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STRUCTURAL AND MORPHOLOGICAL PROPERTIES OF GA-DOPED ZNO FILMS PREPARED BY SPRAY PYROLYSIS TECHNIQUE

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ABSTRACT

The present work report on the results of an investigation of gallium doped nanocrystalline ZnO (GZO) thin films synthesized using simple and economical chemical spray pyrolysis technique with doping concentration from 1 to 5 at%. The effect of doping on the structural and morphological of ZnO thin films was investigated. X-ray diffraction (XRD) has shown that the films are polycrystalline and textured with the c-axis of the wurtzite structure along the (002) growth direction. The scanning electron microscopy (SEM) measurements revealed that the surface morphology of the as-deposited ZnO films is greatly affected with a decrease in the grain size.

KEYWORDS: Spray pyrolysis; ZnO films; structural properties; morphology.

1. INTRODUCTION

Zinc oxide (ZnO) thin films have been an active area of research because of their unique properties such as high electrochemical stability, resistivity control, transparency in the visible range with a wide band gap, absence of toxicity, abundance in nature, etc. [1]. ZnO can be used for preparing transparent conducting contacts for solar cells, surface acoustic wave (SAW) devices and sensors [2]. Moreover, ZnO has increased interest in its various applications for short wavelength optoelectronics, transparent electronic materials [3–5] and tip materials of scanning probe microscopy.

Recently, ZnO nanoparticles have attracted considerable attention due to the unique physical properties caused by the size effect and their potential applications in nano devices. For realization of devices, based on ZnO or doped ZnO, one of the prerequisites is to tailor its properties according to the need. The ZnO:Ga films have been extensively studied because they present exhibit high mobility, high optical transparency, high electrical conductivity and have a lower material cost. However, Ga is less reactive and more resistant to oxidation than Al, and it has been demonstrated that Ga-doping leads to lower resistivity and higher transmittance in the visible region [6-7]. Currently, many methods are being used to prepare TCO films, such as molecular beam Epitaxy (MBE), chemical vapor deposition, electrochemical deposition [8], pulsed laser deposition (PLD), sol–gel process [9], reactive evaporation, and magnetron sputtering technique and spray pyrolysis [10]. The conductivity property of the ZnO:Ga films can be improved after doping and low temperature. Out of these, spray pyrolysis technique has gained a significant degree of interest due to its simplicity, safety and usage of low cost equipments together with less expensive raw materials. For many years good quality ZnO thin films have been reported by this technique, and a vast knowledge of the technique has been obtained [11-12].

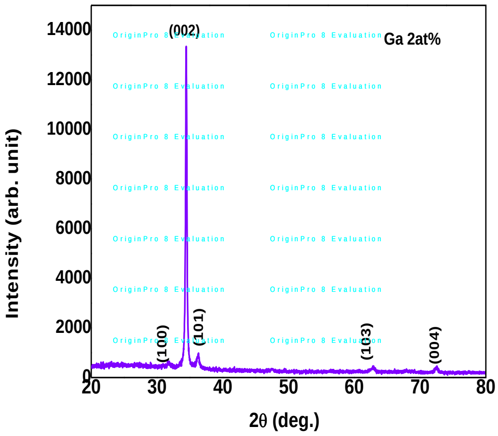
In this study, Ga-doped ZnO thin films were deposited by spray pyrolysis on glass substrates. The influence of Ga concentration on the structural, optical and electrical properties of ZnO: Ga thin films were investigated.

2. EXPERIMENTAL DETAILS

In this investigation, the ZnO:Ga thin films were deposited on preheated amorphous glass substrates using P C controlled spray pyrolysis technique supplied by Holmark (Cochin, India). A solution of zinc acetate in a mixed solvent of 75% methanol and 25% double distilled water was used as a precursor. Compressed air was used as the carrier gas. The GZO films were deposited at optimized temperature of 450 ^{0}C by varying the gallium concentration form 1 to 5 at%. The precursor solution was atomized into the fine droplets and carried to the preheated glass substrates.

3. Results and discussion

3.1. Structural analysis of GZO films



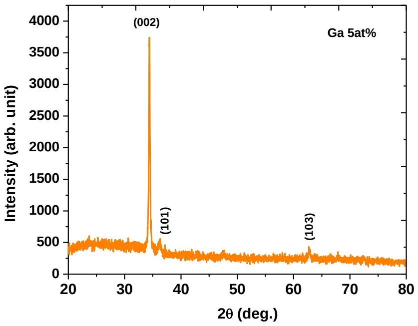


Fig. 1

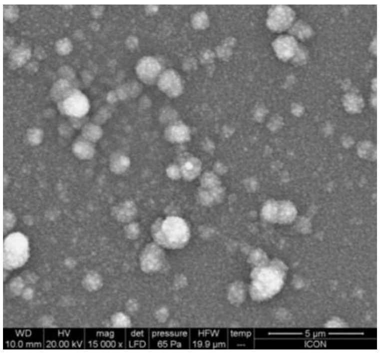
XRD diffractogram of typical Ga doped ZnO thin films

The structural properties of Ga doped ZnO thin films produced by the spray pyrolysis method at 450 ^{0}C substrate temperature were investigated by XRD and the results for all doping levels of Ga are shown in Fig. 1. The XRD patterns of these samples are in good agreement with the JCPDS standard (No. 75-0576) data of wurtzite hexagonal ZnO. As seen from Fig. 1, the films exhibit a dominant peak at 2θ = 34.44 corresponding to the (002) plane of ZnO. However, weaker ZnO peaks like (100), (101), (103) and (004) are also observed, suggesting that during the material deposing some grains grow with another orientation [13]. Similar results were also obtained by T. Prasad Rao [14]. This observation suggests that the film do not have any phase segregation or secondary phase formation. Meanwhile, it was apparent that intensity of (002) diffraction peak decreased and the full width at half maximum (FWHM) of (002) peak decreased with increase in Ga concentration, indicating that the more the Ga concentration in ZnO films the worse the crystal quality. This might be due to the lattice disorder and strain induced by interstitial Ga atoms of the substitution of Ga for Zn

3.2. Surface morphological studies

It is known that the surface properties of the TCO films influence their optical and electrical properties which are important factors for application in optoelectronic devices. The two-dimensional surface morphologies of as-deposited GZO thin films were carried out using SEM images are shown in Fig. 2.

A uniform grain growth in all the film samples is observed from the SEM micrographs. It is also observed that grains are small and distributed uniformly throughout the surface. The uniformity and compactness presented by the films is a result of the specific deposition and solution conditions. In this case, the surface is covered by round and small-size grains, and seems to be a smoother and more uniform surface, whereas, films with a higher content of Ga show an irregular surface, which is covered by different size grains and some big features that seems to be agglomerates of smaller-grains.



Ga 2%

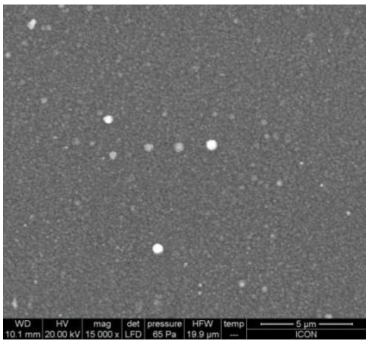


Fig. 2 SEM images of typical Ga doped ZnO thin films

4. CONCLUSION

We have found that Ga plays a key role in film properties although the structure of the films is not sensitively modified by the gallium incorporation. The X-ray diffraction studies revealed that all films have hexagonal wurtzite crystal structure with a strong (002) preferred orientation. The SEM measurements showed that, upon increasing the Ga concentration, the surface morphology of the films is uniform and grains are distributed uniformly throughout the surface.

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