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Effect of annealing temperature on the crystallography, particle size and thermopower of bulk ZnO

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ABSTRACT

The precursor of nanopowder ZnO was synthesized by direct precipitation method and compacted to bulk samples. The bulk ZnO was annealed by furnace at temperature range of 400–650 °C in air for 30 min. The crystallography of precursor and bulk powder of ZnO was analyzed by the X-ray diffraction (XRD) and scanning electron microscopy (SEM) and obtained the hexagonal crystal structure, mean lattice parameters of $a = b = 3.2478$ Å and $c = 5.2037$ Å and unit cell volume of 47.53 Å^3. The particle size was investigated by SEM and evaluated by XRD results about 76.28 nm and bulk density of 3494.14 kg m^{-3}. The thermopower was measured by steady state method and obtained highest value of −92.99 μV K^{-1} at room temperature for annealing temperature of 550 °C.

1. Introduction

Zinc oxide materials are very interesting and have been developed in recent years because of their physical and chemical properties, which promote an achievement of high performance materials for various applications. Recently, many studies have been made in order to understand the microstructure, electrical properties and thermoelectric properties of ZnO for application. For examples, the applications of ZnO include varistor ceramics [1], luminescent materials [2], new coplanar gas sensor array [3], application of sunscreen nanoparticles [4] and, finally, impure ZnO materials are of great interest for high temperature thermoelectric application [5]. However, the properties of bulk and nanoparticles ZnO are dependent on temperature condition.

In this work, we propose an analysis of annealing temperature dependence on lattice parameters, crystal structure, orientation, texture coefficient, bond length of Zn–Zn, Zn–O and O–O, powder distribution, particles size and thermopower of bulk ZnO.

2. Material and methods

The precursor of nanopowder ZnO was synthesized by direct precipitation method using $Zn(NO_3)_2 \cdot 6H_2O$ (QRëC™, 98.5% purity), $(NH_4)_2CO_3$ (QRëC™, 99.5% purity), ethanol, and de-ionized water. $Zn(NO_3)_2 \cdot 6H_2O$ and $(NH_4)_2CO_3$ were dissolved in de-ionized water by the vigorously stirring to form solutions with 1.5 and 2.25 mol/L concentrations, respectively. The precipitates obtained by the reaction between the $Zn(NO_3)_2$ and the $(NH_4)_2CO_3$ solutions were collected by filtration and rinsed three times with de-ionized water and ethanol, respectively, then washed and dried at 80 °C to form the precursor of nanopowder ZnO as shown in Fig. 1(a). The precursor powder was investigated by the relationship between the weight loss and temperature by using thermal gravimetric analysis (TGA–DTA/DSC; NETZSCH STA 449C) to scan the annealing temperature. The nanopowder ZnO was pressured by the hydraulic press about 160 MPa to obtain the bulk ZnO as shown in Fig. 1(b). The bulk ZnO was annealed by furnace at temperature range of 400–650 °C in air for 30 min. The crystallography of nano precursor powder and bulk powder was measured by X-ray diffractometer (XRD; PW1710) with a Cu-Kα1 ($\lambda = 0.15406$ nm)

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