Materials Science in Semiconductor Processing 12 (2009) 212–216

Contents lists available at ScienceDirect

Materials Science in Semiconductor Processing

journal homepage: www.elsevier.com/locate/mssp

Structural, optical and electrical properties of $Mg_xZn_{1-x}O$ ternary alloy films

B.K. Sonawane, M.P. Bhole, D.S. Patil *

Department of Electronics, North Maharashtra University, Jalgaon, Maharashtra, India

A R T I C L E I N F O

Available online 6 December 2009

Keywords:
Sol–gel
$Mg_xZn_{1-x}O$
Optical properties
Electrical properties

A B S T R A C T

The structural, optical and electrical properties of $Mg_xZn_{1-x}O$ (x=0.05–0.3) ternary alloy thin films deposited by the sol–gel method on the glass substrate were investigated. The presence of Mg in deposited samples was confirmed through EDAX. XRD spectra revealed that the deposited Mg doped ZnO films were polycrystalline in nature. The optical band gap of the films was tailored between 3.2 and 3.45 eV by varying Mg mole concentration between 0.05 and 0.3. *I–V* characteristics showed decrease in current with increase in the Mg mole concentration. These results explore the applicability of MgZnO to form effective and efficient heterostructures with ZnO as an active layer for efficient carrier confinement in light emitting devices.

1. Introduction

There has been huge interest in wide band gap semiconductors for the commercialization of efficient and short wavelength light emitting devices. Now the most attention is focused on the zinc oxide due to its potential applications in optoelectronics technology such as laser diodes and light emitting diodes. It is a semiconductor material having wide band gap energy of 3.2 eV and excitonic binding energy of 60 meV [1]. It has wide range of technological applications such as transparent conducting [2] electrodes in solar cells and flat panel displays, surface acoustic wave devices and chemical sensors.

Several ultraviolet light emitting sources have been reported that utilizes the GaN [3,4] and ZnSe [5] material system. Recently, as an alternative to the GaN [6] material system, ZnO alloys are of substantial interest due to its ease of doping mechanism for the formation of ternary alloys. Moreover, alloying ZnO films with MgO potentially permits the band gap to be tailored. The critical challenges in fabricating ZnO laser diodes are p-type doping and band gap engineering in alloy semiconductors to create barrier layers and quantum wells which facilitate radiative recombination by carrier confinement. The addition of impurities among the wide band gap semiconductors often induces dramatic changes in their structural, optical and electrical properties. For example, ternary MgZnO alloy has an energy gap higher than that for ZnO to serve as cladding layer with ZnO active layer for light emission in ultraviolet range.

The heterojunction [7] constructed using ZnO/MgZnO realizes the double confinement actions for electrons and photons in optoelectronic devices. For this purpose, modulation of the band gap while keeping the lattice constants similar to each other is essential. Due to the very small difference in the ionic radius of Mg (0.57 Å) and Zn (0.6 Å) [8], it forms effective heterostructure of ZnO/MgZnO.

Various deposition techniques can be used to fabricate the ZnO/MgZnO films such as, pulsed laser deposition (PLD) [9,10], molecular beam epitaxy (MBE) [11], electron beam evaporation [12], metal organic chemical vapor deposition [13] and sol–gel method [14–21]. The sol–gel deposition technique has advantages over other methods

* Corresponding author. Tel.: +91 257 2257476;
fax: +91 257 2258403.
E-mail address: patildsp@rediffmail.com (D.S. Patil).

1369-8001/$ - see front matter © 2009 Elsevier Ltd. All rights reserved.
doi:10.1016/j.mssp.2009.11.002

that it does not require vacuum apparatus and has the potential to produce films with large areas on various substrates. In order to prepare thin films of compound semiconductors, the sol–gel process is known to have the distinct advantages of process simplicity, lower cost and ease of composition control [22].

Although there are many studies of $Mg_xZn_{1-x}O$ alloys and the heterostructures based on them, very little has been reported on the sol–gel deposition of MgZnO [17,20] ternary compound on the simple and the most economical glass substrate. Ghosh and Basak [17] has reported the preparation of $Mg_xZn_{1-x}O$ thin films on glass substrates by dip coating method using zinc acetate, magnesium chloride in isopropyl alcohol and diethyl-amine (DEA) for the investigation of structural properties and effect on the photocurrent by taking different Mg concentration. Rusop et al. [20] reported the study of $Mg_xZn_{1-x}O$ thin films using 2-methoxyethanol solutions of zinc acetate dihydrate and magnesium acetate dihydrate stabilized by monoethanolamine for the study of structural and optical properties. Particularly, they studied the effect of the variation of drying and annealing on the lattice constant of alloy films. However, the main goal of this paper is to investigate effect of Mg composition on the structural, optical and electrical properties.

We have tailored the band gap of MgZnO films for varying Mg mole concentration to satisfy the pertinent need of cladding layer to form effective heterostructure with ZnO active layer. The paper is organized in the four sections. Following section of the paper describes the experimental procedure used to deposit the MgZnO ternary alloy films. Section 3 discusses in details the effect of Mg mole concentration on various structural and optical properties of the MgZnO films. Finally, conclusions are highlighted.

2. Experimental procedure

Zinc acetate dihydrate $[Zn(CH_3COO)_2 \cdot 2H2O]$ and magnesium acetate $[Mg(CH_3COO)_2]$ were used as starting precursors. Ethanol $[C_2H_5OH]$ and lactic acid $[CH_3CHOH\text{-}COOH]$ were used as solvent and stabilizing reagent, respectively. The Mg and Zn precursors were dissolved in ethanol by stirring at $\sim$80 °C under reflux apparatus for an hour on magnetic stirrer with hot plate by taking 0.05, 0.1, 0.2 and 0.3 as mole concentrations of Mg. Initially, it was noted that the solution became milky white and then converted into the transparent solution. Prepared transparent solutions were used for the deposition of the films. The deposition of films was carried out on glass substrates at room temperature using homemade spin coater. Before deposition, the glass substrates were thoroughly cleaned by chromic acid, de-ionized water and acetone. The speed of the coater was kept at $\sim$2000 rpm for all the films. The coating procedure was repeated for six times to achieve the enough film thickness. After each coating, the films were pre-annealed at 200 °C for 10 min to evaporate the solvent. Finally, the deposited samples prepared for different Mg concentration were annealed at 400 °C for an hour to crystallize MgZnO. It was observed that all the deposited films were highly transparent in nature.

The structural properties of films were studied using Bruker D8 Advance X-ray diffractometer (XRD). The optical properties were investigated by Chemico spectra scan UV 2700 double beam spectrophotometer. The surface morphology and elemental composition were studied by using JEOL scanning electron microscopy (SEM). *I–V* characteristics was examined by KEITHLEY 4200 semiconductor characterization system equipped with SIGNATONE 1160 series probe station.

3. Results and discussion

The most significant results on structural, optical and electrical properties of MgZnO films deposited on glass substrate with varying Mg mole concentration have been discussed here. Figs. 1 and 2 shows the SEM and EDAX spectra of the deposited MgZnO film annealed at 400 °C for the 0.05 mole concentration. The SEM image was taken in the scale of 0.1 μm at 100,000 times the applied voltage magnification. The surface morphology of SEM picture clearly shows the grains of MgZnO on the surface of glass substrate. The surface of the film of the sol–gel deposited film was found to be smooth. The distribution of grains was spread almost equally all over the surface. The EDAX spectra recorded for the above film showed that the Mg has been incorporated in ZnO film successfully using sol–gel technique. The main peaks of Zn, O and Mg were present at 1.012, 0.525 and 1.253 keV energy, respectively. Very minor peaks of Zn were appeared between 8.00 and 10.00 keV. The other peaks of Pt and Si were attributed to the platinum coating applied for the SEM characterization and impurities of glass substrate respectively. The actual atomic % of Mg in the deposited films corresponding to different mole concentration was obtained through EDAX has been listed in Table 1.

Fig. 3 illustrates the XRD spectra recorded between the diffraction angles of 20–60° for the deposited films. Our results clearly showed the XRD peak positions of $Mg_xZn_{1-x}O$ films. The large hump obtained at 2θ value of

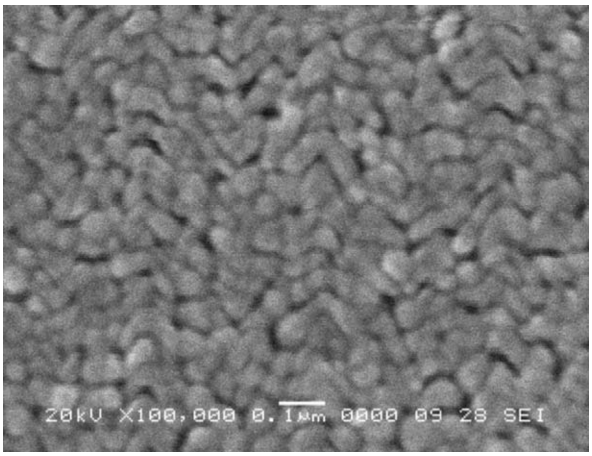

Fig. 1. SEM image of $Mg_xZn_{1-x}O$ film on the glass substrate.