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Research Article

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A Study of Preparation, Structural, Optical, and Thermal Conductivity Properties of Zinc Oxide Nanofluids

Suresh Sagadevan[1]* and Senthil Shanmugam[2]

[1]*Department of Physics, AMET University, Kanathur, Chennai-603112, India*
[2]*Department of Physics, Panimalar Engineering College, Chennai-600123, India*

Abstract

The Zinc Oxide (ZnO) nanofluids were prepared by the one-step solvothermal method. The crystal structure and average crystallite size of the ZnO nanofluids were determined by X-ray diffraction pattern. The morphology and particle size were studied using the scanning electron microscope (SEM) and transmission electron microscopy (TEM). Dynamic light scattering (DLS) is used to calculate the particle size of the ZnO nanofluids. UV-Visible absorption spectrum is used to analyze the optical property of the ZnO nanofluids. The thermal conductivity properties of ZnO nanofluids were examined.

Keywords: ZnO nanofluids; XRD; SEM; TEM; UV-visible spectrum; Thermal conductivity

Introduction

Nanofluids are synthesized by dispersing solid particles, fibers, or tubes with lengths of the order of 1–100 nm in traditional heat transfer fluid. In recent years, Nanofluids have involved extensive consideration due to improved heat transport properties as seen through enhanced thermal conductance [1,2]. Owing to small sizes and extremely large specific surface areas of the nanoparticles, nanofluids have better properties such as high thermal conductivity, minimal clogging in flow passages, long-term stability, and homogeneity. Hence, nanofluids contain a wide range of potential applications such as electronic, automotive, and nuclear applications where improved heat transfer or efficient heat dissipation is required [3]. Nanofluids were of huge concentration due to their wide applications in different fields [4]. ZnO is a wide band-gap semiconductor and that have high surface area as well as good electrical, electrochemical and structural properties. The synthesis and characterization of ZnO nanoparticles, ZnO–ethylene glycol and ZnO–water nanofluids are reported [5,6]. In this paper, ZnO nanofluid has been prepared by the one-step solvothermal method. The prepared ZnO nanofluids were characterized by powder X-ray diffraction analysis, Scanning electron microscopy (SEM), Transmission electron microscope (TEM), Dynamic light scattering (DLS) and UV-analysis. The thermal conductivity of ZnO nanofluids was also studied.

Materials and Methods

All chemicals used in the conduct test were of analytic reagent grade. Zinc oxide nanoparticles were prepared by the one-step solvothermal reaction. In a typical procedure, Zinc acetate dihydrate was dissolved in methanol and a solution of potassium hydroxide was prepared by dissolving potassium hydroxide in methanol. The potassium hydroxide solution was added drop wise to the zinc acetate solution at 52°C under forceful stirring. The reaction was carried out under stirring and boiling for 2 h. The ZnO nanoparticles were settled at the bottom and the excess mother fluid was removed. The precipitate was washed twice with methanol (50 ml) and collected by centrifugation process and allowed to dry at room temperature. Normally agglomeration of nanoparticles takes place when nanoparticles are suspended in the base fluid. The obtained solid was crushed to get a white powder and the obtained powder was dispersed in polyvinyl alcohol (PVA) with ultrasonicator. The dispersed solution was clear and stable for up to 2 weeks. ZnO nanofluids used subsequently for estimation of their properties were subjected to magnetic stirring process followed by ultrasonic vibration for about 5 hours. The size and shape of the particles were controlled by evaporation rate. The crystallite size and structure of the powder was analyzed by X-ray diffraction (XRD) using a powder X-ray diffractometer (Schimadzu model: XRD 6000 using CuK$_\alpha$ (λ=0.154 nm) radiation, with a diffraction angle between 20 and 80°. The crystallite size was determined from the broadenings of corresponding XRD pattern by using Debye Scherer's formula. The surface morphology of the powder was observed by a scanning electron microscope (SEM) using JEOL; JSM- 67001.Transmission electron microscope (TEM) image was taken using an H-800 TEM (Hitachi, Japan) with an accelerating voltage of 100 kV. The particle size of the ZnO nanofluids was analyzed, using the dynamic light scattering (DLS) experiment. UV-Visible absorption spectrum for the ZnO nanofluids recorded using a Varian Cary 5E spectrophotometer in the range of 200-800 nm. For the measurement of Thermal conductivity, KD2 Pro was used.

Results and Discussion

Structural analysis

Structural identification of ZnO nanofluids was done using with X-ray diffraction pattern in the range of angle 2θ between 20° to 80° as shown in Figure 1. The peaks observed at (100), (002), (101), (102), (110), (103), (200), (112) and (201) can be assigned to various crystal planes of hexagonal crystal structure of ZnO. The broadened peak shows the nanometer-sized crystallites. The average crystalline size is obtained from the most intense peak, corresponding to (101) reflection using the Debye-Scherrer formula,

***Corresponding author:** Suresh Sagadevan, Department of Physics, AMET University, Kanathur, Chennai 603112, India, Tel: +91 44 2747 2905; E-Mail: sureshsagadevan@gmail.com

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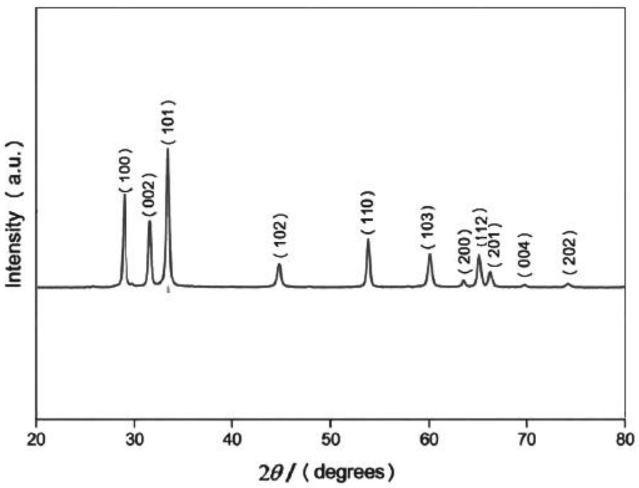

Figure 1: XRD pattern of ZnO nanofluids.

$$D = \frac{0.9\lambda}{\beta \cos\theta} \quad (1)$$

where λ is the X-ray wavelength (CuK_α radiation and equals to 0.154 nm), θ is the Bragg diffraction angle, and β is the FWHM of the XRD peak appearing at the diffraction angle θ. The average crystalline size is calculated from X-ray line broadening using Debye-Scherrer equation to be about 17 nm, which agrees well with the reported values of 15-20 nm [7].

SEM analysis

The surface morphology of the prepared ZnO nanofluids was discovered through the SEM image shown in Figure 2. It shows the clear evidence of spherical shaped particles and it dispersed homogeneously. It is clearly shown that the particles are formed in a spherical shape with the average crystallite size in the range of ~15–20 nm, which is good agreement with the XRD analysis.

TEM analysis

TEM images of the ZnO nanofluids as shown in Figure 3. The particle size-distributions for ZnO nanofluids were calculated from TEM image. It is clear from the grains are segregated together to form large sized agglomerates. It can be seen that the particle size distribution in the range 15–30 nm.

DLS studies

The Dynamic light scattering (DLS) is a expensive instrument for determining and measuring the agglomeration state of the nanoparticles as a function of time or suspending solution. Figure 4 shows the graphical illustration of average particle size distribution of ZnO nanofluids. They were in a range of 0-70 nm. The highest fraction of ZnO nanofluids present in the solution was found to be 30 nm. From the graph it was obvious that the ZnO nanofluids having various sizes which are indeed in agreement of the result obtained by TEM analysis.

Optical studies

To examine the optical properties of ZnO nanofluids, the UV–visible absorption spectrum is analyzed. Figure 5 shows the UV–visible absorption spectrum of the prepared ZnO nanofluids. The absorption peak of the as-prepared ZnO nanoparticles was observed at 345 nm which was blue shifted with respect to the bulk ZnO and the absorption value showed an increased band gap of ZnO nanoparticles from bulk band-gap of 3.37 eV to 3.6 eV. Such superior band-gap properties can give useful behaviour in occurrence of sun-light [8-10]. It is well known that, if the size of ZnO particle decreases the width of the band gap increases and the optical absorption shows a blue shift. From that, the indication of blue shift in the absorption spectrum corresponds to a

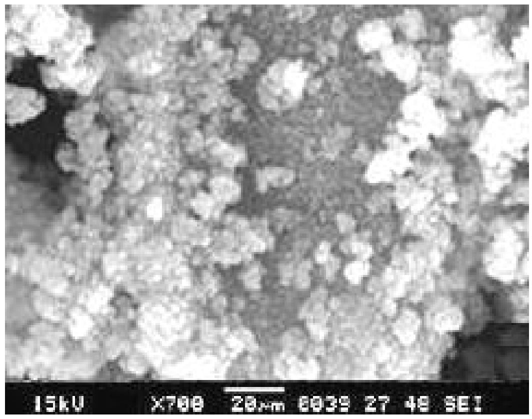

Figure 2: SEM image of ZnO nanofluids.

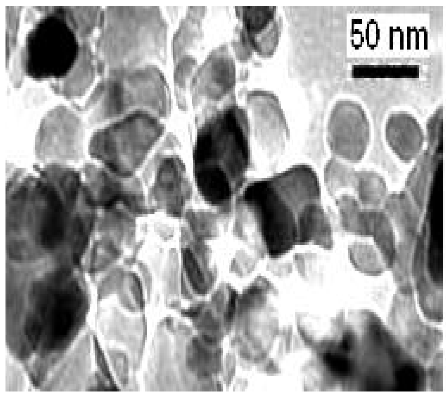

Figure 3: TEM image of ZnO nanofluids.

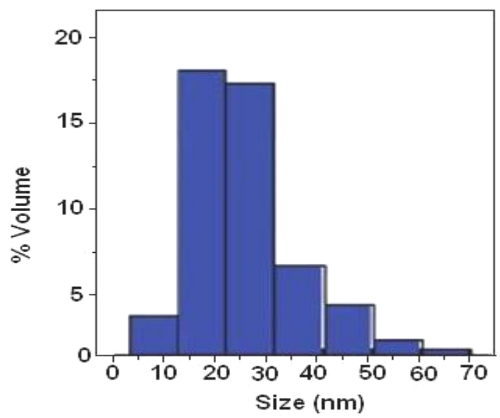

Figure 4: Particle size distribution of ZnO nanofluids.

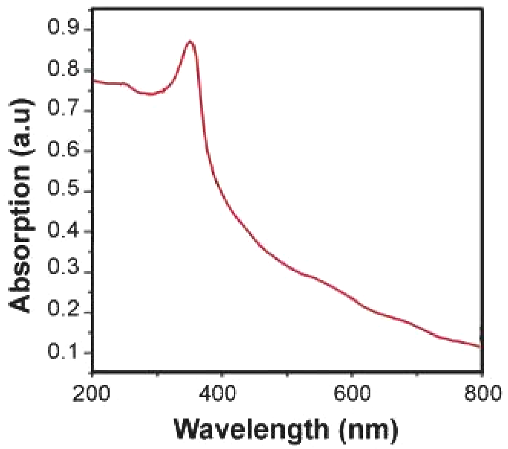

Figure 5: UV-Visible absorption spectrum of ZnO nanofluids.

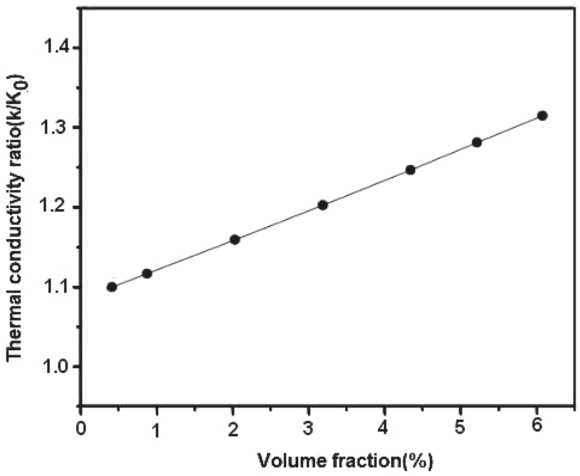

Figure 6: Thermal conductivity ratio as a function of ZnO volume fraction.

quantum confinement effect arising with the decreasing particle size [11]. As a result, the absorbance value is reduced.

Thermal conductivity of ZnO nanofluids

Nanofluids are expected to demonstrate superior heat transfer properties compared with conventional heat transfer fluids. One of the motives is that the suspended particles extremely increase thermal conductivity of nanofluids. It is known that the thermal conductivity of nanofluid is strongly dependent on the volume fraction dimensions and properties of nanoparticles. Figure 6 shows the thermal conductivity ratio of the ZnO nanofluids. It can be observed that the thermal conductivity ratio increases as the particle volume fraction increases, which agree well with the reported results [12].

Conclusion

The ZnO nanofluids have been prepared by the one-step solvothermal method. The formation of ZnO nanofluids was confirmed by X-ray diffraction (XRD).The average crystallite size ZnO nanofluids was found to be 17 nm. The SEM reveals the ZnO nanofluids are spherical in shape. The particle size of the ZnO nanofluids was estimated to be 30 nm using TEM. The particle size of the ZnO nanofluids was found to be 30 nm using the dynamic light scattering (DLS) experiment which is in good agreement with the TEM analysis. Optical properties of the ZnO nanofluids were investigated by using UV–Visible absorption spectrum. The thermal conductivity of ZnO nanofluids increased with the increase of particle loading.

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