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A structural and optical properties of Cu-doped ZnO films prepared by spray pyrolysis

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Abstract
Pure and Cu doped ZnO films were grown by ultrasonic spray pyrolysis onto glass substrates at 450 °C for 30 min. This study aims to investigate the influence of Cu doping content [0.02–0.20] on structural, microstructural and optical properties. X-ray diffraction analysis reveals a structural disorder depending on Cu loading besides the appearance of CuO phase. The doping effectiveness is revealed by EDX analysis of the chemical composition of the films. The transmittance shows a decreasing tendency with increasing Cu concentration. The refractive indices increase, whereas the values of forbidden energy gap decrease with the increase in Cu dopant concentration.

Keywords Thin films · X-ray diffraction · Optical properties

1 Introduction

Zinc oxide semiconductor films have been very useful, particularly in the field of spintronics, because of their wide band gap ($E_g = 3.31$ eV), exciton band energy (60 meV) at room temperature [1] besides its significant transmittance value of 0.9 in the visible region. ZnO crystallizes within a wurtzite-type structure defined by a hexagonal lattice where Zn^{2+} ions occupy the tetrahedral sites formed by O^{2-} ions. Numerous researches have already fabricated ZnO films using various techniques, including spray pyrolysis [2], reactive magnetron sputtering [3, 4], chemical vapor deposition (CVD) [5], sol–gel [6] molecular beam epitaxy [7], and pulsed laser deposition [8, 9].

Recently, the doping of semiconductors by transition metals is of great importance, because of their unusual optical properties and promising potential for optoelectronic applications [10–13]. The doping of ZnO with metal ions has been found to influence its structure and particularly its physical properties such as particle size, dislocation density, bond length, strain deformation, etc.[14, 15].

Copper (Cu) element is of particular interest, thanks to its low toxicity and large abundance [9, 16]. The incorporation of Cu within ZnO host lattice has been found to enhance its physical and chemical properties, such as photocatalysis activity, gas sensitivity, magnetic susceptibility, optical and electrical properties [14, 17].

In this work, thin films of pure and Cu doped ZnO films are deposited by ultrasonic spray pyrolysis (USP) technique onto glass substrates ($30 \times 12 \times 1.2$ mm^3) at 450 °C for 30 min. The effects of the doping on structure, microstructure and optical properties are discussed.

2 Experimental part

2.1 Film preparation

In this study, the use of ultrasonic pyrolytic spray technique for the deposition of thin films of ZnO, $Zn_{1-x}Cu_xO$ [$x = 2$, 5, 10, 15 and 20 at%], offers various benefits, such as better homogeneity, low-power processing, easy-to-control stoichiometry, and large surface covering. Zinc acetate [$Zn(CH_3COO)_2{\cdot}2H_2O$)] (Fulka 99.9%) (0.01 M) and copper chloride ($CuCl_2{\cdot}2H_2O$) (2–20) (Cu, at%) as precursors are dissolved in 20 ml methanol (Merck 99.5%), 30 ml ethanol (Merck 99.5%). This mixture has been chosen for its easy

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