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Synthesize and Characterization of the Thermoelectric Properties of Zinc Oxide

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A B S T R A C T

Zinc Oxide (ZnO) nanoparticles are synthesized via the sol-gel method. The functional groups, crystal structure and surface morphologies of the ZnO nanoparticles are investigated by Fourier transform infrared spectroscopy (FTIR), X–ray powder diffraction and scanning electron microscopy (SEM) respectively. The thermoelectrical properties were also analyzed. From SEM observations, spherical particles are noticed for nanoparticles. As the temperature increases from 30°C to 90°C, the electrical conductivity of the nanoparticles increases from 3.36 to 20.96 mS/cm and the thermal conductivity decreases from 1.031 to 0.669 $Wm^{-1}K^{-1}$. Here, as the annealing of zinc oxide increases, the thermoelectric properties of the nanoparticles improve.

Keywords: Nanoparticles; Zinc Oxide; Sol-gel; Thermal Conductivity; Electrical Conductivity;

1. Introduction

Thermoelectric (TE) materials have received a lot of attention recently due to their potential usage in the electricity generation refrigeration, and thermal sensing. Low temperature variations, albeit frequently available in the environment (such as from solar and geothermal energy) or produced from various power generating or consuming systems, are insufficient for the production of electricity using conventional systems. Traditional inorganic semiconductors with excellent thermoelectric characteristics, such as Bi_2Te_3, PbTe, SiGe, $CoSb_3$, and SnSe, have garnered the most interest. However, the expensive price and challenging processing prevent these inorganic thermoelectric materials from being used widely. Due to their inherent low thermal conductivity, light weight, low processing cost, and mechanical flexibility, nanoparticles are viewed as suitable replacements. ZnO is a conductive oxide that has a well-known broad forbidden bandgap of 3.5 eV. In several chemical and physics-related domains, including as the design of solar cells and Nano generators, the electrical characteristics of ZnO have attracted significant study interest. Due to their low toxicity, excellent thermal stability, and high electrical conductivity, ZnO-based ceramics have attracted attention as high-temperature (1273 K) TE materials ever since Ohtaki and Tsubota first reported on their groundbreaking TE properties. In recent times, metal oxide nanoparticles have been identified as important and novel applications in the thermoelectric field. A good thermoelectric material has high electrical conductivity and low thermal conductivity. In this study, ZnO nanoparticles were fabricated by sol – gel method at room temperature and the nanoparticles were characterized by conventional technologies. The thermal conductivity and electrical conductivity also characterized.

2. Experimental Procedure

2.1. Materials Used

Zinc Acetate Dihydrate ($Zn(CH_3COO)_2.2H_2O$) ⩾99% purity (HmbG Chemicals), Sodium hydroxide (NaOH) ⩾98% (Sigma Aldrich), Ethanol (CH_2COOH) HmbG Chemicals) and distilled water. All reagents were analytical grade and directly used without further purification.

2.2. Synthesis of Zinc Oxide Nanoparticles

Zinc acetate dehydrate (5.2g) was dissolved in distilled water. Sodium hydroxide (6.4g) was dissolved in distilled water. Sodium hydroxide solution is added drop wise to the zinc acetate solution. This mixture is stirred for two hours. The Solution is allowed to rest in for one hour till the white precipitate forms. Finally, the collected precipitate was filtered using whatman filter sheet by ethanol. Then the filtered precipitated is transferred to a petri dish and dried at 60°C. After that the product was grained and took the characterizations.

3. Results

3.1 Fourier Transform Infra-Red Spectroscopy

The FTIR is the best tool to analyse the functional groups of nanocomposites and it has been recorded at the region of 4000-400cm^{-1}. Figure 1 displays the FTIR of the zinc oxide nanoparticles. The primary mode of vibration at 3387 cm^{-1} is brought on by the OH stretching and deformation. The peak 2881 cm^{-1}, which represents the stretching vibration of C=H. An asymmetric stretching vibration of C=O has a peak at 1292 cm^{-1}. The stretching vibration of C=O with a peak at 1670 cm^{-1}. The bond 1112 cm^{-1} represents the vibration of the molecule C-O stretching. The observed peak 412 cm^{-1} confirmed the stretching vibrations of zinc oxide nanoparticles.

3.2 Scanning Electron Microscopy

The SEM image of zinc oxide is shown in Figure 2. Here, a degree of agglomeration is clearly visible in zinc oxide nanoparticles. The observation of some nanoparticles in SEM image is attributed to agglomeration. The figure showed the particle size ranging from 95nm. The SEM image of zinc oxide nanoparticles confirmed, it consist of mono dispersed and spherical shaped nanoparticles.

3.3 X-Ray Diffraction

Zinc oxide is represented by the red colored line in the Figure 3. An X-ray structural investigation reveals the emergence of a crystalline phase. The zinc oxide was annealed at 400°C. The major XRD peak is observed at $2\theta = 33.14°$ while the secondary major peaks are recorded at 32.54° and 36.32°. These peaks corresponds the zinc oxide. The hexagonal wurtzite structure could be identified by the XRD patterns of ZnO nanoparticles.

3.4 Electrical Conductivity

Electrical conductivity is the main measurement to analyse the thermoelectrical properties. The electrical conductivity of the nanocomposites was measured as the temperature increased from 30°C to 90°C. ZnO nanoparticles are shown in Figure 4. Zinc oxide gives 20.96 mS/cm electrical conductivity. Here, we increase the temperature, the kinetic energy of the ions increases and they move faster. So when the temperature increases then the electrical conductivity increases.

3.5 Thermal Conductivity

Thermal conductivity is a crucial parameter to understand when analysing the thermoelectric properties of nanocomposites. Thermal conductivity was measured at temperatures ranging from 30°C to 90°C. The thermal conductivity of polyaniline and zinc oxide nanoparticles are shown in Figure 5. Zinc oxide gives thermal conductivities of 1.031 Wm^{-1}K^{-1} at 30°C. At 90°C, it has thermal conductivitiy of 0.669 Wm^{-1}K^{-1}, which decrease with rising temperature. The thermal conductivity of the samples decreases as the temperature increases.

4. Figures

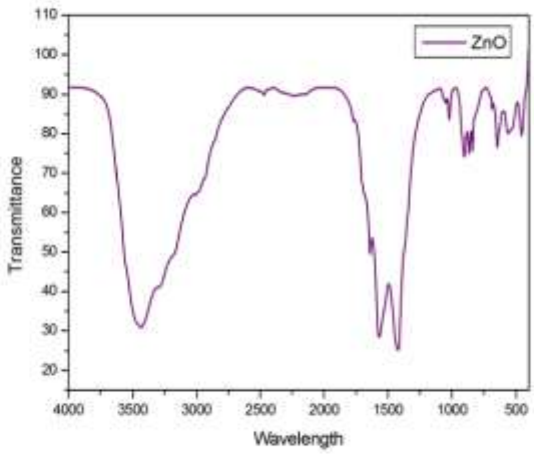

Fig. 1 - Fourier Transform Infra-Red Spectroscopy image of ZnO

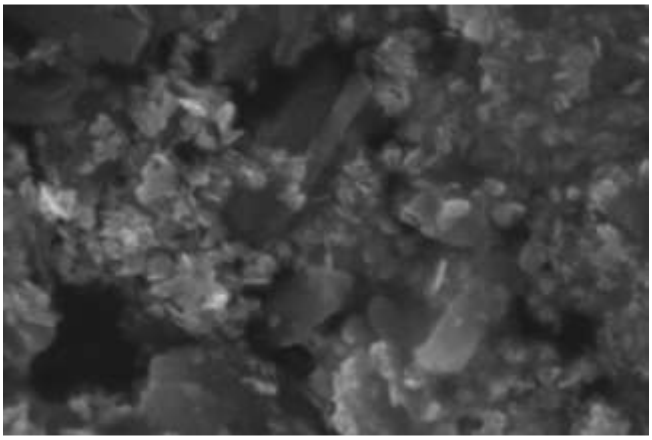

Fig. 2 - Scanning Electron Microscopy image of ZnO

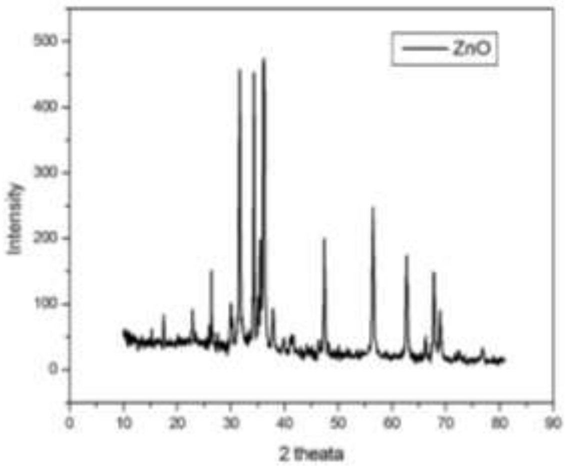

Fig. 3 - X-Ray Diffraction image of ZnO

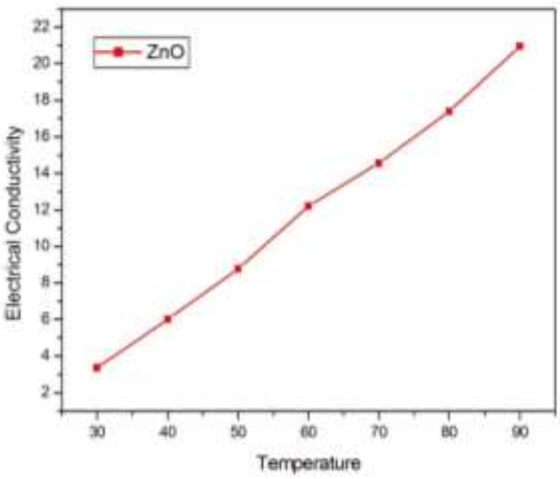

Fig. 4 - Electrical conductivity image of ZnO

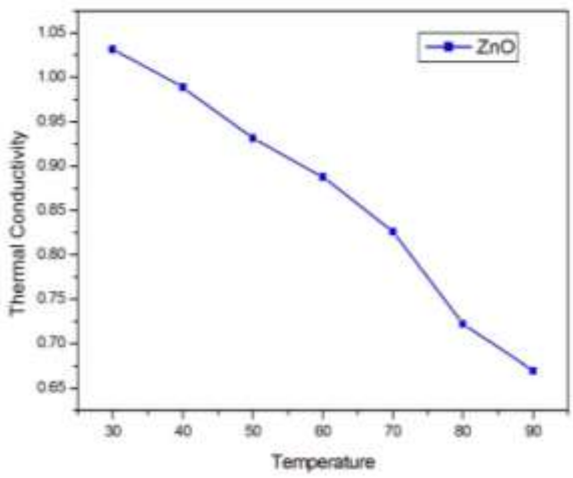

Fig. 5 - Thermal Conductivity image of ZnO.

5. Conclusion

Zinc oxide nanoparticles were synthesized by sol-gel method. Zinc oxide has sphere nanostructure. Electrical and thermal conductivity were characterised. As the temperature increases from 30°C to 90°C, the electrical conductivity of the nanocomposites increases from 3.36 to 20.96 mS/cm and the thermal conductivity decreases from 1.031 to 0.669 $Wm^{-1}K^{-1}$. We have concluded that the zinc oxide nanoparticles can be used to make thermoelectric materials.

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