

EFFECT OF CO DOPANT ON THERMAL CONDUCTIVITY OF ZnO

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Abstract

The ZnO doped with Co under different conditions. $\text{Zn}_{0.9}\text{Co}_{0.1}\text{O}$ and $\text{Zn}_{0.8}\text{Co}_{0.2}\text{O}$ were synthesized from ZnO and Co_3O_4 by solid state reaction (SSR) method. The powder precursor were mixed by ball milling in deionized water for 2 h, calcined at 1073 K, pressed into pellet at 6.86 MPa, and sintered at 1423 K for 5 h. The XRD patterns of all samples corresponded with PDF#00-061-0685 which indicating a hexagonal structure. The SEM images shows grain size of materials arrangement changed after sintering from 1 μm to 20 μm . It was found that, thermal conductivity of ZnO decrease when doped Co (0.1, 0.2), it interesting for study thermoelectric properties.

Keywords: Thermal conductivity, zinc cobalt oxide, thermoelectric material

Introduction

ZnO have been receiving significant attention in recent years because is materials improved thermal, electrical, and mechanical properties and the powder has smaller resolution at the

nanometer scale due to the properties of ZnO (Olorunyolemi *et al.*, 2002). Its high thermal and mechanical stability at room temperature make it attractive for potential use in electronics,

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and laser technology (XU *et al.*, 2010). The $\text{Zn}_{1-x}\text{Co}_x\text{O}$ bulk ceramics have been also prepared through a solid state reaction method (Seo *et al.*, 2012 and Arda *et al.*, 2014) and $\text{Zn}_{1-x}\text{Co}_x\text{O}$ polycrystalline nanoparticles with different ($x = 0.03, 0.05, 0.1, 0.15, 0.2, 0.25$, and 0.3) com-positions were synthesized using the sol-gel technique (Seo *et al.*, 2012), and $\text{Zn}_{1-x}\text{Co}_x\text{O}$ ($x = 0.01, 0.05$ and 0.1) bulk ceramics were prepared through a two-step, solid state reaction method combined with spark plasma sintering technique (Maensiri *et al.*, 2006). In spite of the recent rapid developments, controlling the electrical conductivity of ZnO has remained a major challenge. While a number of research groups have reported achieving n-type ZnO, there are still problems concerning the electrical resistivity of the n-type conductivity (Kolodziejczak-Radzimska and Jesionowski, 2014).

In this work, we report attempted to decrease the thermal conductivity of $\text{Zn}_{1-x}\text{Co}_x\text{O}$ bulk ceramics prepared by solid state reaction method.

Experimental Details

$\text{Zn}_{1-x}\text{Co}_x\text{O}$ was synthesized solid state reaction (SSR) method. The powders precursor in the experiments used zinc oxide powder (ZnO) and Cobalt oxide powder (Co_3O_4). The powder precursor were mixed by ball milling in deionized water for 2 h, calcined at 1073 K,

pressed into pellet at 6.86 MPa, and sintered at 1423 K for 5 h. Crystal structure characterized by ZnO and $\text{Zn}_{1-x}\text{Co}_x\text{O}$ ($x = 0.1, 0.2$) was analyzed by X-ray diffraction from 20° to 80° (2θ) with $\text{CuK}\alpha$ radiation utilizing a Shimadzu diffract meter XRD-6100 at room temperature. The microstructure was obtained from scanning electron microscopy, JSM-6301F (JEOL). Thermal conductivity was measured by steady state technique as shown in the Figure 1 and follow with Equation 1 (Nolas *et al.*, 2001)

$$\kappa = \frac{dQ}{dt} \frac{l}{A(T_2 - T_1)} \quad (1)$$

when l is the distance between the T_1 and T_2
 A is cross-sectional area of the specimen
 T is temperature

Results and Discussion

The X-ray diffraction results at room temperature of solid state reaction (SSR) method samples are shown in Figure 2. All the sintered samples at 1423 for 5 h contain mainly the ZnO phase. No cobalt oxide was detected in the sintered samples. The X-ray diffraction patterns were indicated with PDF #00-036-1451 and indicate a hexagonal structure with high intensity in (hkl) of (101).

The SEM images in Figures 3-5 show the microstructure of the ZnO, $\text{Zn}_{0.9}\text{Co}_{0.1}\text{O}$ and

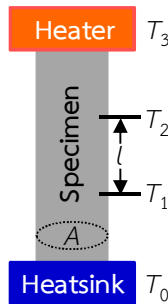


Figure 1. Thermal conductivity measurements with steady state method

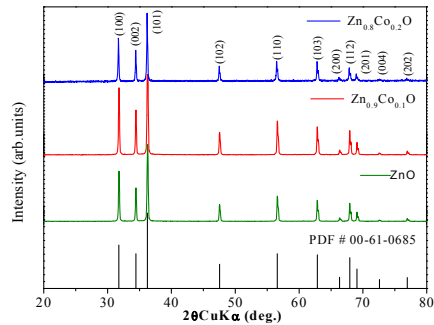


Figure 2. X-ray diffraction pattern of ZnO and $\text{Zn}_{1-x}\text{Co}_x\text{O}$ ($x = 0.1, 0.2$) sintered at 1423 for 5 h

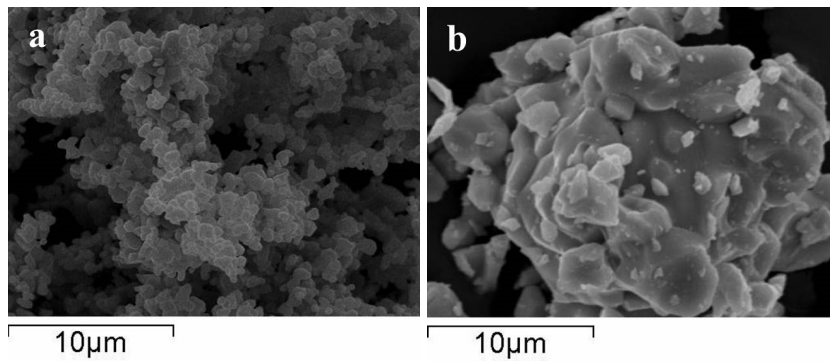


Figure 3. SEM image of ZnO, (a) calcined at 1073 K for 5 h and (b) sintered at 1423 K for 5 h

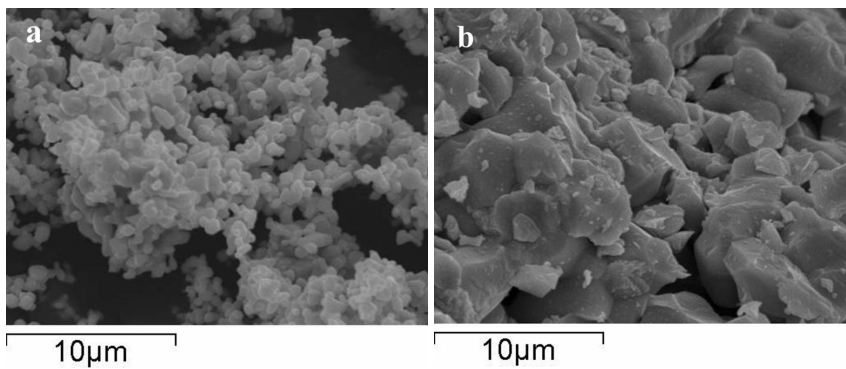


Figure 4. SEM image of $\text{Zn}_{0.9}\text{Co}_{0.1}\text{O}$, (a) calcined at 1073 K for 5 h and (b) sintered at 1423 K for 5 h

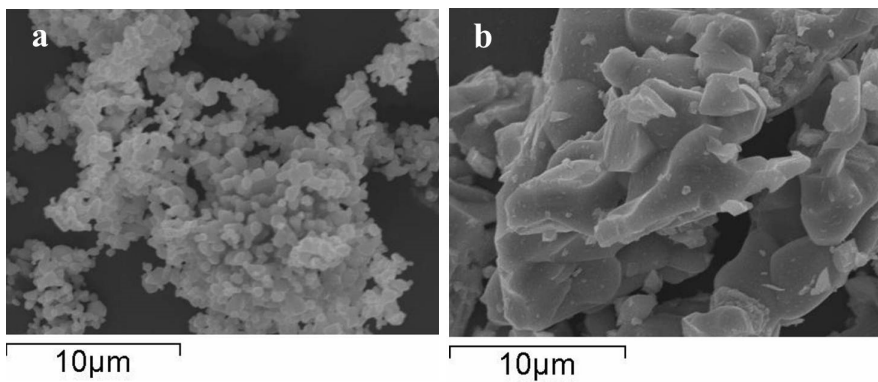


Figure 5. SEM image of $\text{Zn}_{0.8}\text{Co}_{0.2}\text{O}$, (a) calcined at 1073 K for 5 h and (b) sintered at 1423 K for 5 h

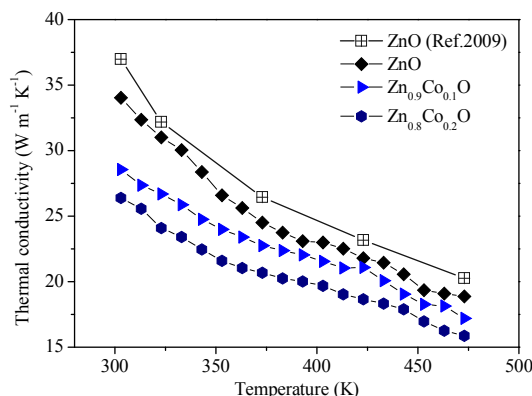


Figure 6. Temperature dependence of Thermal conductivity for ZnO and $\text{Zn}_{1-x}\text{Co}_x\text{O}$ ($x = 0.1, 0.2$) sintered at 1423 for 5 h measured in temperature range of 303 K - 473 K

$\text{Zn}_{0.8}\text{Co}_{0.2}\text{O}$ calcined and sintered samples. The Powder which was obtained through the solid state reaction, calcined at 1073 K for 5 h, and sintered at 1423 K for 5 h ambient in atmosphere.

The thermal conductivity as a function of temperature and Co substitution value as shown in Figure 6 shows decreased the thermal conductivity of ZnO with increased Co. Because the ZnO substituted by Co 0.1, 0.2 do too decrease phonon scattering in ZnO and increased the by temperature. The thermal conductivity of ZnO, $\text{Zn}_{0.9}\text{Co}_{0.1}\text{O}$ and $\text{Zn}_{0.8}\text{Co}_{0.2}\text{O}$ were $18.86 \text{ W m}^{-1} \text{K}^{-1}$, $17.20 \text{ W m}^{-1} \text{K}^{-1}$ and $15.87 \text{ W m}^{-1} \text{K}^{-1}$ respectively. Increasing the temperature steadily reduces the thermal conductivity as observed the doped ZnO samples. So, the phonon behavior has effect on thermal conductivity.

Conclusions

$\text{Zn}_{1-x}\text{Co}_x\text{O}$ ($x = 0.1, 0.2$) was prepared by solid state reaction (SSR) method. Results obtained shows phase X-ray diffraction patterns with match PDF#00-061-0685 indicate a hexagonal structure. The SEM images show the microstructure of the ZnO, $\text{Zn}_{0.9}\text{Co}_{0.1}\text{O}$ and $\text{Zn}_{0.8}\text{Co}_{0.2}\text{O}$ samples has an average grain size

of $\sim 1\text{-}20 \text{ }\mu\text{m}$. The thermal conductivity of ZnO, $\text{Zn}_{0.9}\text{Co}_{0.1}\text{O}$ and $\text{Zn}_{0.8}\text{Co}_{0.2}\text{O}$ were $18.86 \text{ W m}^{-1} \text{K}^{-1}$, $17.20 \text{ W m}^{-1} \text{K}^{-1}$ and $15.87 \text{ W m}^{-1} \text{K}^{-1}$ respectively. Increasing the temperature steadily reduces the thermal conductivity as observed the doped ZnO samples. So, the phonon behavior has effect on thermal conductivity.

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