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Low-Temperature Synthesis of Zinc Oxide Nanorods by Wet-Chemical Method

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ABSTRACT

Zinc Oxide nanorods (ZnO_{NR}) have been deposited by simple wet-chemical method from the zinc nitrate solution at 60^0C on ITO coated glass substrates. Synthesized thin films were annealed at 500^0C for 5 hr. The obtained thin films have been characterized by X-ray diffraction (XRD) and scanning electron microscope (SEM). XRD pattern showed preferential orientations along (002) crystallographic plane which revealed polycrystalline nature of the film. SEM micrograph clearly showed the formation of highly oriented ZnO_{NR}.

Key words: ZnO nanorods, wet-chemical method, XRD, SEM, FTIR, UV-Vis spectrum

INTRODUCTION

Nanostructured zinc oxide has attracted attention of researchers and scientists in the last few years because of their useful properties in several applications. It is one of the most used inorganic materials due the flexibility of preparation in different morphologies and tunable properties [1]. It has potential applications in optoelectronic devices due to the direct band gap of 3.3eV [2-4]. It also has some unique and interesting physical as well as chemical properties such as, large exciton binding energy (60meV) [5-6], chemical [7] and thermal stability [8], radiation hardness [9], piezoelectricity and photoelectricity [10], high conductivity, etc.

It is abundantly available in nature and nontoxic. Due to such intriguing properties of zinc oxide it became a most attractive semiconducting material for the applications in photo-detector [11], gas sensor [12], LED's [13], solar cells [14], photonic crystals [15], UV-protectors filters [16], chemical sensors [17] and photodiodes [18]. Zinc oxide is binary (II-IV) n-type semiconductor due to the Zn interstitials and presence of oxygen vacancies. It has high visible transparency and low electrical conductivity [5]. Zinc oxide thin films have been prepared by various deposition techniques such as; Chemical Vapor Deposition (CVD) [19], magnetron sputtering [20], spray pyrolysis [21-22], Pulsed Laser Deposition (PLD) [23], sol-gel method [25-26], electron beam evaporation [27]. Among all these methods, the wet-chemical method is one of the most important method and widely used for the preparation of metal oxide nanostructures. This is an attractive technique for fabricating uniform thin films due to the homogeneity of precursor, a large-area deposition and low cost fabrication. In this study, ZnO thin films were prepared by wet-chemical method at 60^0C temperature using ITO coated glass as a substrate. Uniformly deposited thin films of ZnO were subjected for structural and morphological characterizations.

METHODOLOGY

Analytical grade zinc nitrate hexahydrate [$Zn(NO_3)_2.6H_2O$] (Sigma Aldrich, 99.99%) (0.2 M) was dissolved in deionized double distilled water at 60^oC. Then, the 0.5 mM ethylenediamine tetra-acetic acid (EDTA) (Merck, 99%) was added to trap impurities present in the solution [28]. The 0.1 M ethylenediamine [$C_2H_4(NH_2)_2$] (Sigma-Aldrich, ReagentPlus, 99%) (0.1 M) was added to start formation of ZnO nanostructures. Polyethylene glycol (PEG-600) (Merck) (5 ml) was added as a surfactant to get the porous nanostructures. After the slight stirring of solution, it was kept at 60^oC for 6 hr using water bath. Here, water bath was used to maintain the temperature consistency. The solution colour was changed from transparent to white after the addition of ethylenediamine, which indicate the formation of zinc oxide nanostructures. ITO-coated glass plate (Sheet resistance of 10 Ω/sq) was immersed into the solution and left for 12 hr to get the thin layer of ZnO deposited onto the glass substrate. The deposited thin film of ZnO nanostructures was dried in a vacuum and then it was annealed at 400^oC for 30 min. Finally, the obtained ZnO thin film was dried in a vacuum. The good quality as well as highly transparent ZnO thin film was obtained and subjected for structural and morphological characterization.

RESULTS AND DISCUSSIONS

X-ray diffraction pattern of the synthesized ZnO nanorods are shown in figure 1, in the range of $20\text{-}80^0$. XRD pattern indicates that all the diffraction peaks corresponds to hexagonal wurzite structure (JCPDS 36-1451).

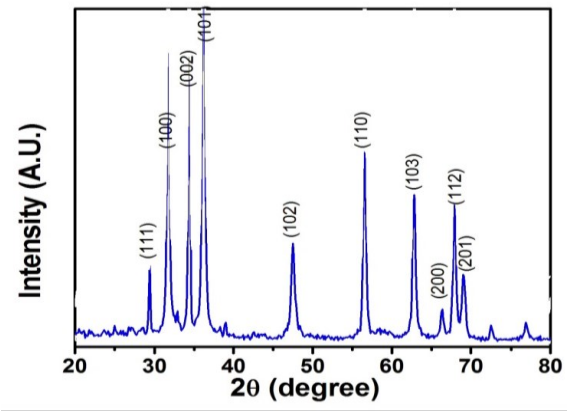

Fig.1: XRD pattern of ZnO nanorods

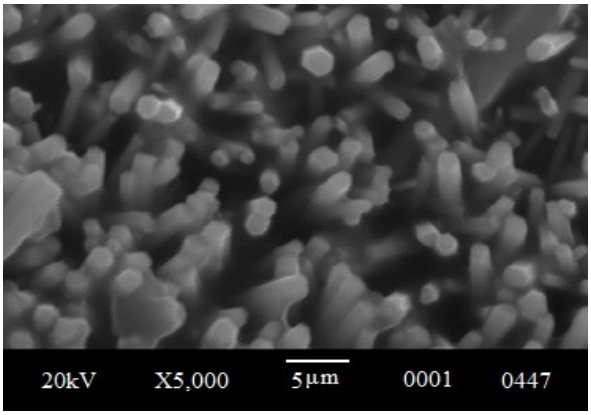

Fig.2: SEM micrographs of ZnO_{NS} at 5000x magnification

XRD pattern does not show any diffraction peak corresponding to the impurity which confirming the formation of high purity ZnO nanorods. The peak at 34.20 2θ value is strongest and corresponding to (002) plane. Other peaks at 2θ values of 31.50, 36.11, 47.62, 56.57, 62.64, 66.30, 67.57, 69.29 corresponds to (100), (101), (102), (110), (103), (200), (112), (201) lattice planes, respectively. The average crystallite size of ZnO was determined from FWHM by using Debye Scherrer's formula and it was found to be 65nm.

The SEM micrograph of ZnO nanorods are represented in figure 2. The SEM of ZnO thin film at X5000 magnification clearly showed homogeneous morphology. SEM micrograph showed the formation of ZnO nanorods having preferential c-axis orientation. The average diameter of the nanorods is 185nm. SEM image strongly support the results obtained from XRD analysis.

CONCLUSION

In this research work, zinc oxide nanorods have been synthesized by low temperature and easy wet-chemical deposition method. Structural and morphological properties of post-heated ZnO thin films at 500^0C temperature have been studied. XRD pattern reveals that, the synthesized material exhibit hexagonal wurtzite crystal structure with preferential orientation along (002) crystallographic plane. The structural analysis confirms the polycrystalline nature of ZnO. It is also conclude that results obtained from XRD analysis strongly support the SEM micrograph. The morphological study through SEM micrograph clearly showed highly oriented ZnO_{NS}.

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