Original Research Article

Zinc oxide nano thin film for solar cell device applications

Sarika Jadhav[1*], Limbraj Ravangave[2]

[1]Department Of Physics Sant Tukaram College Of Arts And Science, Parbhani, INDIA.
[2]Department Of Physics, Shri Sant Gadge Maharaj College Loha District Nanded, INDIA.
Email:sarika.jadhav125@gmail.com, lsravangave@gmail.com

Abstract

Background: Zinc Oxide (ZnO) thin film was deposited using simple low cost spray pyrolysis technique. The deposited film was characterized by X-ray diffractometer (XRD), Scanning Electron Microscope (SEM) and UV-Visible spectroscopy. XRD Spectra revealed that ZnO film represents polycrystalline wurzite crystal structure. Full Width at Half Maximum (FWHM) was estimated using Lorentz Fit of XRD data. The crystallite size calculated was to be 26.31 nm. The SEM image of ZnO thin film shows whole surface was uniformly coated with spherical ZnO grains of average size 111.55 nm. Purity of the deposited sample was investigated by using Energy Dispersive X-ray Analysis (EDX). The deposited ZnO film shows 78% transmittance. The optical band gap estimated by Tauc plot was 3.76eV.

[*]**Address for Correspondence:**
Dr Sarika Jadhav, Department Of Physics Sant Tukaram College Of Arts And Science, Parbhani, INDIA.
Email:sarika.jadhav125@gmail.com
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INTRODUCTION

Zinc oxide (ZnO) is a wide band gap, n-type semiconducting (II–VI) material exhibit good transparency in visible region, and large exciton binding energy of 60 meV.[1,2] Due to these ample properties ZnO have potential applications in Optoelectronic devices such as Optical wave guide, Light emitting diodes (LED), Thin Film Transistors (TFT)[3-5] etc. ZnO thin films exhibit high optical transmittance in the visible region of electromagnetic spectrum therefore it can be used as a window layer material in solar cell applications.[7] In recent years ZnO nano material have created much more interest for their application in laser diodes, piezoelectric transducers, bulk acoustic devices and in biomedical materials such as in making antiseptic creams, lotions and antibacterial creams. Various kinds of gas sensors, chemical and biological sensors were based on Zinc oxide thin films.[6,7] ZnO film have been prepared by using various techniques, such as radio-frequency magnetron sputtering,[8] chemical vapor deposition,[9] sol–gel method,[10] atomic layer deposition,[11] Laser ablation,[12] thermal evaporation,[13] pulsed laser deposition,[14] and chemical spray pyrolysis (CSP).[15] Spray pyrolysis is a promising method due to its low-cost nature and suitability for depositing large area thin-films.[16]However, the particle size, quality of micro structure and orientation of ZnO grains in particular directions were depending on the preparation methods. In this view, researchers have been continuously working to modify and improve the structure and optical properties of the ZnO material by proper molding of structure and morphology. In present report ZnO thin film was deposited by simple spray technique using perfume atomizer and structure, morphology and optical properties have been investigated.

MATERIAL AND METHOD

Experiment consists of pre-cleaned glass substrates were heated at $(300\pm5)^{o}$C by simple digital hot plate on which clear precursor have been sprayed using perfume atomizer. Precursor was prepared by dissolving reagent grade 0.25 M Zinc acetate hydrated ($Zn(CH_3COO)_2$: $2H_2O$) in distilled water. The solution was stirred by using magnetic stirrer for two hours. The clear precursor

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was sprayed on pre-heated glass substrates which were cleaned ultrasonically with organic solvents. The temperatures of the substrate were monitored by using automatic digital temperature controller. The distance of spraying nozzle form substrate was suitably adjusted so that whole substrate was exposed to spray. Spray deposited ZnO film was then annealed at 300℃ in muffle furnace for one hour. The annealed ZnO film was characterized by XRD, SEM, EDX and Uv-Visible Spectrophotometer.

RESULTS AND DISCUSSION

Structure of ZnO film: Spray deposited ZnO thin film was scanned by Meni FlexII Difracometer in the range 2θ = (20-80^o). XRD pattern of deposited ZNO film was shown in figure 1. The XRD pattern of ZnO film shows Brag's reflections at (2θ) = (31.4506, 34.1191 and 36.8039^o) which were assigned by (100), (002) and (101) lattice planes respectively. XRD pattern of ZnO thin films represents wurtzite polycrystalline crystal structure. Similar structure was represented by standard JCPDS card no. 75-1526. The XRD pattern represented in figure 1 exhibit dominant (002) peak at 34.1191^o Bragg's reflection. Similar finding have been reported by Kumar J. S.[17]

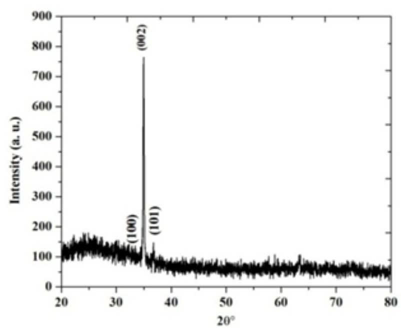


Figure 1: XRD Pattern of ZnO Thin Film.

The martial growing along (002) direction was widely useful in solar cell device applications. Because (002) peak provides the lattice matching to the chalcogenide semiconductors.[6] The full width at half maximum (FWHM) of (002) peak estimated by Lorentz fit of XRD data. the calculated FWHM was 0.1762 radians. The crystallite size[18] was estimated from full width at half maximum (FWHM) by using equation (1).

$$D = \frac{0.95\lambda}{\beta \cos \theta} \quad (1)$$

where, λ is wavelength of X-ray (1.504 A^o), β is full width at half maximum (FWHM) and θ is the position of (002) peak. The calculated crystallite size was 26.31 nm.

Surface Morphology of ZnO Thin film: The SEM Image of deposited ZnO thin film was shown in Figure 2. The same image shows that whole surface was uniformly covered with spherical ZnO grains. The average size of ZnO grains was found to be 111.55 nm. Average size of ZnO grains is larger than crystallite size calculated from XRD data. This is due to agglomerations of ZnO nano crystals.

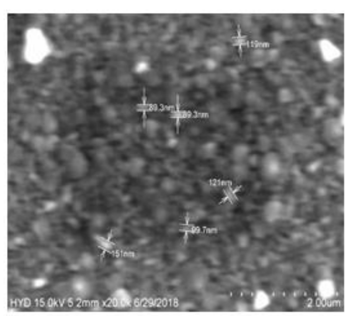


Figure 2: SEM Micrograph of ZnO Thin film.

Elemental Analysis: Elemental analysis of deposited ZnO thin film was done by using EDX technique. Figure 3 shows the EDX spectra of ZnO thin film. The elemental composition was displayed in Table 1. The elemental analysis confirms that prepared sample composed by Zinc and oxygen elements. There were no other impurities present in the sample. The weight % and atomic % was shown in table 1. The ZnO phase formation was concluded by weight % and atomic % of deposited film.

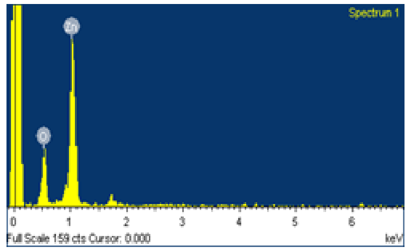


Figure 3: EDX Spectra of ZnO Thin Film.

Table 1. Composition of ZnO Thin Film.

Film Sample	Element	Weight%	Atomic%
	O K	**22.32**	**54.00**
ZnO	**Zn L**	**77.68**	**46.00**
	Totals	**100.00**	**100.00**

Optical Properties of ZnO Thin film: The optical absorption and transmittance spectra were recorded by using Systronics (2201) double beam spectrophotometer in the 350 to 999 nm range and presented in figures 4 and 5 respectively. Figure 4 represents ZnO film exhibit low absorption in the wide range from 360 to 999 nm of the electromagnetic spectra.

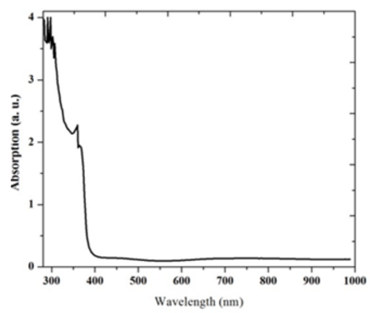
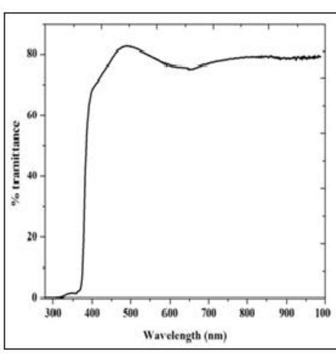


Figure 4: Absorption Spectra of ZnO Thin Film.

Figure 5 show deposited ZnO film exhibit 78 % transmittance in the 360 to 999 nm range. The low absorption and higher transmission is most important characteristics of the window layer used in solar cell device application.[6]The optical band gap ($\boldsymbol{Eg}$) can be obtained by using Tauc's relationship. Tauc relation explains variation of the absorption coefficient $\boldsymbol{\alpha}$ is linked to $\boldsymbol{Eg}$ of the material by the following expression (2)[19]:

$$(\alpha h\nu) = A(h\nu - Eg)^{n} \quad (2)$$

where, Eg (eV) is the band gap energy and A is an energy-independent constant. The index n is theoretically equal to 1/2and 3/2 for direct allowed and forbidden transitions respectively. ZnO is direct band gap material therefore, n is set equal to 1/2. The band gap energy value Eg was calculated by extrapolation of the linear part of $(\alpha h\nu)^2$ versus $h\nu$plot. Figure 6 shows Tauc plot of ZnO thin film. The band gap obtained for deposited ZnOfilm was 3.76 eV.



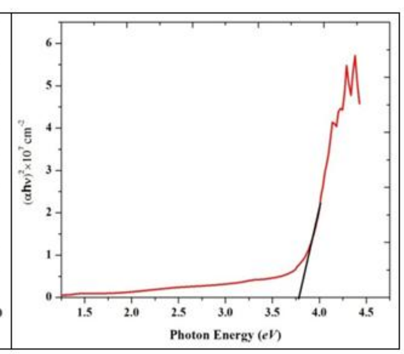


Figure 5 **Figure 6**

Figure 5: Plot of % transmittance verses wavelength (nm) of ZnO thin film; Figure 5: **Tauc Plot of ZnO Thin Film**

CONCLUSIONS

In this report ZnO thin film was deposited by using low cost chemical spray pyrolysis using locally available perfume atomizer successfully. The deposited film was exhibited dominant (002) peak. Surface morphology shows spherical ZnOgranules were uniformly distributed over whole surface of the film. On the basis of overall discussion it was concluded that deposited ZnO thin film by using above described technique exhibit dominant (002) peak, higher transmittance (($\geq 78\%$) and suitable band gap 3.76 eV can be used in solar cell device application as a window layer material.

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