Superlattices and Microstructures 77 (2015) 171–180

Contents lists available at ScienceDirect

Superlattices and Microstructures

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

# Dip coated nickel zinc oxide thin films: Structural, optical and magnetic investigations

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ARTICLE INFO

*Article history:*
Received 30 October 2014
Accepted 11 November 2014
Available online 26 November 2014

*Keywords:*
Band gap
Doping
Dip coating
Magnetic properties
Structural properties
Thin films

ABSTRACT

Dip-coating technique was used to deposit NiZnO thin films on glass substrates at varying withdrawal speed in the range of 150–350 mm/s and annealed at 500 °C for 4 h. X-ray diffraction (XRD) results showed that the deposited NiZnO thin films have a pure wurtzite structure without any significant change in the structure caused by substituting Zn ion with Ni ion. Crystallite size increased from 248 to 497 nm with increase in withdrawal speed. Vibrating Sample magnetometer (VSM) results indicated that NiZnO thin films exhibit ferromagnetic properties. Increase in saturation magnetization with increase in withdrawal speed is observed. Evaluated optical band gap of the films reduced from 3.18 eV to 2.50 eV with the increase in withdrawal speed of the substrate.



## 1. Introduction

ZnO has attracted remarkable interest due to its applications in optoelectronics. It has large band gap (3.37 eV), high exciton binding energy (60 meV) [1]. ZnO is inexpensive and environmentally safe. Diluted magnetic semiconductors (DMSs) have got attention of researcher due to their contribution in creating and operating spin-polarized currents [2]. Optically transparent ferromagnetic DMSs, synthesized by doping 3d transition metal ions (V, Mn, Fe, Co, or Ni) into wide band gap semiconductors, have attained considerable importance for integrated opto-spintronic applications [3,4]. Studies on

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http://dx.doi.org/10.1016/j.spmi.2014.11.011
0749-6036/

DMSs have been accelerated on by the need to fabricate storage device and spin electronics. Ni doped ZnO is regarded as an important II–VI diluted magnetic semiconductors (DMSs) due to its magnetic, electrical, optical and transport properties [5,6]. Certainly, there are reported results on the characteristics of Ni ZnO thin films deposited by different deposition methods such as pulsed laser deposition [7], spin coating [5,8], sputtering [9,10], sol–gel [11], auto-combustion method [12], electron beam evaporation [13], SILAR [14] but in the present study, an effort has been carried out to synthesize Ni ZnO thin films by sol–gel dip coating technique varying withdrawal speed of substrate from 150 mm/s to 350 mm/s. Such withdrawal speeds are novelty of this project. By increasing withdrawal speed band gap lowered from 3.18 to 2.50 eV. Such low band gaps are also novelty of this project. This technique is unique, low cost, effective and time saving.

## 2. Experimental details

Zinc acetate dihydrate and nickel acetate tetra hydrate were used as precursor materials. Ethanol, isopropanol and diethyl amine were used as solvents. One ml diethyl amine was added into the 30 ml isopropanol and then stirred at 80 °C for 1 h until a transparent solution is formed. Then 3.5 g zinc acetate di-hydrate was added into above solution and stirred at same temperature for one hour. Then it was left at room temperature for 2 days for stabilization and aging. The above sol was again stirred at temperature of 80 °C for half an hour and 4 g nickel acetate tetra hydrate was added into it and stirred for 4 h so that nickel acetate tetra hydrate was fully dissolved into sol. At last 30 ml ethanol is added into this mixed sol of zinc acetate dihydrate and nickel acetate tetra hydrate and stirred for one hour at temperature of 80 °C and left for one day at room temperature. After one day of aging NiZnO sol was properly stabilized for thin film deposition. Soda lime glass substrates were ultrasonically cleaned in acetone and isopropanol for 15 min. NiZnO thin films were deposited on glass substrate by means of TL 0.01 dip coater by varying withdrawal speed (150, 200, 250, 300 and 350 mm/s). The deposited films were dried in a wiseven oven at a temperature of 100 °C. In order to obtain homogenous, dense and smooth thin films, deposition process is repeated for 3 times. After three coats thin films were annealed in a furnace at temperature of 500 °C for 4 h for evaporation of organic solvent and purification. Theses thin films were characterized by various techniques such as Scanning Electron Microscope SEM (S-3400N, Hitachi), Fourier Transform Infrared FTIR (Model M 2000 Midac USA Resolution up to 0.5 $cm^{-1}$), X-ray Diffractometer XRD (Bruker XRD model D8 (Advanced Germany), Vibrating Sample magnetometer VSM (Lakeshore 7406) and UV–Visible Spectrophotometer (Hitachi U-2800 UV–VIS–NIR).

## 3. Results and discussion

This paper analyzes the deposition process of NiZnO thin films. These thin films were deposited by sol gel dip coating technique to study its structural, chemical, optical, magnetic and morphological properties. In this project change in withdrawal speed is fundamental factor to change the crystallite size, thickness and optical properties of thin films.

### *3.1. FTIR*

Fig. 1 shows FTIR spectrum of NiZnO thin films. The FTIR spectrum of NiZnO thin films were investigated in the range of 4000–400 $cm^{-1}$. In Fig. 1, first absorption band that is visible at 403 $cm^{-1}$ related to the stretching vibrations of Ni—O bond of nickel oxide [15]. The peak at 505 $cm^{-1}$ is due to ZnO [16]. The band which is recorded at 1110 $cm^{-1}$ corresponds to the stretching vibrations of C—O—C [17]. The absorption bands located at 1401 $cm^{-1}$ and 1642 $cm^{-1}$ is due to the stretching vibration of C—O and C═O groups respectively 1 [17].

### *3.2. Structural studies*

The XRD patterns of NiZnO thin films depositedat different withdrawal speed of substrate are shown in Fig. 2. Diffraction angle was adjusted from 20° to 80° with step width of 0.02°. These films