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Effect of tin incorporation on physicochemical properties of ZnO films prepared by spray pyrolysis

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Abstract

Spray pyrolysis system was used to obtain tin doped ZnO thin films on heated glass substrates. The structural, optical and electrical properties of the films were been studied. The effect of heat treatment for as deposited films in vacuum was studied. X-ray diffraction spectra showed that doping improves the crystallinity. Tin doped ZnO films with over 85% transmittance and conductivity as low as $5 \times 10^{-2}\ \Omega$ cm were obtained. On the other hand, the annealing of as deposited films in vacuum leads to reduction of resistivity and improvement of crystallinity and optical transmission.

Keywords: Tin incorporation; ZnO films; Spray pyrolysis

1. Introduction

Zinc oxide-based films have recently gained much attention due to many advantages over other oxide thin films. For instance, these are more stable than tin or indium oxide films in the presence of hydrogen plasma. Moreover, doped ZnO films have many interesting potential applications such as transparent electrode [1], piezoelectric device [2], gas sensor [3] and it can be used as windows layer in heterojunction solar cells [4].

High quality ZnO films can be deposited by several techniques such as sputtering [5], chemical vapour deposition [6], sol gel [7], pyrosol technique [8] and spray pyrolysis [9,10].

In this paper, the structural, optical and electrical properties of tin doped zinc oxide thin films by spray pyrolysis have been investigated. The effect of heat treatment in vacuum on the resistivity and optical transmission was studied.

2. Experimental

Spray pyrolitic system was used to obtain tin doped zinc oxide thin films. The experimental set up has been previously described [11,12]. 0.05 M starting solution of zinc chloride ($ZnCl_2$) in a mixture of deionised water was used. The compound source of dopant was tin chloride ($SnCl_2$, $2H_2O$). Indeed, previous works have used the $SnCl_4$ as precursor doping which is dangerous and fowl, for this reason we have used the $SnCl_2$, which is not noxious compound. The optimum conditions of preparation are reported in Table 1.

The crystalline structure was studied by X-ray diffraction using Cu (Kα) radiation. The surface morphology is examined by scanning electron microscopy (SEM). The film composition was studied by X-ray photoelectron spectroscopy (XPS), using magnesium X-ray source (1253 eV) and by EPMA analysis, background correction was carried out using a software program (PGI-IMIX PTS) and the percentage of all elements were obtained. The optical transmission measurements were performed with a Shimadzu 3101 PC UV-Vis-NIR spectrophotometer. The electrical resistivity was measured at room temperature by the Van Der Paw method. The thickness of films were calculated from optical transmission by interference method.

Table 1
Optimum preparation conditions of tin doped ZnO films

	Optimum parameters
Solvent	Deionised water
Substrate temperature (°C)	450
Carrier gas	Air
Spray rate (ml min^{-1})	5
Zinc chloride (M)	0.05
Tin chloride (at.%)	*X*
Substrate	Glass
Films thickness (μm)	0.5

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3. Results and discussion

3.1. Structural properties

Zinc oxide crystallises in the hexagonal system with a wurtzite structure. Fig. 1 shows the X-ray diffraction spectrum of tin doped ZnO films deposited at different tin doping ratio at substrate temperature of $T_s = 450\,^{\circ}C$. X-ray diffraction analysis indicates that the deposited films were polycrystalline and oriented to the substrate surface (*c*-axis orientation). As shown in Fig. 1, with increasing doping concentration the location of the measured diffraction peaks do

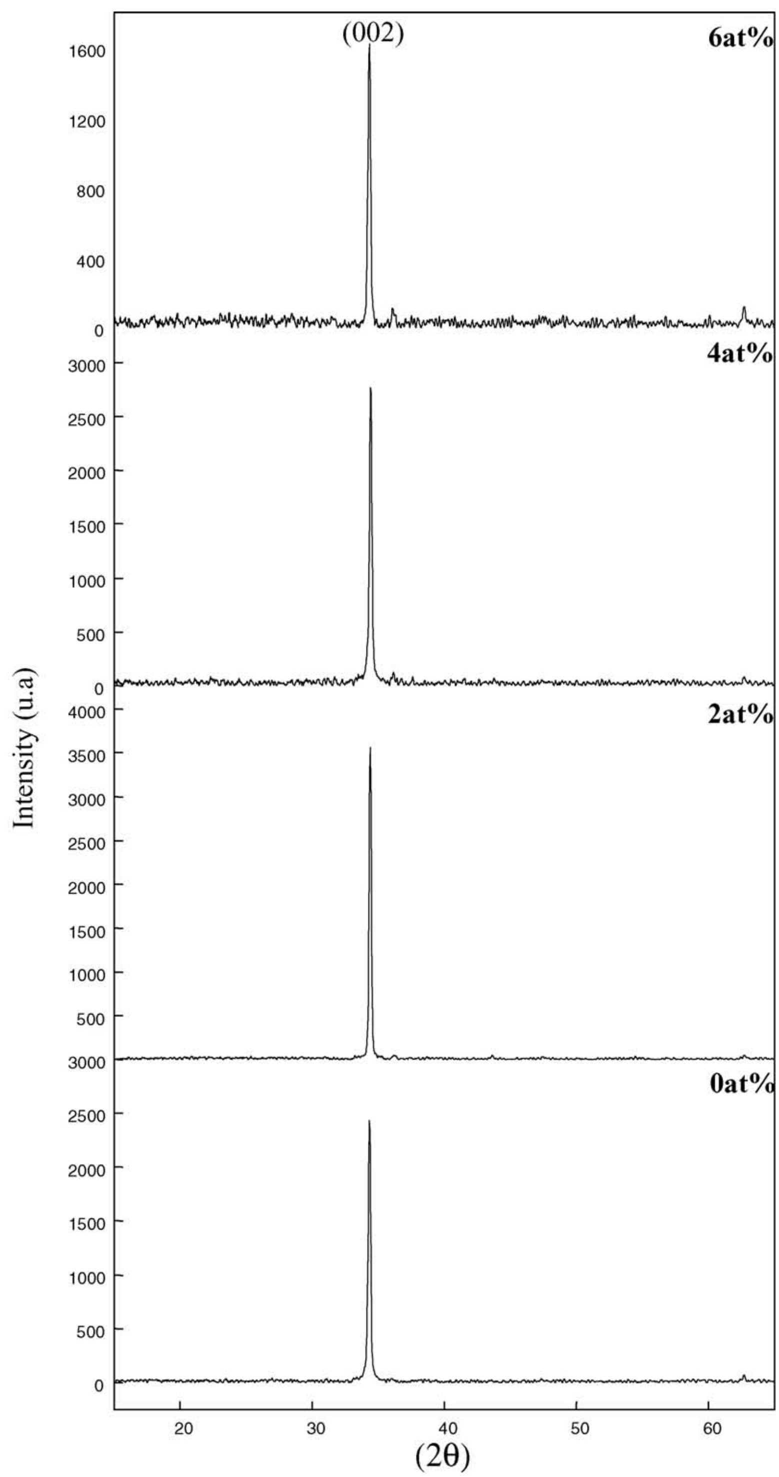

Fig. 1. XRD spectra of ZnO:Sn films prepared at different doping rates.