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Preparation of transparent, conductive ZnO:Co and ZnO:In thin films by ultrasonic spray method

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Abstract

This paper examines the growth of undoped and doped thin films with (Co and In) on glass substrate at 350°C using ultrasonic spray technique. We have investigated the influence of doping concentrations ranging from 0 to 4 wt.% on structural, optical, and electrical properties of ZnO thin films. Zinc acetate dehydrate, $CoCl_3$ $4H_2O$ or $InCl_3$, ethanol, and monoethanolamine were used as a starting materials, dopant source, solvent, and stabilizer, respectively. The X-ray diffraction analysis indicated that the undoped and doped ZnO thin films have polycrystalline nature and hexagonal wurtzite structure with (002) preferential orientation. The maximum average crystallite sizes of ZnO:Co and ZnO:In were 55.46 and 45.78 nm at concentrations of 2 wt.% Co and 3 wt.% In, respectively, indicating that the crystallinity of doped films improved after doping. The optical absorption spectra showed that all undoped and doped ZnO films are transparent within the visible wavelength region. The band gap energy of ZnO:Co thin films increased after doping from 3.25 to 3.36 eV; however, the optical gap of ZnO:In decreases after doping from 3.25 to 3.18 eV, indicating the increase and decrease, respectively, in the transition tail width. The electrical conductivity of doped films is stabilized after doping. Transparent, conductive Co-doped ZnO thin films deposited by ultrasonic spray technique are of good quality.

Keywords: ZnO; Thin film; Semiconductor doping; Transparent conducting oxides; Ultrasonic spray

Background

Zinc oxide (ZnO), which is one of the most important binary II-VI semiconductor compounds, has a hexagonal wurtzite structure and a natural n-type electrical conductivity with a direct energy wide band gap of 3.37 eV at room temperature and a large exciton binding energy (approximately 60 meV) [1]. The resistivity values of ZnO films may be adjusted between 10^{-4} and 10^{-1} Ω cm by changing the annealing conditions and doping [2]. Transparent conducting oxides are widely used in microelectronic devices, light emitting diodes, thin films, antireflection coatings for transparent electrodes in solar cells [3,4], and gas sensors in surface acoustic wave devices [5], varistors, spintronic devices, and lasers [6].

ZnO thin films which can be produced by several techniques such as reactive evaporation, molecular beam epitaxy [7], magnetron sputtering technique, pulsed laser deposition [8], sol-gel technique, chemical vapor deposition, electrochemical deposition [9], and spray pyrolysis [10] have been reported. Among these, we will focus more particularly in this paper the spray ultrasonic technique that is a low-cost method suitable for large-scale production. It has several advantages in producing nanocrystalline thin films, such as relatively homogeneous composition, simple deposition on glass substrate because of the low substrate temperatures involved, easy control of film thickness, and fine and porous microstructure. It is possible to alter the mechanical, electrical, optical, and magnetic properties of ZnO nanostructures.

The doped ZnO thin films have various applications such as transparent conductors, in ferromagnetism, semiconductors, and in piezoelectric and solar cells; moreover, the films have low resistivity and good optical gap energy at low temperature and are transparent in the visible region. There are several reports on ZnO nanostructures doped with different elements, such as Al, Ga, Mg, Li, P, N, Ni, In, and Co [11-15]. ZnO:Co and ZnO:In films have been extensively studied because they exhibit high mobility, good optical transparency, and good electrical conductivity and have lower material cost.

In this paper, the CZO and IZO thin films were deposited on glass substrate by ultrasonic spray technique; at

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Competing interests
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