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Growth and Characterization of Sputter Deposited ZnO Thin Film

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ABSTRACT

Structural and optical properties of zinc oxide (ZnO) thin film prepared by radio frequency magnetron sputtering is reported in this paper. A ZnO target was used to sputter deposit the thin films on a glass substrate in Argon ambient without any substrate heating. The X-ray diffraction was used to investigate the crystal structure and orientation. Grain size was calculated using Sherrer formula. The scanning electron microscopic results conforms the grain size. The optical transmittance of the thin film was analyzed in the wavelength range 190-900 nm using UV-Vis spectrometry. The optical band gap of 3.2 eV was evaluated. The structural and optical property correlation have been carried out to explore ZnO thin film in application such as transparent thin film transistors.

KEYWORDS:ZnO thin film, Sputtering, Crystal structure, Optical band gap.

INTRODUCTION

The thin films of transparent conductive oxides (TCOs) have been of great interest recently for the development of opto-electronic components flat panel displays and solar cells. Indium Tin oxide (ITO) is currently the prevalent for all of these applications. However, ITO is chemically unsuitable, expensive and a toxic raw material. An alternative to ITO, Zinc oxide (ZnO) is used and is one of the most promising candidate for TCOs. [1-2]

ZnO, a II-VI most important binary compound having direct band gap semiconductor of wurtzite structure with minimum energy gap is 3.2 eV at room temperature and 3.44ev at 4K. Due to its good bond strength, better optical quality, extreme stability of exitons and excellent piezo-electric protection, it shows many prodigious characteristics. Inaddition to these features, the low prize of ZnO makes it as a high potential and economical candidate for industrial applications[3-4]. Various techniques are available for the preparation of thin films of ZnO. Magnetron sputtering [5], spray pyrolysis [6], pulsed vapor deposition [7], molecular beam epitaxy [8] and sol gel process [9] are the few examples. Out of these magnetron sputtering is the preferred method since it can operate in lower temperature and produces better film quality.

Magnetron sputtering is a physical vapor deposition method that create plasma in the chamber to sputter the target material, the commonly used processing gas for sputtering is Argon (Ar). In the work, Radio frequency (RF) magnetron sputtering was used for the deposition of thin layers. The process was initiated by the glow discharge produced in the vacuum chamber. Under controlled gas flow, ZnO thin film was deposited onto the glass substrate. Objective of this work was tostudy the structural and optical characteristics occasioned by the film.

EXPERIMENTAL DETAILS

ZnO thin films were fabricated on a glass substrate by sputtering method. The ZnO thin film was deposited at room temperature by Radio Frequency (RF) magnetron sputtering with a power of140W. The sputtering process was carried out in Argon (Ar) ambient at 15 Pa. The high transparency ZnO thin films were gained.

The glass substrates were cleaned using soap solution, deionized water and acetone. The microstructure and surface morphology of ZnO film was evaluated by X-ray diffraction (XRD) and Scanning electron microscopy (SEM). The X-ray automatic diffraction was taken using the CuKr radiations (λ=1.5406Å) in the range of 2θ between 20° and 60° to obtain the X-ray diffraction patterns.

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The diffractometer reflection was taken at room temperature. The optical measurement of the film was carried out at room temperature using UV-Vis spectrometer in the wavelength range from 190 to 800 nm.

RESULTS AND DISCUSSIONS

a. Structural properties XRD

XRD pattern of ZnO fabricated by sputtering on a glass substrate is shown in **Fig1**. This spectra reviles that the film obtained is polycrystalline with hexagonal wurtzite structure [9]. A strong diffraction peak along (002) implies most of the c-axis of ZnO grains are arranged perpendicular to the substrate surface [10].

The unit cell 'a' and 'c' of the polycrystalline ZnO film is calculated using the relation,

$$a = \frac{1/\sqrt{3}\lambda}{S}$$

$$c = \frac{\lambda}{S}$$

The unit cell values are obtained and the calculated lattice parameters are presented in the **Table1**.

Formation mechanism of the preferential oriented thin films could be the minimization of the surface free energy of each crystal plane and usually films grows so as to minimize surface energy. Due to minimization of surface energy, heterogeneous nucleation readily happens at the interface of the substrate [11].

Table1. Lattics Parameters of ZnO thin film

a(Å)		c(Å)	
Standard	Calculated	Standard	Calculated
3.253	3.022	5.215	5.235

The crystalline size (D) of the ZnO film can be estimated from Scherrer formulae [12]:

$$D = \frac{K}{\beta}$$

Where K is a constant and its value is taken to be 0.49, λ is the wavelength of X-ray (λ=1.54Å), β is the full width half maximum peak of XRD pattern, Bragg angle 2θ is around 34.21°. The average value of grain size is found to be 27nm.

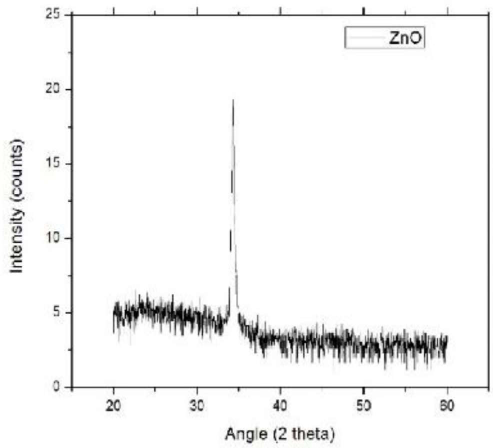

Fig1: X-ray diffraction pttern of ZnO thin film

d (Å)	FWHM (2θ)	2θ°	D (nm)	$\delta x10^{-2}$ (nm)$^{-3}$	$\varepsilon x10^{-2}$
2.618	0.288	34.21	27	1.37	6.88

Dislocation density (δ) is the length of dislocation lines per unit volume and is estimated using the equation:

$$\delta = \frac{1}{D^2}$$

Strain of the thin film is determined from the formulae

$$\epsilon = \beta \quad \theta/4$$

Calculated structural parameters are given in **Table2**.

a. Surface morphology

Surface morphology of a thin film is very important tool to investigate the microstructure of the thin films. **Fig 2** shows the SEM micrograph of ZnO thin film. The tightly packed nanocrystalline grains are distributed on the glass substrate and the crystalline size is approximately 27nm. The grains made a smooth and transparent surface.

b. Optical properties

Fig 3 shows optical transmittance spectra of sputter deposited ZnO thin film in the UV-Vis region from 200-800 nm. The transmittance is over 80% in the visible region from 400-800 nm.

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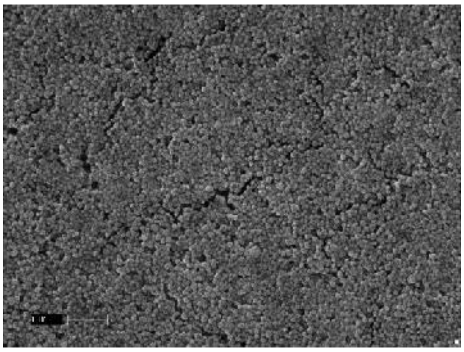

Fig 2: SEM micrograph of thin film ZnO

Table2. Structural parameters of ZnO thin film

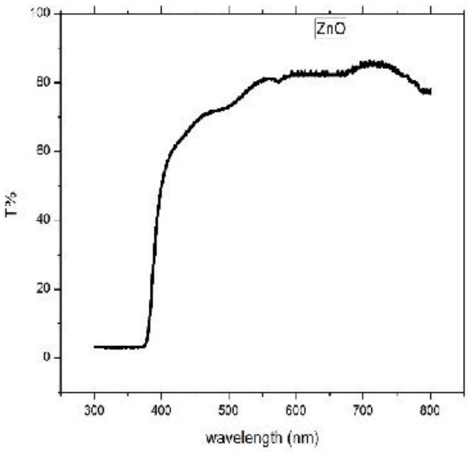

Fig 3: Optical transmittance spectra of ZnO

A sharp absorption edge is located at 370 nm which is due to the fact that ZnO is a direct band gap semiconductor. The optical band gap of ZnO thin film is estimated by extrapolation of linearrelationship between $(\alpha h\nu)^2$ and hνaccording to the equation [13]:

$$\alpha h\nu = A(h\nu - E_g)^{1/2}$$

Where αis the absorption coefficient, hν is the photon energy, E_g is the optical band gap and A is a constant.

Fig 4 depicts the plot of $(\alpha h\nu)^2$ versus photon energy (hν). The bandgap is estimated from the pot by taking the intercept of a straight line from the curve to $(\alpha h\nu)^2$ to 0. The presence of the single slop in the plot suggests that film has direct and allowed transition.

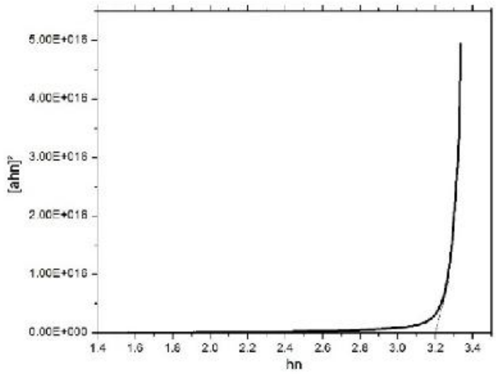

Fig 4: Tauc's plot obtained from UV-Vis transmittance spectra of ZnO thin film

The band gap of ZnO thin film is found to be 3.2 eV and for bulk ZnO it is 3.37 eV. The difference in the band gap values is due to many factors including granular structure, nature and concentration of precursors, structural defects and crystal structure of the film. The change in band gap is also affected by the stoichiometric departures from the lattice defects and impurity sites, grain boundaries and imperfections of polycrystalline thin film stress and interaction potentials between defects and host material in the film [14-15].

CONCLUSION

The structural and optical properties of ZnO thin film deposited by RF magnetron sputtering have been investigated. XRD spectra reveals that the film is polycrystalline in nature. The grain size was found to be approximately 27nm. In the visible region the film is highly transparent, above 80%. Due to these attractive properties, ZnO thin film can be effectively used for active channel layer for transparent thin film transistors.

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