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Synthesis, Structural and Ultrasonic Characterization of CuO Nanofluid

Pallavi B. Nalle[1], Asha Navpute[2], S. P. Jadhav[3], B. R. Shinde[4], S. U. Shinde[5], K. M. Jadhav[6]

[1]Department of Physics, Shivchhatrapati College, Aurangabad, (M.S.) India

[2, 6]Department of Physics, Dr. Babasaheb Ambedkar Marathwada University, Aurangabad (M.S.) India.

[3]Department of Chemistry, Adarsha College Omerga, Omerga, (M.S.) India

[4]Department of Physics, Sanjeevani Rural Eng. Society College of Eng, Kopargaon, (M.S.) India

[5]Department of Physics, Pratishthan Mahavidyalaya, Paithan, Aurangabad, (M.S.) India

Abstract: ***Nanoparticles of CuO were synthesized by sol-gel method using copper chloride and sodium hydroxide. The prepared Copper Oxide sample was sintered at 400^o C for 4 h and characterized by X-Ray Diffraction (XRD) and Fourier Transform Infrared (FTIR) spectroscopy technique. The X-ray analysis confirms the formation of monoclinic base centered structure. The most intense peak of the XRD pattern was used to determine the crystallite size which was found to be around 16 nm. Lattice parameter and volume of unit cell, were calculated by using XRD data. The values of lattice parameter, volume and FTIR spectra characteristics peak are found to be in the reported range. The prepared copper oxide powder was immersed in polyvinyl alcohol (PVA) to get nanofluid. The ultrasonic investigation of the water, 4 % of PVA and copper oxide powder dispersed in PVA matrix nanofluid were carried out using ultrasonic interferometer technique operated at 2MHz frequency. The density ρ was measured using specific gravity bottle. Using ultrasonic velocity and density, relaxation strength is obtained.***

Keywords: Nanofluid, CuO, ultrasonic velocity, molecular interaction

1. Introduction

Nanotechnology is an intensive branch of science that interesting in the materials among the size of 1-100 nm with different shapes of spherical nanoparticles, nanorods, nanoribbons, nanobelts and nanoplatelets [1, 2]. The unique physical and chemical properties are due to its high surface-to-volume ratio comparing with micro or bulk-sized. Most of work in nanotechnology deals with materials in the solid state. However, nanofluids are no less interesting. Nanofluids are new kinds of fluids engineered by dispersing nanoparticles in base fluids. The term nanofluid was introduced by Choi [3]. Nanofluid are composites consisting of solid nanoparticles with sizes varying generally from 1 to 100 nm dispersed in heat transfer liquids such as water, ethylene glycol, propylene glycol and so on. In the last decade, nanofluid has gained significant attention due to their enhanced thermal properties. 0.3 vol% of copper nanoparticles are suspended in ethylene glycol, thermal conductivity of the fluid increases by 40%[4]. The convective heat transfer coefficient increases by 75% for an Al_2O_3 particle concentration of 2.78% at a fixed Reynolds number [5]**.** Such novel nanofluids have potential applications in numerous important fields such as microelectronics, micro-electromechanical systems, microfluidics, transportation, manufacturing, instrumentation, medical, and HVAC systems [6-10]. Nanofluids offer major importance to power generation, thermal therapy, heating, cooling, ventilation, air conditioning loud speaker, MEMS, optoelectronic devices [11, 12].

The synthesis procedure plays crucial role in controlling the size, shape of the nanostructure and hence detecting different properties of the material. CuO nanoparticles have been prepared by wet-chemistry route [13], sonochemical preparation [14], alkoxide based preparation [15], hydrothermal process [16], solid-state reaction in the presence of a surfactant [17] etc. Among various chemical synthesis methods for metal oxides, sol–gel process offers several advantages over other methods, including good homogeneity, low cost, and high purity. Recently, sol–gel method has been developed for preparation of magnetite nanoparticles using metallorganic precursors [18, 19].

Ultrasonic investigations of binary and ternary liquid mixtures of various types have been carried out by several investigators [20-21]. However, in the literature very few reports are available on the ultrasonic investigations of the nanofluids of CuO and ZnO. The particle shape will not have an effect on the ultrasound velocity for homogeneous dispersion was reported by Subhrakanti Chakraborty et al in 2011.

In the present study, we have synthesized CuO nanoparticles using ethanol as a solvent by a low cost sol-gel process. The aim of the present paper is to characterize the nanoparticles and ultrasonic investigation of that nanoparticle in PVA as base fluid and calculate acoustic parameter that is relaxation strength.

2. Experimental Details

A. Materials and Methods

The chemicals copper (II) chloride ($CuCl_2$), sodium hydroxide (NaOH) and ethanol (C_2H_5OH) were purchased from Merck with purity 99.9%. The chemicals were used as purchased without further treatment.

B. Synthesis of Copper Oxide Nanopowder

The synthesis of PVA based copper oxide nanofluid obtained by sol-gel method. 3.0 g of copper (II) chloride was dissolved in 160 ml of ethanol. 1.8 g of sodium hydroxide was dissolved in 50 ml ethanol. The prepared sodium hydroxide solution was added drop wise to copper (II) chloride solution with constant stirring at room temperature. Reaction occurs and colour of solution becomes black. Centrifuge machine is used to filter the gel and washed with ethanol and water. The sample of dried copper hydroxide gel was annealed at temperature 400°C. The annealed sample of copper oxide nanoparticles was grinded.

C. Synthesis of PVA base Nanofluid

Aqueous solution of concentration 4% of PVA was obtained by dissolving 10.0 g of PVA in 250 ml water at 70°C with constant stirring for 2 hrs. CuO nanofluid was obtained by dissolving CuO NPs in prepared aqueous solution of PVA with ultrasonicator at room temperature**.**

Characterization

a) XRD

The crystalline phase of the prepared CuO sample was identified by X-ray diffraction technique using XPERT-PRO system. X-ray powder diffractions were performed at room temperature using monochromatic Cu Kα1 radiation with λ=1.54060A^o operated at 40 kV and 35 mA with 2θ ranging from 20 to 80 degree at a step size 0.02^o per second.

b) FTIR

FTIR The Fourier transformed infrared absorption spectra of the sample were recorded using FTIR spectrometer (Thermo Nicolet, Avatar 370) in the wave number range of 4000 to 400 cm^{-1} with Potassium bromide (KBr) as a binder. Magnetic measurements were made on a pulse field hysteresis loop tracer (PFHLT, MAGNETA) technique at a room temperature.

c) Ultrasonic Investigation

Ultrasonic investigation was carried out using single frequency ultrasonic interferometer (Model F-81, Mittal Enterprises, India) operated at 2 MHz with an accuracy ±0.05%. Density measurements were carried out by using specific gravity bottle.

3. Results and Discussion

Structural Studies (XRD)

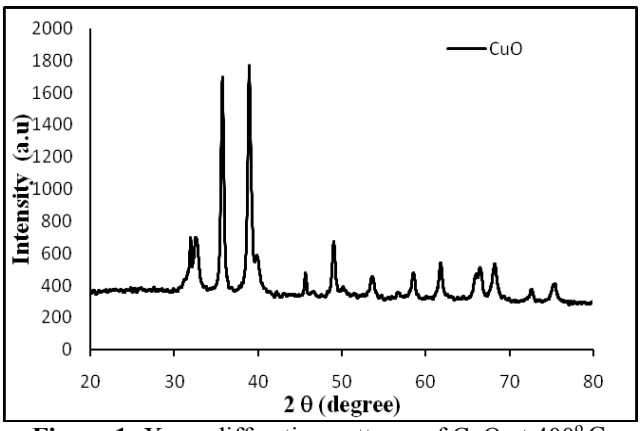

Figure 1: X-ray diffraction patterns of CuO at 400^o C

Fig.1 shows that X-ray diffraction pattern of copper oxide nanoparticles. The diffraction peaks observed at 2θ = 32.57°, 35.75°, 38.94°, 45.66°, 49.03°, 53.59^o, 58.55°, 61.80°, 66.49°, 68.26° and 75.44° corresponding to the (110), $(11\bar{1})$, (111), (201), $(20\bar{2})$, (020), (202) $(11\bar{2})$, (022), $(11\bar{3})$ and (004) planes, respectively. In this XRD pattern other oxides or impurity phases are not detected therefore XRD patterns confirm the formation of monoclinic base centered structure which matches well with the standard XRD pattern (JCPDS No: 89-2529). The lattice parameters of copper oxide are a = 4.6854, b = 3.4089, c = 5.0934 Å and unit cell volume v = 80.27 was established from X-ray data. The crystallite size (D) has been calculated from FWHM (full width at half maximum) of most intense peak data using Debye-Scherrer's equation [21].

$$D = (0.9\lambda) / \beta \cos \theta \quad (1)$$

Where, D is the crystallite size, λ is the wavelength of Cu Kα(1.540562 Å), β is the full width at half maxima of the most intense diffraction peaks, and θ is the Bragg's angle. Obtained values of crystallite size is16 nm which confirms nanocrystalline nature of CuO.

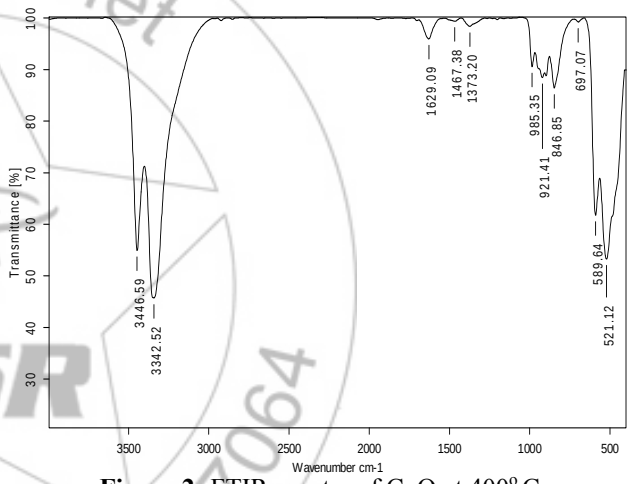

Figure 2: FTIR spectra of CuO at 400^o C

FTIR Spectrometry technique is used for understanding the role of the organic molecules. Fig.2 shows the IR spectra of CuO Nanoparticles in the range of 4000 to 400 cm^{-1}. Characteristics peak of CuO positioned from 985 cm^{-1} to 521 cm^{-1}. All major peaks related to hydroxyl and acetate groups were observed. The large band observed between 4000 cm^{-1} and 400 cm^{-1} is linked to the stretching O-H from the inter molecular and intra molecular hydrogen bands. Different functional groups and structural features in the molecule absorb at characteristics frequencies. The Frequency and intensity of absorption are the indication of the band structures and structural geometry of the molecules.

Acoustical Studies:

The ultrasonic velocity is measured in pure water, PVA and nanofluid for the sake of comparison and the obtained values are tabulated in table 1. The comparative study of the ultrasonic velocity in these materials shows that the ultrasonic velocity is maximum in copper oxide nanofluid. The increasing velocity is attributed to increase in the concentration of the solutions which is similar to reported by S. Ravichandran et al in 2010 [22]. The density

measurements are carried out by using specific gravity bottle and the obtained values are also listed in table 1. Density of CuO nanofluid under investigation is found to be 992.22 kg/m^3. Relaxation Strength (r) is found to be decrease with increasing concentration, which indicates solvent-solute interactions is present in this system [23].

Table 1: Ultrasonic Velocity (v), Density (ρ), relaxation strength (r) at 303 K

Solution	Ultrasonic Velocity U (m/s)	Density ρ (kg/m^3)	r
Water	1420	997.77	0.2123
PVA	1457	1001.60	0.1708
PVA + 0.3%CuO	1458	992.22	0.1696

Acoustical parameter like relaxation strength (r) was calculated using ultrasonic velocity (U) and density (ρ).
Relaxation Strength

$$r = 1 - (U/U_\infty)^2 \qquad (2)$$

Where,
$U_\infty = 1.6\times10^5$cm/s.

4. Conclusion

CuO nanofluid in PVA has been synthesized by sol-gel method successfully and examined using ultrasonic investigation. The acoustical parameters have been analyzed. The crystallite size of the prepared nanoparticles is found to be 16 nm from XRD pattern**.** This pattern clearly suggests the end centered monoclinic structure of the samples. The ultrasonic investigation leads to the understanding of the molecular interactions taking place between the particles and base fluid.

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