Fabrication and characterization of NiO/ZnO heterojunction thin film by sol-gel method

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ABSTRACT

The aim of this study was to fabricate the p-n heterojuction of zinc oxide (ZnO) and nickel oxide (NiO) thin film using sol-gel dip coating method. The structural property of thin film was characterized by the X-ray diffraction (XRD) and the surface morphology was examined by Field emission scanning electron microscopy (FE-SEM). The electrical property was investigated I-V characteristic measurement by Source Meter. The XRD results showed that the NiO/ZnO heterojunction thin film was polycrystalline while FESEM image of thin film showed smooth surface morphology and average grain size was about 50 nm. For electrical result, the current-voltage curve of thin film exhibited the diode characteristic with forward threshold voltage of 0.6 V.

Keywords: NiO/ZnO, heterojunction thin film, sol-gel, dip coating.

INTRODUCTION

Zinc oxide (ZnO) is a n-type semiconductor that has been widely used materials for optoelectronic application such as UV-light emitting diode (LEDs) (Chichibu, 2005), laser diodes (Singh, 2001) and ultraviolet photodetectors (Zhou, 2011) due to its unique properties such as wide band-gap (3.37 eV), large exciton binding energy (60 meV) at room temperature (Adler,1970). Recently, there are several reports on the growth n-type ZnO on p-type materials to form p-n heterojunction which has potential applications in nanoelectronic and materials science (Gupta, 2011, Zahedi, 2013 and Jlassi, 2014) Among the p-type semiconductor, NiO has been extensively investigated because of its excellent chemical stability and has wide band-gap energy range from 3.6 to 4.0 eV at room temperature (Cavas, 2012). In the present study, NiO/ZnO p–n heterojunctions thin film was fabricated on indium tin oxide (ITO) coated glass substrates by a sol–gel process. The structural, surface morphology and electrical properties of thin film were investigated.

MATERIALS AND METHOD

All chemicals were of analytical grade and they were used as received without further purification. The NiO/ZnO heterojunctions

thin film has been deposited on ITO coated glass by sol-gel dip coating process. Firstly, nickel acetate tetrahydrate ($C_4H_6NiO_4 \cdot 4H_2O$) was dissolved in 2-methoxyethanol solution and monoethanolamine (MEA) at room temperature. The concentration of Nickel acetate was 0.4 M and the molar ratio of MEA to Ni^{2+} was 1:1. The solution was continuously stirred at 80 ºC for 1 h until homogenous solution was obtained. For the deposition of thin film, the ITO coated glass substrate was dipped into the prepared sol and pulled up with constant rate of 4.0 cm min^{-1}. After each layer deposition, the coated film was dried at 100 °C in air for 10 min to remove organic solvent in the film and this procedure was repeated 4 times. The dried film was annealed in air at 300 °C for 1 h to obtained NiO thin film.

The next step, ZnO thin film was deposited on the layer of NiO thin film by the sol-gel process with using zinc acetate dehydrate ($C_4H_6O_4Zn \cdot 2H_2O$) as a Zn source. The concentration of Zinc acetate was 0.7 M and the molar ratio of MEA to Zn^{2+} was 1:1. The process of ZnO thin film preparation was the same as the process using for the NiO thin film. After ZnO depositon, the sample was annealed in air at 530 °C for 1 h to obtain the NiO/ZnO thin film.

The structural properties of thin films were carried out by X-ray diffractometer (XRD, Bruker D8 ADVANCE) with CuKα radiation as X-ray source and measured in a low angle mode. The surface morphology and cross-section of thin film was examined by using the Field-Emission Scanning Electron Microscope (FE-SEM, Hitachi, S-4700). The current–voltage measurements at room temperature were performed by a Keithley Current-Voltage Source meter with used silver electrode to form ohmic contact for NiO/ZnO heterojunctions thin film.

RESULTS AND DISCUSSION

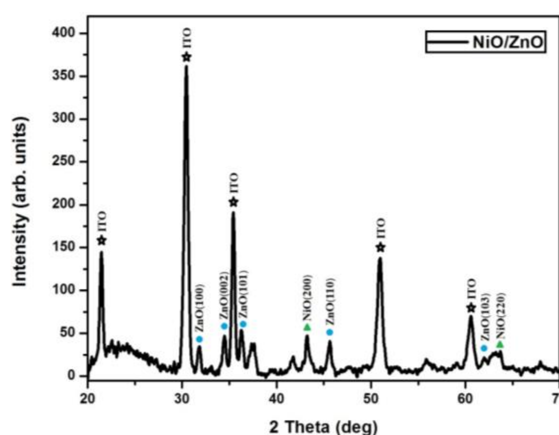

Fig. 1 XRD patterns of NiO/ZnO heterojunction thin film

The grazing angle X-ray diffraction patterns of NiO/ZnO heterojunctions thin film are shown in Fig. 1. It was found that all samples showed the diffraction peaks matched the standard diffraction pattern of a hexagonal wurtzite ZnO structure (JCPDS card file no. 36-1451) and NiO cubic structure phase (JCPDS no. 01-1239). This indicated that ZnO and NiO thin films were polycrystalline structure. The average grain size (D) has been calculated using Scherrer formula (B. D. Cullity, 2001);

$$D = \frac{0.9\lambda}{\beta \cos\theta} \quad (1)$$

where λ, θ, and β are the X-ray wavelength (1.5406 Å), Bragg diffraction angle, and full width at half maximum of diffraction peak, respectively. The crystallite size obtained was 22 nm. and 21 nm. for ZnO and NiO respectively.

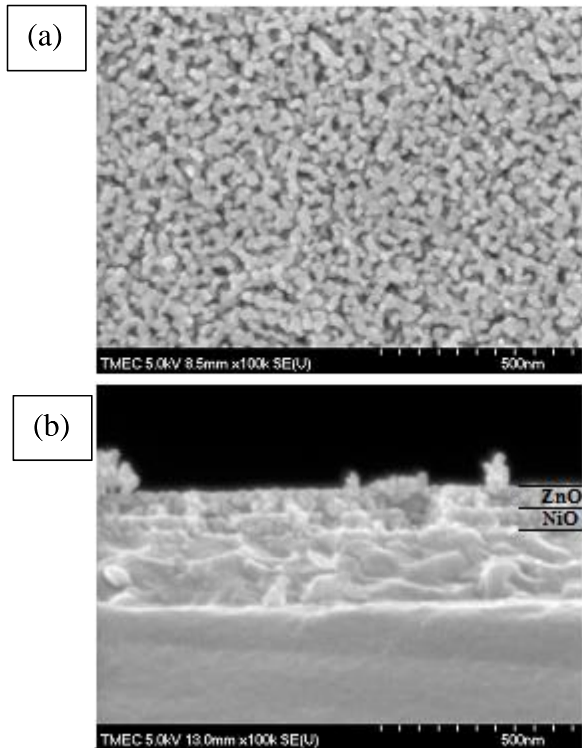

Fig. 2 FESEM images of NiO/ZnO heterojunction thin film (a) surface morphology (b) cross section morphology

Fig. 2 shows the FESEM photographs of the surface (a) and cross-section (b) morphologies of NiO/ZnO heterojunctions thin film. It was observed that the surface morphologies of ZnO thin film coated on NiO thin film annealed at 530 °C had very fine microstructure with average grain size of about 50 nm. Cross-section FESEM images revealed the thicknesses of NiO and ZnO thin films about 60 and 55 nm, respectively.

Fig. 3 shows the results of the current-voltage (I-V) measurements at room temperature for NiO/ZnO heterojunction thin film. It was observed that the I–V curve rectifying behavior with threshold voltage 0.6 V. The maximum forward to reverse current ratio was about 50 at 1.0 V. These results were confirmed the formation of the p-n heterojunction at the interface of ZnO and NiO layers.

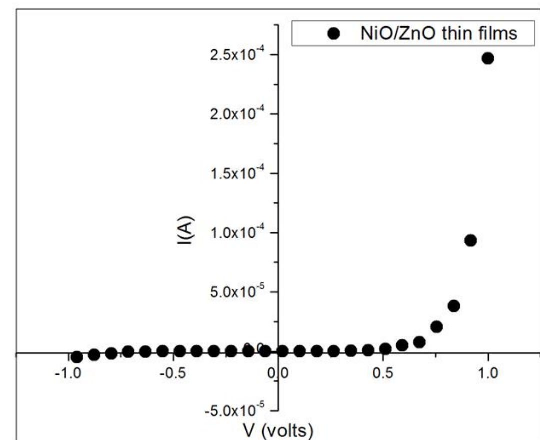

Fig. 3 Current–voltage characteristics of NiO/ZnO heterojunction thin film

CONCLUSION

In this work, NiO/ZnO heterojunction thin films have been successfully deposited on ITO substrate by sol–gel dip coating method. The structural, morphological and electrical properties of NiO/ZnO thin films were investigated. The XRD and FESEM results indicated that NiO/ZnO thin film was polycrystaline and average grain size in nano range. The current-voltage characteristics of NiO/ZnO heterojunction exhibited the diode behavior with maximum forward to reverse current ratio about 50 at 1.0 V

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