room temperature, its exciton binding energy of 60 meV is greater than the thermal energy [1–3]. Al, Ga, and In doped ZnO thin films are group III elements that have shown great promise for use as transparent electrodes in optoelectronic devices. ZnO films doped with Group III elements exhibit high transmittance and low resistance. According to numerous studies of the doping's effects because of its benefits, Al appears to be the most successful and promising element in ZnO with impurities. Al is the dopant that produces high-quality, low-resistivity thin films of AZO. Chemical vapor deposition, spray pyrolysis, pulsed laser deposition, magnetron sputtering, and the sol-gel process are some of the deposition methods used to create ZAO thin films [4–9]. To meet the requirements for commercializing all transparent conducting oxide films, including high-rate and large-area

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deposition, low equipment costs, and good film quality, DC magnetron sputtering has been considered one of the most appealing and successful fabrication processes in the mass production of ZAO thin films. In this work, we examined how layer thickness affected the optical characteristics and surface morphology of nanostructured AZO films are applied to glass substrates using the RF magnetron sputtering process

2. Experimental Details

The target and substrate distance was fixed at 60 mm, and the base pressure in the chamber was 3 X10-4 Pa. The glass substrates underwent ultrasonic cleaning in ethanol and acetone, followed by a 15-minute ultrasonic bath in deionized water and oven drying before to deposition. Metered using mass flow controllers, high quality (99.99%) Ar and O2 gas was introduced into the chamber with a fixed total flow rate of 25 sccm. 10 minutes of argon pre-sputtering was followed by deposition at a working pressure of 1Pa. While deposition was taking place, the sputtering power was kept at 100 W. By altering the deposition period, the depositions were performed at various thicknesses. The Talysurf thickness profilometer was used to measure the film's thickness. The films' final thicknesses were determined to be 230, 250, 300, 320, and 500 nm.

3. Results and Discussions

3.1 Structural characterization

Figure 1.1 depicts a normalized XRD pattern of AZO thin films produced on glass substrates at room temperature and varying thicknesses. The films show the hexagonal wurtzite structure's ZnO (0 0 2) diffraction peak. It shows that the films are highly textured in the film growth direction since the c-axis orientation is the most densely packed and thermodynamically beneficial in the wurtzite structure. However, the diffraction angle of the (0 0 2) peak increases from 34.05º to 34.65º. Figure 1.2 depicts how the lattice parameter varies with thickness. The lattice constant reduces as film thickness increases due to structural changes caused by film thickness and composition improvement, which alters the density of native defects and, hence, the structural quality of the films. The full width at half-maximum (FWHM) may be used to determine the crystallite size calculated from the Scherrer formula, which decreases from 46 to 26 nm as the film thickness increases, as shown in Fig 1.3.

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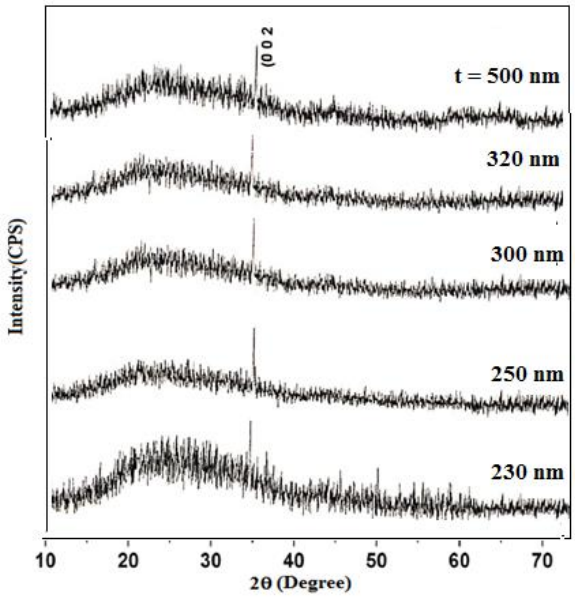

Fig.1.1. XRD patterns of AZO thin films deposited at various thicknesses

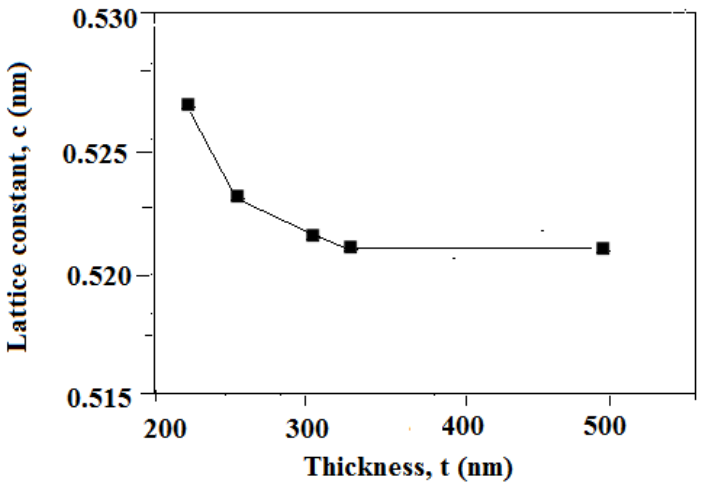

Fig.1.2. The lattice constant of AZO films as a function of different thickness

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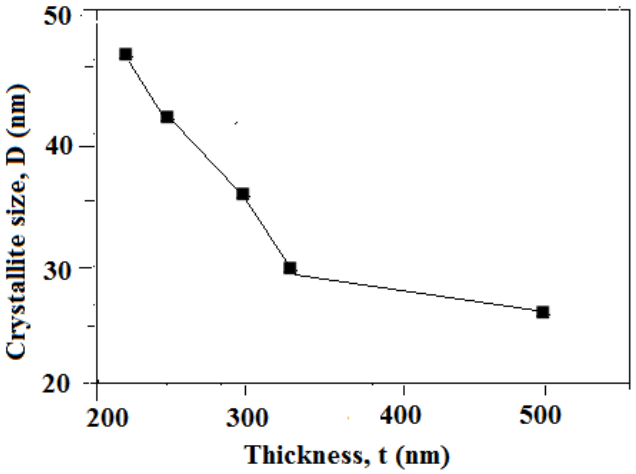

Fig.1.3. Crystallite size versus film thickness of AZO thin films

XRD confirmed the existence of compressive stress in the AZO films, typical of films formed by sputtering. Stress may be traced back to structural flaws at the substrate-AZO interface, as seen by the diffraction line's asymmetry. As seen in Fig. 1.4, the compressive residual stress reduced with increasing film thickness. This effect might be related to the increased surface mobility of high-energy molecules impinging on the film. This phenomenon might enable more structurally sound films. It might suggest that the observed stress was mostly driven by growth.

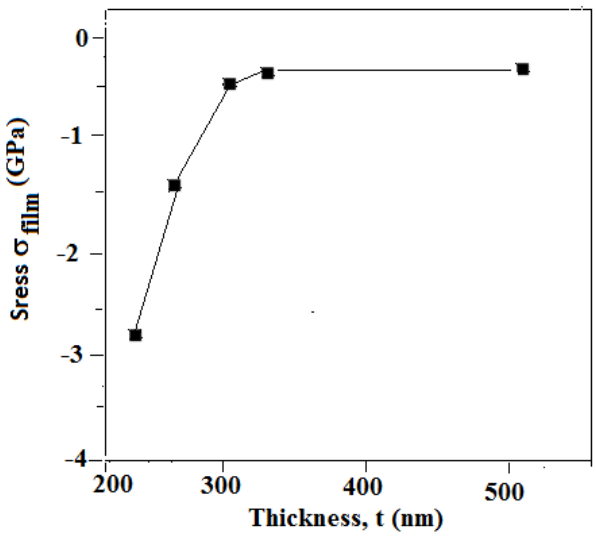

Fig.1.4. Residual stress of AZO thin films as a function of film thickness

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3.3.2. Surface morphological analysis:

Figure 1.5 depicts scanning electron microscopy (SEM) images of AZO thin films placed on a glass substrate at varying thicknesses. It has been discovered that grains in SEM pictures have an ellipsoid geometric form rather than a columnar structure, which is typically created by sputtering [10] or the sol-gel method [11–13]. SEM images reveal grain sizes ranging from 20 to 44 nm.

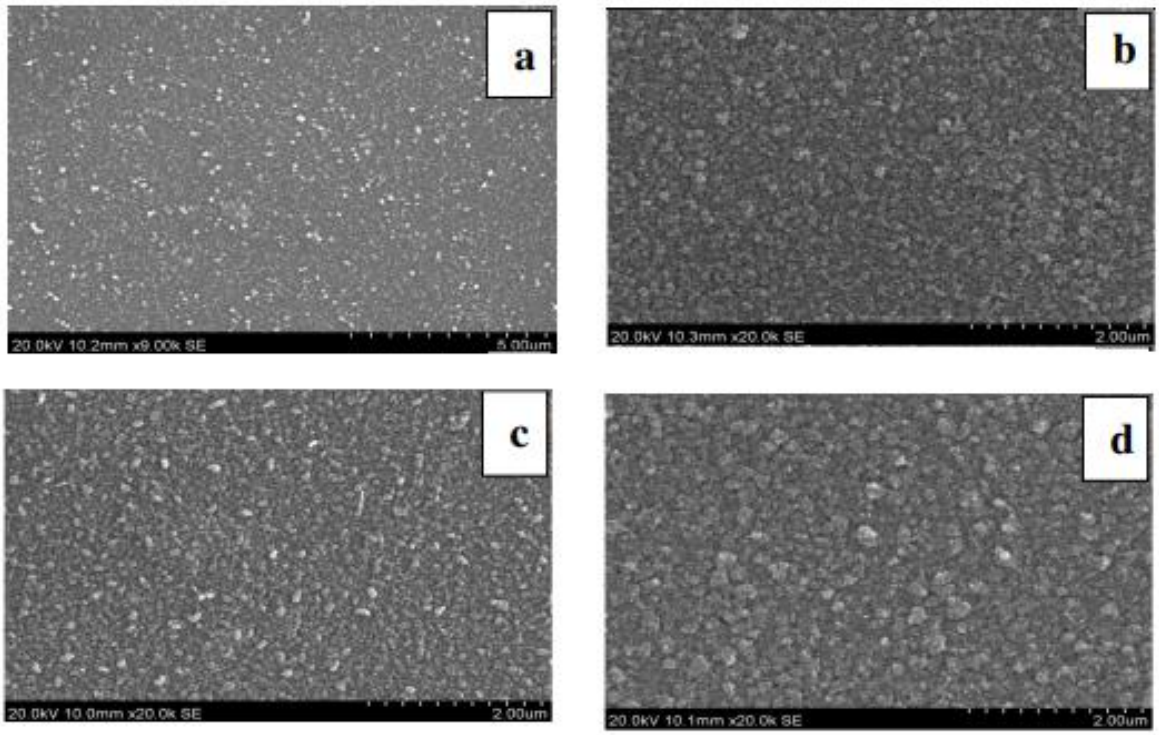

Fig.1.5. SEM images of AZO thin films deposited with thicknesses of (a) 250 nm, (b) 300 nm, (c) 320 nm and (d) 500 nm

3.3.3 Compositional analysis:

Fig.1.6 shows the compositional analysis of AZO films deposited with thicknesses from 23 to 500 nm. The elements present and their atomic percentages are shown within the plot. The sputtering power of Al is kept in control to have less content of Al. If more Al content is present, the crystallinity of the films will diminish. The grain size obtained from the SEM image is in the range of 30-42 nm.

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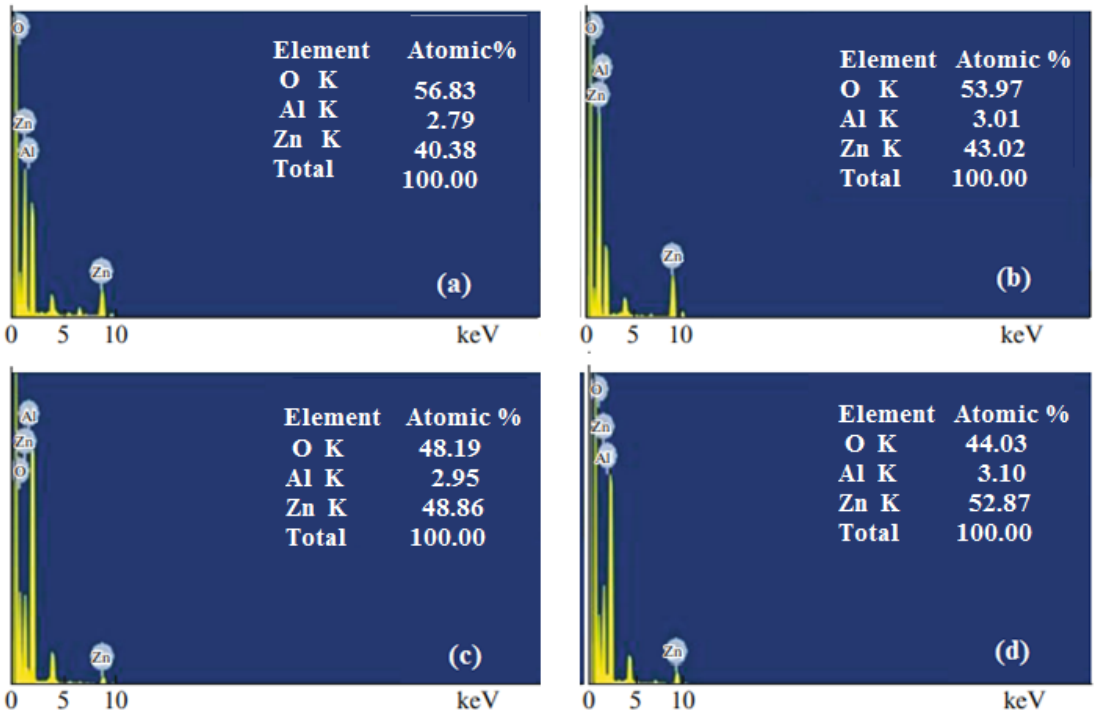

Fig.1.6. EDS plot for AZO thin films deposited with a thickness of (a) 250 nm (b) 300 nm (c) 320 nm and (d) 500 nm

3.3.4 Atomic force microscopy Analysis:

The morphology of thin films with varying thicknesses provides insight into the films' development mechanism. Morphology research and knowledge of growth mechanisms are also required to create materials in a controlled manner for desired attributes. Scanning probe methods, such as atomic force microscopy (AFM), are critical for studying surface morphology in real space. An AFM can photograph the top surface, providing information on the morphology and the change in roughness as a function of thickness. Figure 1.7 displays AFM images of AZO films with 250, 300, 320, and 500 nm thicknesses. AFM pictures of AZO thin films of varying thicknesses reveal that they are dense and homogenous. The surface morphology grows rougher as the thickness of the coating increases. The RMS surface roughness values of AZO thin films with 250, 300, 320, and 500 nm thicknesses are 1.86, 1.88, 2.10, 2.13, and 2.26 nm, respectively. The RMS surface roughness of thin films rises with increasing thickness. These film surface topologies can improve light trapping, especially in solar applications. However, grain size varies greatly across the deposited films of various thicknesses. For a 300 nm film thickness, the surface was made up of extremely minute trapped grains that appear to increase with deposition time. According to the Vander Drift model, the random orientation nuclei were developed at the initial stage of deposition

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and then nanocrystalline structures preceded in the next competitive growth stage; finally, crystals with higher vertical growth rate might have a greater probability for survival and, as a result, large and well-oriented grains were obtained.

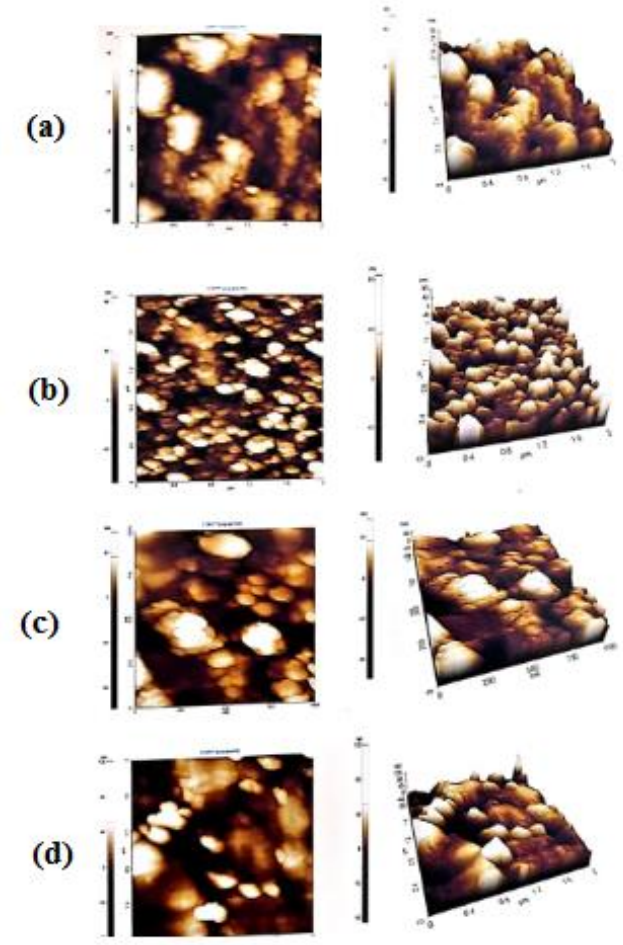

Fig.1.7. AFM images (2D and 3D) of AZO films deposited with thicknesses of (a) 250 nm, (b) 300 nm, (c) 320 nm and (d) 500 nm

4.Conclusions

AZO thin films of various thicknesses were prepared by RF magnetron sputtering technique on glass substrates. It can be concluded that the RMS surface roughness of thin films rises with increasing thickness. These film surface topologies can improve light trapping, especially in solar applications.

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