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Influence of Sb dopant on physical and electrical properties of Co-precipitated ZnO nanoparticles

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Abstract

In this work, the facile synthesis of Sb-doped ZnO nanoparticles by co-precipitation process was conducted employing zinc nitrate ($Zn(NO_3)_3$) and antimony chloride ($SbCl_3$) as starting precursors for Zn and Sb source, respectively. After precipitation, the intermediate powders with varied of Sb-doping concentrations (0-10%) were calcined at 500 ˚C for 2 hours. Their crystallinity and morphological properties were performed by X-ray diffraction (XRD) and scanning electron microscope (SEM), respectively. The XRD results exhibited decrease crystallinity with increasing of Sb doping content. Regarding electrical properties, it can be suggested that Sb dopant plays a significant role on relevant electrical properties including electrical conductivity.

Keywords: Sb doped ZnO, Nanoparticles, Co-precipitation process

1. Introduction

In recent decades, ZnO-based nanostructured materials has recently become one of the most useful nanomaterials being utilized in various practical applications including gas sensors, biosensors, photovoltaic and optoelectronics devices. Moreover, it can be modified to meet the practical requirement for specific application because of their excellent and exceptional mechanical, optical and electrical properties. In general, undoped ZnO is n-type semiconductor material with wide band gap (E_g) ~ 3.2-3.4 eV at 300 K and a large exciting binding energy (~60 meV) [1]. ZnO material can be obtained by various growth techniques such as hydrothermal [2], co-precipitation [3] and sol-gel method [4]. Co–precipitation method is one of the important techniques for synthesis nanoparticles because of low cost, ease of equipment set-up and uncomplicated processing. Moreover, p-type ZnO is still in focus for applied in widely use. It has been reported that p-type ZnO can be achieved by doping technique with either metal or non-metal elements such as Ag, P and N. However, Sb is one of the most proper elements widely used as a dopant for ZnO because it may produce more stable p-type conductivity and higher hole concentrations. Furthermore, Sb-doped ZnO has been usually reported to be a useful material for a variety of technological applications [5]. In this work, the facile synthesis of Sb-doped ZnO nanoparticles grown by co-precipitation process. The obtained nanoparticles were verified by X-ray diffraction (XRD), field emission scanning electron microscopy (FE-SEM) and electrical conductivity.

2. Experimental details

The Sb doped ZnO nanoparticles with varied Sb-doping contents at 0%, 1%, 3%, 5%, 7% and 10% were prepared via co-precipitation method. Firstly, Zinc nitrate hexahydrate

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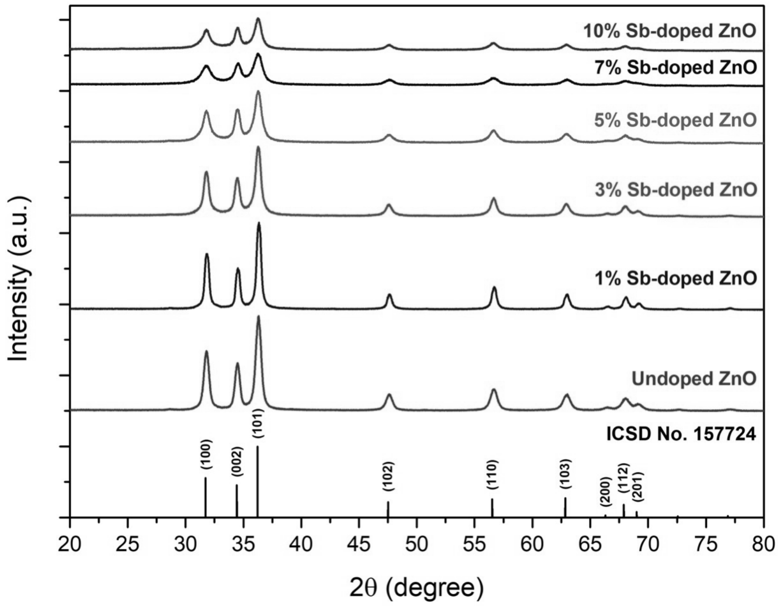

Fig. 1. XRD patterns of Sb doped ZnO nanoparticles with different 0-10 % of Sb doping.

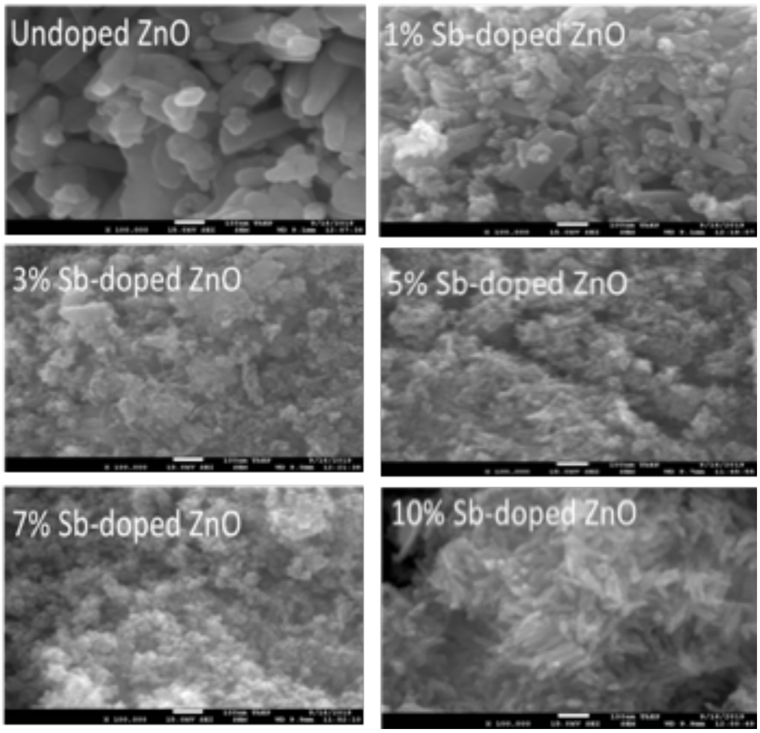

Fig. 2. FE-SEM micrograph of Sb doped ZnO nanoparticles with different 0-10 % of Sb doping.

($(Zn(NO_3)_2 \cdot 6H_2O)$ and antimony chloride ($SbCl_3$) were dissolved by mixing absolute alcohol and deionized water for preparation starting solution. After that, the prepared solutions were mixed together under continued stirring at room temperature. The pH value of mixed solution was adjusted by dropwise of NH_3 until the solution to be neutral. Finally, all as-prepared particles were calcined for 2 hours at 500 ˚C. The characteristic of Sb doped ZnO nanoparticles were investigated by several techniques. The crystal structures and morphologies of all samples were observed by XRD (Bruker D8 discover diffractometer) and FE-SEM (Hitachi S-4700), respectively. The sheet resistance analysis of Sb-doped ZnO nanoparticles was investigated by four-point probe. The obtained nanoparticles were coated on glass slide. After that, the four-position configuration to the center of each sample was measured.

3. Results and discussion

The XRD patterns of undoped ZnO and Sb doped ZnO nanoparticles with varied concentration of antimony dopant are shown in Fig. 1. As seen in XRD patterns, undoped and Sb-doped ZnO nanoparticles exhibit main peaks which are corresponding to the hexagonal wurtzite structure of ZnO ($2\theta = 31.77^{o}$ (100), 34.42^{o} (002) and 36.25^{o} (101) (JCPDS card No. 80-0075)) [6]. In addition, peak intensity of all diffraction peaks were significantly decreased which is clearly observed in deterioration of crystallinity quality with increasing Sb doping content. Figure 2 illustrates surface morphologies of undoped and Sb doped ZnO nanoparticles with different concentration of Sb dopant which were annealed at 500 °C. It is clearly that the increasing of Sb dopant concentration affected to grain size and density of particles which according to the XRD results. During of crystallization process of Sb-doped ZnO nanoparticles, the Sb atoms may generate intermediate product of Zn and Sb assisting which is the formation of Sb-doped ZnO nanoparticles and leading to the deterioration of crystallization quality with increasing doping content. The diameter sizes of undoped and Sb doped ZnO nanoparticles with different dopant concentration were varied in 30-100 nm. The existence of relevant elements in Sb doped ZnO was measured by EDS which is shown in Fig. 3. The inset table in the figure shows the contents of existing elements in the obtained nanoparticles.

The variation of sheet resistance of the undoped ZnO and Sb doped ZnO nanoparticles with different dopant concentration were exhibited in Figure 4. The sheet resistance of the undoped ZnO, 1% Sb doped ZnO 3% Sb doped ZnO and 5% Sb doped ZnO are approximately 1 k ohm/sq, 37 k ohm/sq, 183 k ohm/sq and 560 k ohm/sq, respectively. The high sheet resistance of the Sb doped ZnO nanoparticles with different concentration of Antimony indicated that the decreasing of the electron concentration. The increase in the sheet resistance of the Sb doped ZnO structure because the structural disorder and some scattering centers induced by the Sb doping into ZnO structure.

4. Conclusion

The In summary, the different Sb doping content are critical parameters for the growth of undoped ZnO and Sb doped ZnO nanoparticles prepared by co-precipitation process. The XRD patterns of all samples exhibit three strong peaks corresponding to the hexagonal wurtzite structure of ZnO. The size of undoped ZnO and Sb doped ZnO nanoparticles with different concentration of Antimony could be modified with diameter range of 30-100 nm. XRD, FE-SEM and sheet resistance results acknowledged that the Sb doping into ZnO

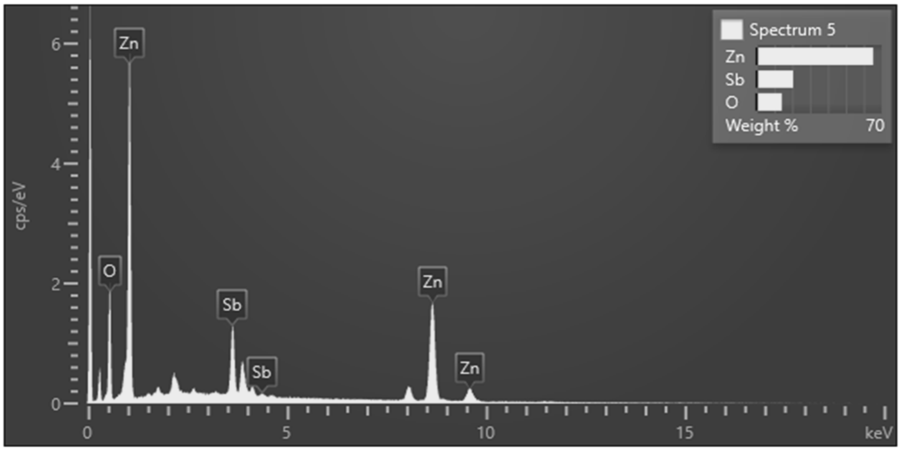

Fig. 3. EDS spectra of Sb doped ZnO nanoparticles.

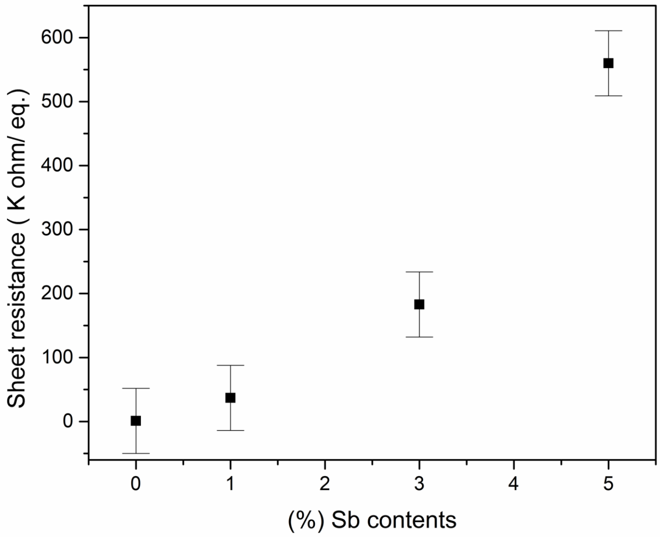

Fig. 4. Variation of sheet resistance with Sb doping content in ZnO nanoparticles.

structures had significant effect on the morphology, crystallization and electrical properties of Sb doped ZnO nanoparticles.

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