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Research Article

ELECTRICAL CHARACTERIZATION OF ZINC OXIDE THIN FILMS PREPARED BY SPRAY PYROLYSIS METHOD

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ABSTRACT
Nanostructured zinc oxide (ZnO) thin films were deposited onto glass substrates by using chemical spray pyrolysis technique at 573K using $Zn(CH_3COO)_2$ as precursor solution. Structural characterization of as deposited thin films was studied using X-ray diffraction technique, which reveals that zinc oxide thin films are polycrystalline in nature with typical hexagonal wurtzite structure with preferentially oriented along (002) direction and has band gap of 3.34eV. The electrical resistivity of ZnO thin films is of the order of 10^2 Ωcm. The thermo-emf measurement confirms n-type conductivity of zinc oxide thin films.

Keywords: *Thin Films, Nanostructures, Electrical Properties, N-Type Conductivity*

INTRODUCTION
Transparent conducting oxides (TCOs) have been widely used in different areas due to their high optical transparency, low resistivity and wide energy band gap. Hence, there has been great deal of work on investigating their preparation process and optimizing their properties. Among the various transparent conducting oxide materials available, zinc oxide has attracted attention of researchers and scientist due to its wide direct band gap (3.3eV) (Jeong *et al.*, 2007; Sui *et al.*, 2009; Mohite and Kothawale, 2015). ZnO is composed of hexagonal wurtzite crystal structure with unit cell a = 3.253 Å and c = 5.215 Å due to their unique optical, electrical and semi-conducting properties, ZnO thin films form the mainstay of the electronics industry and the cornerstone of modern technology. Due to intriguing properties zinc oxide became a most attractive semiconducting material for the applications in photo-detector, gas sensor, LED's, solar cells, photonic and photodiodes etc. Nanostructures of ZnO are fabricated using various thin film techniques such as sputtering (Minami *et al.*, 2007), spray pyrolysis (Caglar *et al.*, 2006) metal-organic chemical vapour deposition (MOCVD) (Lu *et al.*, 2007), molecular beam epitaxy (MBE) (Chen *et al.*, 1998), pulsed laser deposition (PLD) (Shan *et al.*, 2007) and the sol-gel process (Ilican *et al.*, 2008). Among these methods, the spray pyrolysis 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.

Experimental Details
The films of ZnO were deposited onto glass substrates by chemical spray pyrolysis technique. It is a very simple and relatively cost-effective method for preparing films of any desired composition under controlled conditions, involving the spraying of a solution containing a soluble salt of the cation of interest onto a heated substrate. In the present investigation the ZnO thin films were deposited on properly cleaned glass slides. Glass slides were first immersed into dilute hydrochloric acid for 24 hours which were then washed thoroughly with constant rubbing by soft tissue papers, after that glass slides were put into freshly prepared chromic acid for a few minutes for further fine cleaning. After that the glass substrates were rinsed with doubled distilled water several times and dried. The precursor solution used was of 0.1 M concentration of high purity $Zn(CH_3COO)_2$ prepared in distilled water. This solution was sprayed using compressed air as a carrier gas onto hot glass substrates kept at 573 ±5K temperature. The experimental setup of advanced spray pyrolysis technique and its other details have been reported elsewhere (Ubale and Ibrahim, 2015). During the course of spray, other parameters viz. nozzle to substrate distance (28cm), spray rate (6mL/min), air pressure (10LPM) and hot plate core temperature (573 ±5K) were essentially kept the same.

RESULTS AND DISCUSSION

Electrical Studies

The measurement of electrical conductivity at different temperatures allows us to obtain information about important properties of the film such as, the activation energy and the donor level and from the comparison between the average grain size and the Debye screening length, we can determine if a potential barrieris created because of band bending, and even if the mobility of charge carriers is limited by the thermionicor thermo field emission of electrons.

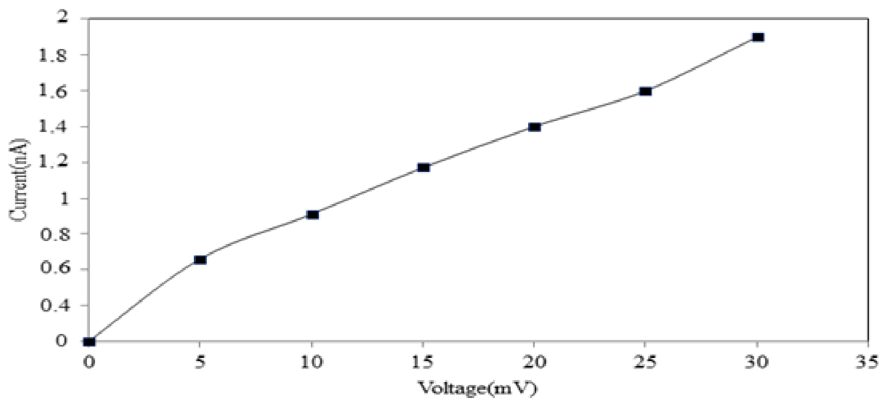

Figure 1: I-V Characteristic of ZnO Thin Films

The electrical properties are dependent on various film and growth parameters such as film composition, thickness and substrate temperature and deposition rate. In the present work silver paste was used to make ohmic contacts to ZnO thin films. The nature of ZnO/Ag contacts were checked up to 30 V using two-probe method by plotting I-V characteristics (Figure 1).

The variation of dc-electrical resistivity with temperature was studied for ZnO thin films in the temperature range 303K to 483 K. The electrical resistance was found to be of the order of $10^2 \Omega$cm. The conductivity of the film samples increases with increase in temperature indicating the semiconducting nature.

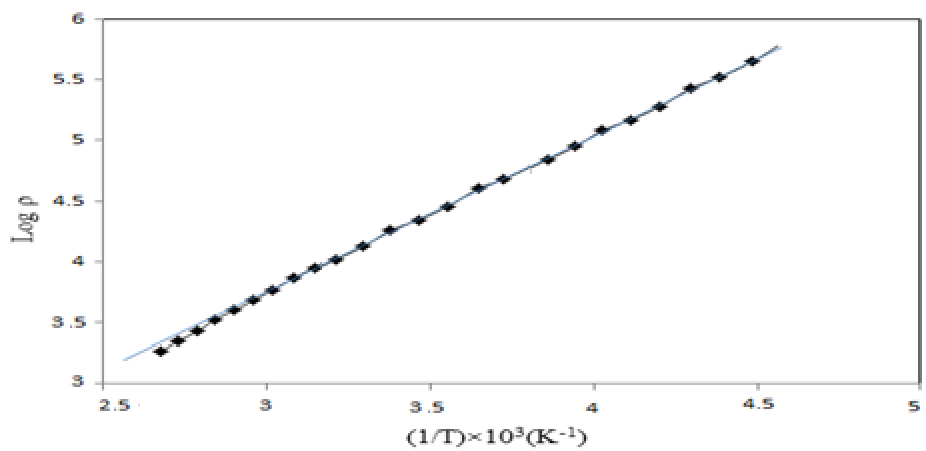

Figure 2: Variation of Log of Resistivity with 1/T for ZnO Films

The variation of log (ρ) with reciprocal of temperature (1/T) for ZnO films is shown in figure 2. The dependence of resistivity on temperature is almost linear indicating the presence of only one type of conduction mechanism in the film.

The thermal activation energy was calculated using the relation,

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$$\rho = \rho_0 \exp^{(E_0/KT)} \quad (1)$$

where, ρ is resistivity at temperature T, ρ_0 is a constant; K is Boltzmann constant. The activation energy (E_0) was calculated from the resistivity plots.

Thermo-emf Measurement

The type of conductivity exhibited by chemical bath deposited ZnO thin films is determined by thermoelectric power (TEP) measurement, the TEP depends on the location of fermi energy level in the material and the type of scattering mechanism. From the sign of the terminal connected towards hot end it can be deduced the sign of the predominant charge carriers.

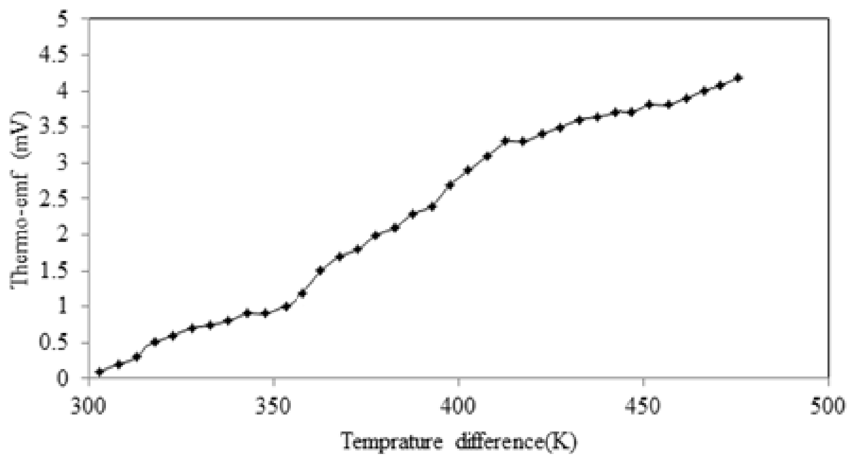

Figure 3: Variation of Thermo emf (mV) with Temperature Difference for ZnO Thin Films

The thermo-emf developed across hot-cold junction of zinc oxide thin film in dark was measured as a function of temperature difference (Figure 3). The polarity of the generated thermo-emf was negative at the cold end with respect to the hot end, which confirms that zinc oxide thin films are of n-type.

Conclusion

Nanostructured highly transparent conductive zinc oxide thin films have been deposited onto glass substrate using chemical spray pyrolysis method. The films are polycrystalline in nature with typical hexagonal wurtzite structure with preferentially oriented along (002) direction and has band gap of 3.34eV. The electrical resistivity of the films is of the order of $10^2\Omega$cm. The thermo-emf measurement confirms n-type conductivity of zinc oxide thin films.

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