





A comparative study on structural and optical properties of ZnO and Al-doped ZnO thin films obtained by ultrasonic spray method using different solvents

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Abstract

Transparent conducting ZnO and Al doped ZnO thin films were deposited on glass substrate by ultrasonic spray method. The thin films with concentration of 0.1 M were deposited at 350°C with 2 min of deposition time. The effects of ethanol and methanol solution before and after doping on the structural, optical and electrical properties were examined. The DRX analyses indicated that ZnO films have nanocrystalline nature and hexagonal wurtzite structure with (100) and (002) preferential orientation corresponding to ZnO films resulting from methanol and ethanol solution, respectively. The crystallinity of the thin films improved with methanol solution after doping to (002) oriented. All films exhibit an average optical transparency about 90%, in the visible range. The band gaps values of ZnO thin films are increased after doping from 3.10 to 3.26 eV and 3.27 to 3.30 eV upon Al doping obtained by ethanol and methanol solution, respectively. The electrical conductivity increase from 7.5 to 15.2 (Ωcm)⁻¹ of undoped to Al doped ZnO thin films prepared by using ethanol solution. However, for the methanol solution; the electrical conductivity of the film is stabilized after doping.

Introduction

Zinc oxide (ZnO) is a very interesting semiconducting material with a wide and direct band gap of 3.4 eV at room temperature and a high exciton binding energy of 60 meV [1], [2]. Transparent conducting oxides (TCO) are widely used in microelectronic devices, light emitting diodes, thin films, antireflection coatings, transparent electrodes in solar cells [3], [4], gas sensors surface acoustic wave devices [5], varistors, spintronic devices and lasers [6]. ZnO thin films can be produced by several techniques such as molecular beam epitaxy (MBE), chemical vapor deposition, electrochemical deposition [7], pulsed laser deposition (PLD), sol-gel process [8], reactive evaporation, magnetron sputtering technique and spray pyrolysis [9].

Although the ultrasonic spray method is especially efficient in producing thin films, transparent, multi-component oxide layers of many compositions on various substrates, including glass, there are still many factors affecting the physical properties of ZnO thin films. These factors include ZnO solution concentration, solvent, substrate temperature, post-annealing temperature, annealing atmosphere and film thickness [10], [11], [12], [13], [14]. Among these factors, the influence of solvent on structural and optical properties of ZnO thin films (Al doped ZnO thin films) derived from ultrasonic spray method was less studied.

Venkatachalam et al. [15] deposited Al-doped thin films on to glass and silicon (100) substrate by pulsed laser deposition method at different doping concentrations; followed by annealing at comparatively low temperature of 1000 °C. They observed with the increasing doping concentration, the optical band gap of Al-doped thin films increased, leading to decreasing of the particle size. Tomakin [16] demonstrated that the methanol solution was used to produce high-quality and dense Al-doped thin films and the crystallinity of the ZnO thin films is higher than that of the films prepared by using propanol solution.

In this work, the undoped and Al doped ZnO thin films were deposited on glass substrates by ultrasonic spray technique. The thin films with concentration of 0.1 M were deposited at 350 °C with 2 min of deposition time. We have studied the effects of ethanol and methanol solution and the Al doping on the structural, optical and electrical properties of ZnO thin films.

Section snippets

Preparation of spray solution

ZnO solution were prepared by dissolving (0.1 M) zinc acetate-dihydrate $\text{Zn}(\text{CH}_3\text{COO})_2 \cdot 2\text{H}_2\text{O}$ in the solvent containing equal volumes absolute ethanol [17] and methanol solution (99.995%) purity, then have added a drops of HCl solution as a stabilized, the mixture solution was stirred and heated at 50 °C for 2 h to yield a clear and transparency solution.

ZnO:Al solution were prepared by adding to the precedent solution a 0.03 M solution of aluminum chloride, 6-methoxyethanol, such that the ratio of Al/Zn...

Crystalline structure

The XRD patterns of undoped and Al doped ZnO thin films prepared by using ethanol and methanol solution are displayed in Fig. 1, Fig. 2, respectively. Four diffraction peaks were observed at $2\theta = 31.8^\circ$, 34.5° , 36.3° and 47.2° which can be attributed respectively to (100), (002), (101) and (102) planes of ZnO phase for undoped and Al doped ZnO thin films obtained by methanol solution. However, only (002) diffraction peak were obtained in the films prepared using ethanol solution. This result...

Conclusion

In conclusion, highly transparent conducting ZnO and Al doped ZnO thin films were deposited on glass substrate by Ultrasonic spray method. The thin films with concentration of 0.1 M were deposited at 350 °C with 2 min of deposition time. The effects of ethanol and methanol solution before and after doping on the structural, optical and electrical properties were investigated. From the DRX analyses indicated that ZnO films have nanocrystalline nature and hexagonal wurtzite structure with (100) and...

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2022, Materials Today: Proceedings

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...Intrinsic ZnO, however, is extremely resistive. gallium (Ga) Aluminium (Al) or indium (In) are the favoured dopants for develop the electrical behaviour of zinc oxide thin films, as their ionic radii is similar to that of zinc (Zn) [7–9]. Zn²⁺, Ga³⁺, Al³⁺ and In³⁺ ions have an ionic radii of 0.074 nm, 0.062, 0.054 and 0.080 nm respectively [10,11]...

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...In recent years, due to its excellent optical, electrical, and mechanical properties, ZnO itself and its doping have attracted more attention and have been used in various devices, such as ultraviolet sensors, gas sensors, transistors, solar cells, etc. [1–4]. Among the many doped materials, such as Mg, Al, Cu, and Mn materials [5–8], Al-doped ZnO (AZO) is considered to be one of the most promising materials due to its low synthesis cost, low electrical resistivity, non-toxicity, thermal and chemically stability, high transmittance in the visible light region, and many other competent properties [9–11]. The piezo-phototronic effect, which is a three-way coupling effect of piezoelectricity, semiconductor, and optical excitation in piezoelectric semiconductors, is confirmed as a promising methodology to optimize the performance of optoelectronic devices [12,13]...

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...ZnO has a variety of application in many fields like, optoelectronics, gas sensors and solar cells [2]. Up to now, several methods have been used to prepare ZnO thin films such as pulsed laser deposition [3], ultrasonic spray [4], electrochemical method [5] and co-precipitation method [6]. Among these methods, sol-gel method is widely used due to its advantages such as, low cost, large-scale production, low fabrication temperature, morphology and thickness controlling [7]....

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...In available literature, a maximum value of Seebeck coefficient ($-60 \mu\text{V}/\text{K}$ at 300 K) has been achieved by Tambasovet et al. [20] for Al-doped ZnO thin films deposited by atomic layer deposition (ALD) on glass substrate. Pure and doped-ZnO films have been deposited by different methods such as sputtering [21], CVD deposition [22], electro-deposition process [23], spray pyrolysis [24,25] and sol gel deposition [26,27]. The spray pyrolysis technique is one of attractive method to obtain a good quality thin films at a minimal cost....

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