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Synthesis and characterization of ZnO Thin Films

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Abstract

Zinc oxide (ZnO) films were prepared by an alternative route to the sol-gel process and their structural and optic properties carefully investigated. The deposition of the films was carried out on glass substrates by using a dip-coating technique. Zinc acetate dihydrate was used as inorganic precursor. This compound was first dissolved in ethanol and nitric acid. The obtained solution was then mixed with a citric acid and ethylenglycol, which were previously dissolved. XRD pattern confirmed the hexagonal wurtzite structure of the synthesized material. Optical transmittance spectra showed absorption band at 3.3 eV. Scanning Electron Microscope (SEM) analysis showed excellent morphology of the samples with very flat surfaces.

Keywords:Zinc Oxide, dip-coating, sol-gel films, optical devices.

1. Introduction

Zinc oxide (ZnO) is a member of the II–VI compound semiconductors with a wide band gap (3.31 eV) and a large excitonic binding energy (60meV) [1]. It possesses an unique position among materials owing to its superior and diverse properties such as piezoelectricity, chemical stability, optical transparency in the visible region, high voltage–current nonlinearity, etc. [2]. In this way, ZnO seems to be a good candidate for diverse applications as short wavelength optoelectronic devices [3]. ZnO-based thin films are indeed interesting for their applications in semiconducting, photoconducting or piezoelectric and optical waveguide materials [4]. Although physical methods (molecular-beam epitaxy,sputtering or spray pyrolysis) have been extensively used, sol-gel processes and variants as the polymeric precursor method are particularly adapted to produce ZnOcolloid and films, in a simple, low cost and highly controlled way [5]. In this work, the growth of high-quality ZnO films by a chemical method as well as the corresponding structural and optic characterization is reported.

2.Experimental Methods

Zinc acetatedihydrate was used as inorganic precursor. Firstly, the Zinc acetate was dissolved in ethanol and nitric acid. The obtained solution was then mixed with citric acid andethylenglycol, which were previously dissolved. ZnOfilms were deposited on glass substrate by dip coating with a velocity of 4 cm/min. After deposition, the films were heat-treated at 200ºC for 30 min, 350ºC for 30min and 550ºC for 30 min with increments of 2 ºC/min between each temperature. The crystalline phase of thZnO films were determined by x-ray diffraction (XRD) (using the Cu K□ = 1.54). Themorphology of the sample was investigated by Scanning Electron Microscope (SEM) and EDS. The UV absorption spectra were investigated by using a spectroscopic D2-Lamp. An optical fiber was used to transmit the UV-light continuum to the sample. The detection system is sensitive in the spectral range between 200 nm and 900 nm.

3. Results and discussion

Fig.1 displays the XRD pattern of the as grown ZnO thin film. Analysis of this pattern reveals that the film is monophasic with a very good crystallinity, showing the hexagonal wurzite structure. No additional peaks were observed suggesting that there is not inclusion of additional phases. The right compositional content of the film is evident from the EDS analysis, plotted in the inset of Fig. 2. Room temperature (RT) transmittance spectroscopy has been conduced measuring the band gaps of the samples. Fig. 3 shows the transmittance spectra of a ZnO thin film. The measured sample is highly transparent in the visible region and has a sharp absorption band in the UV region. Theory of optical absorption gives the relationship between the absorption coefficients □ and the photon energyh□ fordirect allowed transition as (□ h□)2= h□-Eg. The calculated optical direct band gap is presented in Fig. 4. A value of 3.1 eV is obtained for this film, which is very close to the theoretical one (3.37 eV) [3]. Thus, the quality of the grown films is further demonstrated.

A SEM image of the deposited film, shown in Fig. 5, gives a general view of the morphology of ZnO thin films synthesized by the described chemical route on glass substrates. Interesting enough, the surface of these films is extremely flat and the frequently reported granular character of ZnOthin films was not observed for the samples reported in thiswork. Such surfaces are desired to the growing of multilayered system, which find direct application in electronic devices.

4.Conclusion

In summary, high quality ZnOthin films on glass substrates have been achieved by a variant route to the standard sol-gel technique. The films show good structural, optical and morphological properties. The surface quality of the grown films would make possible that devices based on multilayers involving this material to be currently fabricated.

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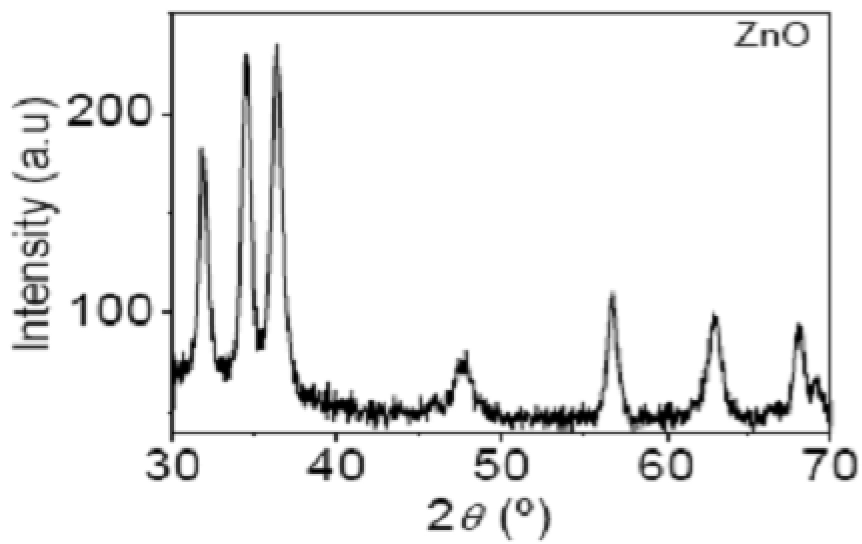

Fig.1 XRD pattern of ZnO film grown by chemical route on a glass substrate.

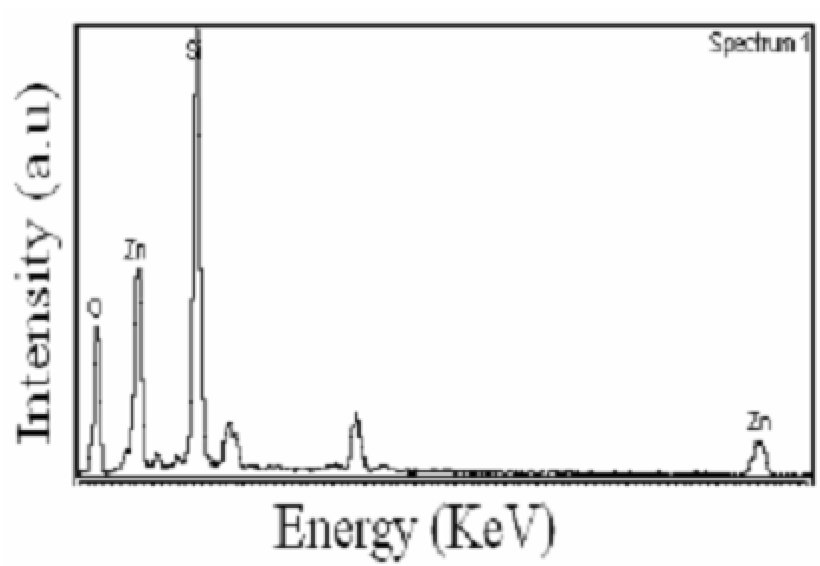

Fig. 2 EDS spectrum of a ZnO film showing its chemical composition. The Si peak corresponds to that of the substrate

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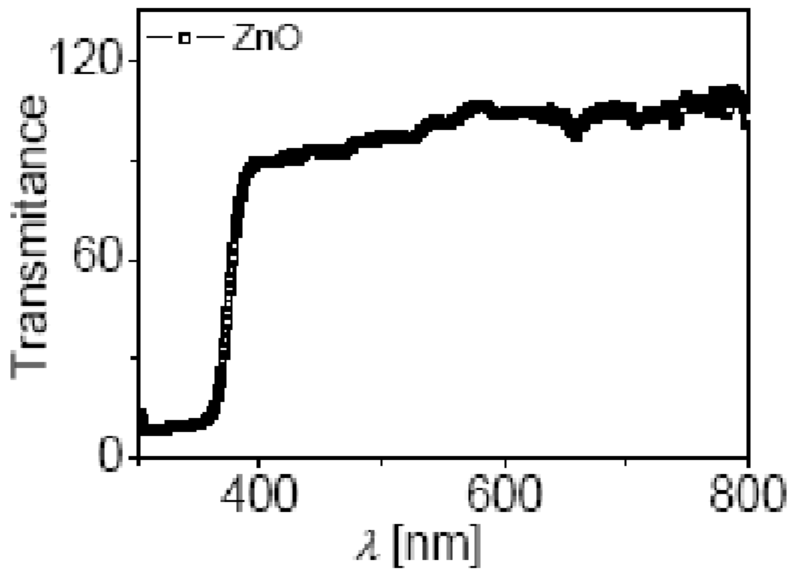

Fig. 3 Transmittance spectrum of a ZnO film.

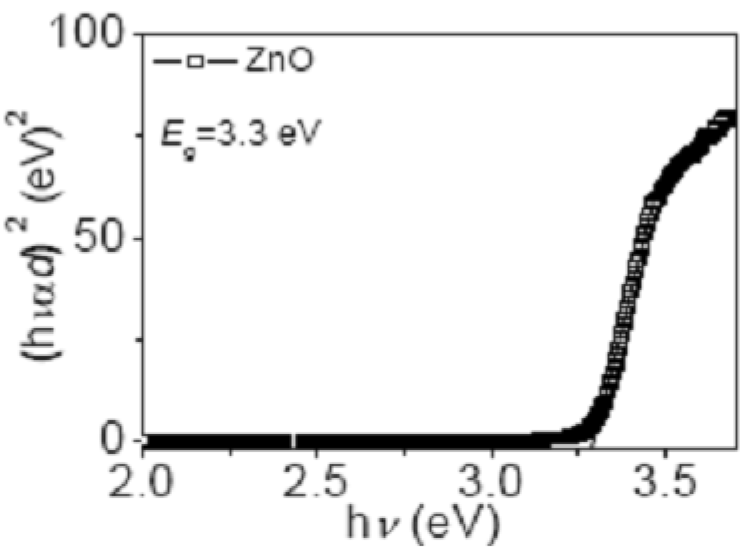

Fig. 4 Optical direct band of the same film. A band gap of 3.3 eV is calculated extrapoling the straight part of the curve to the energy axis.

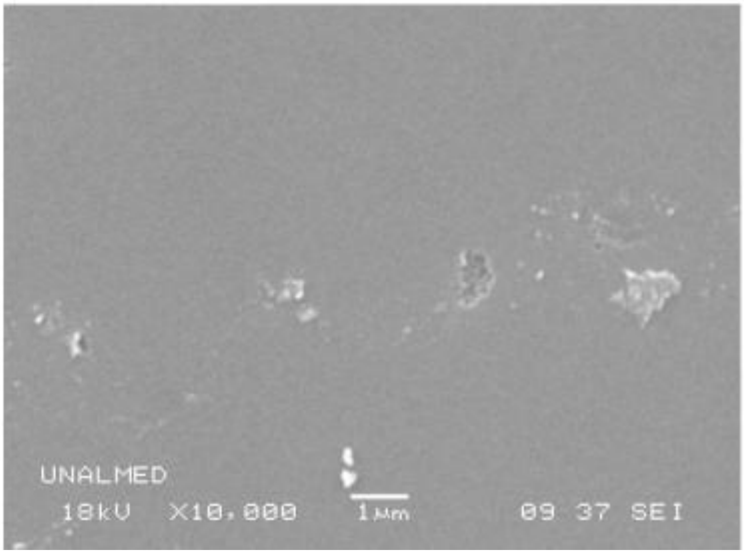

Fig. 5 SEM morphology of a ZnO film. No evidence of granular character of the surface of the film is appreciated from this picture.