Synthesis and investigate the thermoelectric properties of polyaniline

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Abstract

Polyaniline is synthesized via the sol-gel method. The functional groups, crystal structure and surface morphologies of the PANI nanoparticles are investigated by Fourier transform infrared spectroscopy (FTIR), X–ray powder diffraction and scanning electron microscopy (SEM) respectively. The thermoelectrical properties were also analysed. 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 7.6 to 17.97 mS/cm and the thermal conductivity decreases from 1.091 to 0.697 $Wm^{-1}K^{-1}$. Here, as the annealing of zinc oxide increases, the thermoelectric properties of the nanoparticles improve.

Keywords: *Polyaniline, Nanoparticles, Thermal Conductivity, Electrical Conductivity.*

1. Introduction

Thermoelectric (TE) materials have received a lot of attention recently due to their potential usage in electricity generation, refrigeration and thermal sensing [1]. 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 [2]. The conversion of waste heat to electric power by means of thermoelectric devices has become more urgent and significant, especially since the combustion of fossil fuels has generated highly worrisome environmental problems [3]. High electrical conductivity and low thermal conductivity are significant for good thermoelectric materials [4]. 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 widely used [5]. Due to their inherent low thermal conductivity, light weight, low processing cost, and mechanical flexibility, some nanoparticles are viewed as suitable replacements [6]. In this study, polyaniline was fabricated by the sol-gel method at room temperature and the nanoparticles were characterised by conventional technologies. The electrical conductivity and thermal conductivity were also calculated. The TE properties of the nanocomposites were measured from 30°C to 90°C.

2. Experimental Procedure

2.1. Materials

Aniline hydrochloride ($C_6H_7N.HCl$) assay > 98%, Ammonium persulfate (APS) ($N_2H_8S_2O_8$) assay > 99%(SRL), Hydrochloric Acid (HCl) assay>35%, Ethanol (CH_2COOH) (HmbG Chemicals) and distilled water. All reagents were analytical grade and were directly used without further purification.

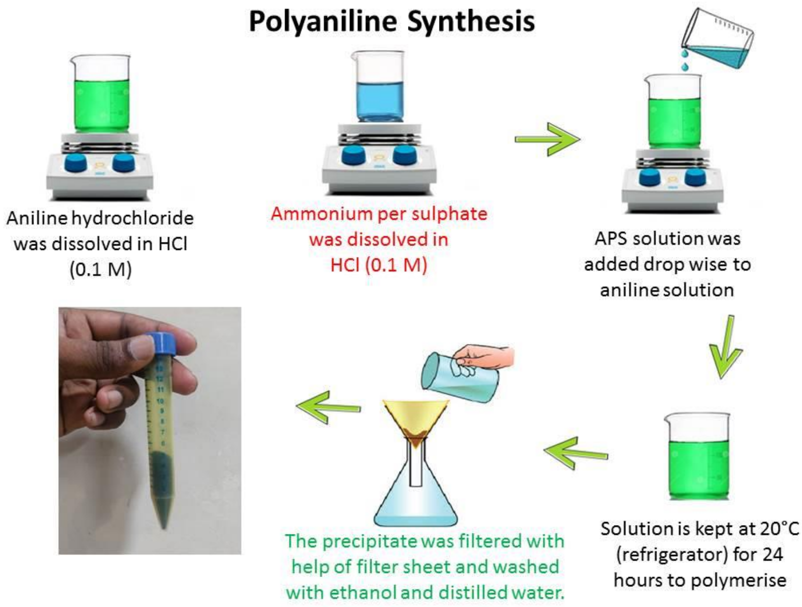

Figure 1 Schematic diagram of polyaniline synthesis

2.2. Synthesis of Polyaniline

Aniline hydrochloride (2g) was dissolved in 50 ml of HCl (0.1 M). Ammonium per sulphate (4g) was dissolved in 20 ml of HCl (0.1 M). Both solutions were stirred separately for 5 minutes without heat. The APS solution was added drop wise to the aniline solution under stirring. This mixture is stirred for an hour. The solution is kept at 20°C (refrigerator) for 24 hours to polymerize without any disturbance. The greenish precipitate forms. The precipitate was filtered with the help of a Whatman filter sheet and washed with ethanol and distilled water. Finally, polyaniline has been transferred to a petri dish and dried at 80°C.

3. Results and Discussion

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 in the region of 4000-400cm^{-1}. The vibrational bands of polyaniline are indicated by black lines in Figure 2. A broad peak at 3443 cm^{-1} is associated with NH_2 stretching. A peak at 2967 cm^{-1} due to CH stretching and CN stretching is observed at 1316 cm^{-1}. The benzenoid ring is represented by a peak at 1568 cm^{-1}. A peak due to the C=C vibration of the aromatic ring at 1484 cm^{-1} indicating chain formation. A characteristic band with peaks between 1132 cm^{-1} and 1243 cm^{-1} is caused by protonation of polyanline [7].

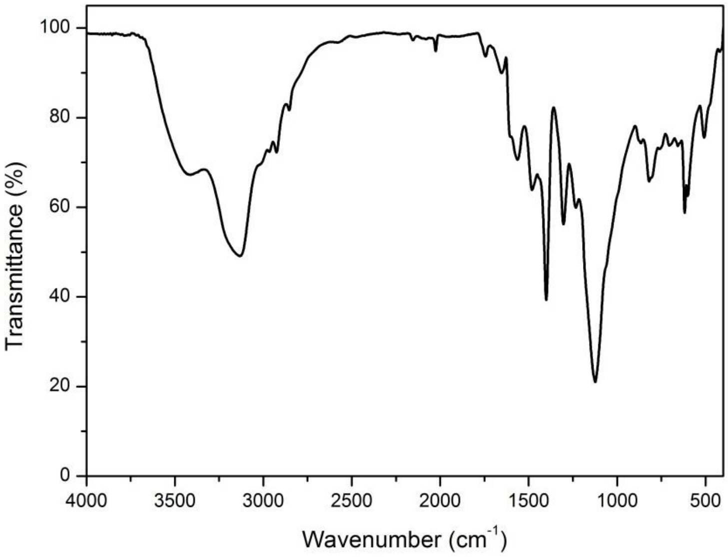

Figure 2. FTIR image of polyaniline

4.3.2. Scanning Electron Microscopy

Scanning electron microscopy is the best tool to analyse the surface morphology of the samples. The SEM image of polyaniline is shown in figure 3. The nanoparticles were slightly aggregated. The shape and size of some isolated particles seem to be mostly globular or ellipsoidal shapes. The SEM image of polyaniline shows the morphology of nano structural and granular. Through the SEM image, we can ensure that the surface morphology of particles has an almost spherical shape [8].

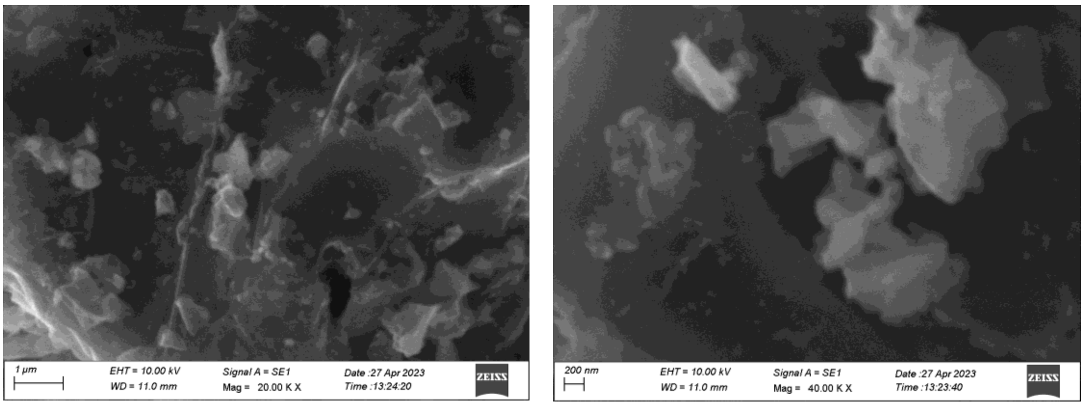

Figure 3. SEM images of polyaniline

4.3.3. X-Ray Diffraction

The X-ray diffraction method was used for structural analysis. The XRD pattern of PANI is displayed in Figure 4. The polyaniline XRD pattern shows a broad peak at 2θ value of 23.53° with a hkl value of (110) that is PANI. The amorphous aspect of the polyaniline's diffraction pattern may be caused by a change in the hkl values, which are what give PANI its partial crystallinity [9]. The average particle size of the nanoparticles was calculated by the Debye Scherrer equation. The calculated particle size of PANI is 79 nm.

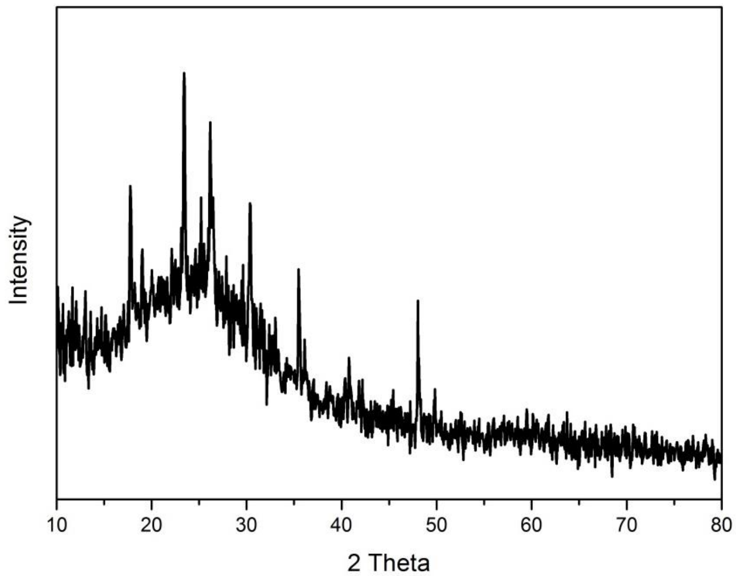

Figure 4. XRD image of polyaniline

4.3.4. Electrical Conductivity

Electrical conductivity is the primary measurement used to analyse thermoelectric properties. Based on this, we can evaluate the quality of newly developed nanocomposites. The electrical conductivity of the polyaniline was measured as the temperature increased from 30°C to 90°C. The electrical conductivitiy of polyaniline is shown in Figure 5. The electrical conductivity of the polyanilne was measured as the temperature increased from 30°C to 90°C. Polyaniline gives 17.97 mS/cm electrical conductivity at 90°C [10].

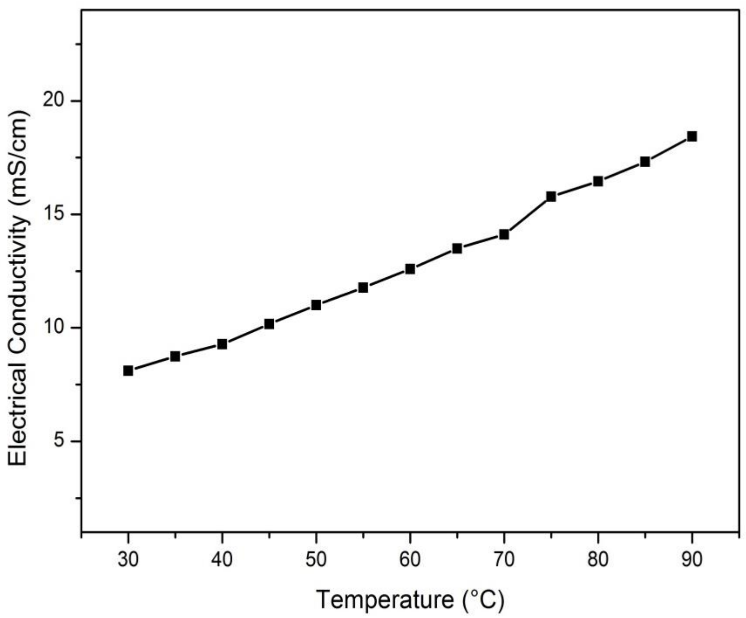

Figure 5. Electrical Conductivity image of polyaniline

4.3.5. Thermal Conductivity

While analysing the thermoelectric characteristics of polanilne, thermal conductivity is a crucial factor to understand. The measurement of thermal conductivity was done between 30°C to 90°C. Figure 6 displays the thermal conductivity of polyaniline. The thermal conductivity of polyanilne nanoparticles are decreases with temperature increase. Polyaniline gives thermal conductivity of 1.091 $Wm^{-1}K^{-1}$at 30°C. At 90°C, it has thermal conductivitiy of 0.697 $Wm^{-1}K^{-1}$ which decrease with rising temperature [11].

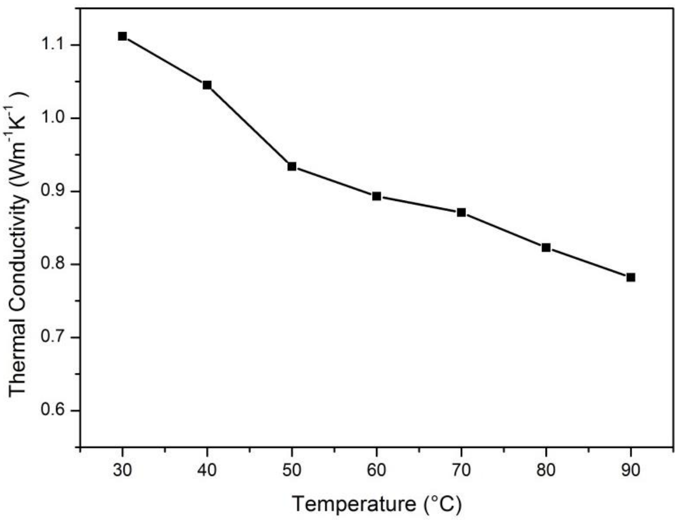

Figure 6. Thermal Conductivity image of polyaniline

4.4. Conclusion

Polyaniline was prepared by the sol-gel method based on the above-mentioned procedures. The study results confirm that the particles are polyaniline. Thermoelectric properties analysis was done for polyaniline. As the temperature increases from 30°C to 90°C, the electrical conductivity of the nanocomposites increases from 7.6 to 17.97 mS/cm and the thermal conductivity decreases from 1.091 to 0.697 $Wm^{-1}K^{-1}$. We have concluded that the polyaniline nanoparticles can be used to make thermoelectric materials.

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