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Research Article

Acoustical and thermal conductivity study of Ag nanofluids

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ABSTRACT

Nanofluid is a kind of navel engineering material consisting of metal particles with a size typically of 10nm–100 nm suspended in base fluid. These fluids offer the excellent scope of enhancing the thermal conductivity of common heat transfer fluids. In the present study, Nanofluids are synthesized using two-step method. First, Ag nanoparticle is synthesized by using the wet chemical method. In this method, silver nitrate used as a precursor, sodium borohydride used as reducing agent, and then nanofluids is prepared by synthesized silver nanoparticle dispersed into DD water by using ultrasonication method without any agglomeration. Morphology of the produced nanoparticles is studied by Transmission Electron Microscopy (TEM); Ultrasonic velocity (v) has been measured for different concentrations of silver nanofluid at different temperatures using Ultrasonic Interferometer technique and then calculated other acoustical parameters like Adiabatic compressibility (β), Acoustical impedance (Z) intermolecular free path (L_f) and its thermal conductivity (k) by using modified Bridgman equation for Nanofluids. Since the addition of only a few volume percent of nanoparticles to a base fluid and significantly improves its thermal conductivity.

Keywords: Nanofluids, TEM, Nanofluid Interferometer, Ultrasonic velocity. Thermal Conductivity.

INTRODUCTION

Nanofluids are novel suspensions of solid nanoparticles in base fluids. Since last several decades, scientists have an attempted to develop fluids, which offer better cooling or heating performance than conventional fluids for a variety of thermal engineering applications. Choi proposed a novel concept of ‘‘nanofluids” by applying nanotechnology (S.K. Das, et al., 2008) from Argonne National Laboratory of USA in 1995 to thermal engineering to meet the various challenges (Bergles et al., 1988). The nanofluids can be synthesized by dispersing nanometer-sized (one billionth of a meter) solid particles may be metallic (e.g. Ag, Cu, Fe, Au), or different forms of carbon (fullerene, graphene) (P. Krajnik, *et. al.,* 2011) into base fluid may be water, vegetable oils (e.g. coconut), and organic liquids (e.g. Butanol, ethylene glycol) or polymeric solutions Nanofluids (U.S. Choi 1995) have recently been demonstrated to have great potential for improving the thermal properties of liquids. One fabulous feature of nanofluids is that they have anomalously high thermal conductivity (W. Yu and L. J. Thompson: 2001; S. Choi, et al., 2001; D. H. Kumar et al., 2004); it makes nanofluids strong candidates for the future generation of coolants for improving the style and performance of thermal properties of systems. From the investigations in the past decade, nanofluids were found to show significantly higher thermal properties, like thermal conductivity, than those of base fluids. Ultrasonic wave propagates in a certain material (K. Balasubramaniam and S. Sethuraman, 2006); it depends on material elasticity and density of the fluid. In this work, we have measured the ultrasonic velocity at different temperature and concentrations of samples using ultrasonic Interferometer technique because development of nanotechnology is the need to understand the study of matter in nanoscale (G. Cao, 2007). Nanofluids find their wide applications in fields like electronic applications, thermal management, industrial cooling application, nuclear system cooling, magnetic sealing space and defense, solar absorption, brake fluids, friction reduction, medical applications like antibacterial activity, nano-drug delivery, fuel cell, nanofluids based optical filters and sensors (G.A.Mansoori, 2006) etc.

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MATERIALS & PREPARATION METHOD

In this, nanofluid was prepared by using two-step method. First, a Wet chemical method is used to synthesize the nanoparticle, in this, 20 mM Silver nitrate

($AgNO_3$) was taken and mixed with 100ml DD water. Then 100 ml of 40 mM $NaBH_4$ aqueous solution was added dropwise to the above solution with constant stirring at room temperature, the color of the solution was turned from translucent to grayish black. The resulting suspension was centrifuged and washed several times thoroughly with ethanol and deionized water respectively. After that, the black precipitate was dried at 80˚C in the hot air oven. The chemical equation of sodium borohydride reduction of silver nitrate to silver is given below.

Then, synthesized Ag nanoparticle dispersed slowly into small beaker consisting of double distilled water by using ultrasonication method for 30 minutes and kept aside for 3 to 4 hours to form a uniform and stable nanofluid without any agglomeration. Here we prepared nanofluid of varying concentration from0.01% to 0.06% of Ag nanofluid. Preparation of uniform and the stable sample is an essential for the effective for nanofluid application.

EXPERIMENTAL DETAILS

To study the ultrasonic velocity measurement, here we used the multi-frequency ultrasonic interferometer (Model NF 10X, Mittel Enterprises). It is simple in construction and operation, gives accurate and reproducible results. One can readily determine the velocity of sound in a liquid with good accuracy. This can generate ultrasonic waves of several frequencies from 1 MHz to 12 MHz in the medium. In this, the frequency of 2 MHz has been used. The high-frequency generator is designed to excite the quartz plate fixed at the bottom of the measuring cell. A microammeter is available to observe the changes in current and two controls knobs are provided for adjusting sensitivity regulation and initial adjustment of microammeter on the high-frequency generator. A specially designed double-walled measuring cell for maintaining the temperature of a liquid constant during the experiment. A fine micrometer screw has been provided at the top of the generator, which can lower or raise the reflector plate in the cell through a known distance. The quartz plate fixed at its bottom the ultrasonic interferometer may be used for determination of ultrasonic velocity. Initially, the cell is filled with the experimental liquid before switching on the generator, the fixed to the generator. The ultrasonic wave moves the normal form to the crystal till they are reflected back from the movable plate, it results the standing waves are formed in the liquid in between the reflector plate and the quartz crystal. Now the micrometer is slowly moved till the anode in the current meter on high-frequency generator shows a maximum value. A number of such maximum readings of anode current is passed on and counted the total distance ‘x’. Thus it gives the value of wavelength ‘λ’ which can be calculated with the help of the following relation;

$$x = n \times \lambda /2 \qquad (1)$$

$$\lambda = 2x/n \qquad (2)$$

Once the wavelength is known, the ultrasonic velocity V of specimen Silver nanofluid can be calculated with the help of the following relation;

$$V = \lambda \times n \qquad (3)$$

With these ultrasonic velocity measurements, we can calculate other acoustical parameters like Adiabatic compressibility (β), intermolecular free mean path (L_f), Acoustical impedance (Z) and then Thermal conductivity (K) by using Bridgman’s equation modified by J Hemalatha for nanofluid by considering particle and base fluid masses.

$$K_{nf} = 3\left(\frac{\rho_{nf} N}{Mnf}\right)^{\frac{3}{2}} k_B V_s$$

EVALUATION

The ultrasonic velocity measurements technique has been successfully used to detect and assess weak and strong molecular interactions present in nanofluids. These studies are employed to determine the extent of complexation and calculate the stability constants of such complexes (G. Cao, 2007). Nanofluids are a suspension of nanoparticles in fluid shows a significant enhancement of their thermal properties at moderate nanoparticle concentrations. As nanofluids contain a suspended metallic nanoparticle, which increases the thermal conductivity of the base fluid by a substantial amount (G.A. Mansoori, 2006; C.H. Chon and K.D. Kihm: 2005). The term Nanoscience often refers to research that discovers and characterizes new behaviors and properties of materials at the nanoscale. Nanotechnology describes how discoveries at the nanoscale are put to work, especially by controlling the behavior of matter and building useful devices (Y. Xuan and Q. Li, 2006). Measurement of ultrasonic velocity gives the valuable information about the physiochemical behavior of the liquid and particle- liquid mixtures. There are several relations and semi-empirical formula are available for the theoretical computation of ultrasonic velocity in liquid and Particle-liquid mixtures (W. Yu and H. Xie, 2012; G.Cao, 2007). The ultrasonic velocity measurements, density (ρ) and its other acoustical parameter like adiabatic compressibility (β), intermolecular free length (Lf), acoustical impedance (Z) and thermal conductivity (K) has been calculated for the ultrasonic wave frequency 2 MHz of silver nanofluid from room temperature 35°C to 60°C. For different concentrations, the variations of ultrasonic velocity and thermal conductivity are shown in Table 1. And the variation of ultrasonic velocity and thermal conductivity at different temperatures also showed in Table 2.

RESULTS AND DISCUSSION

Chemical reduction method is used for the synthesis of Silver Nanoparticles. Transmission Electron Microscope

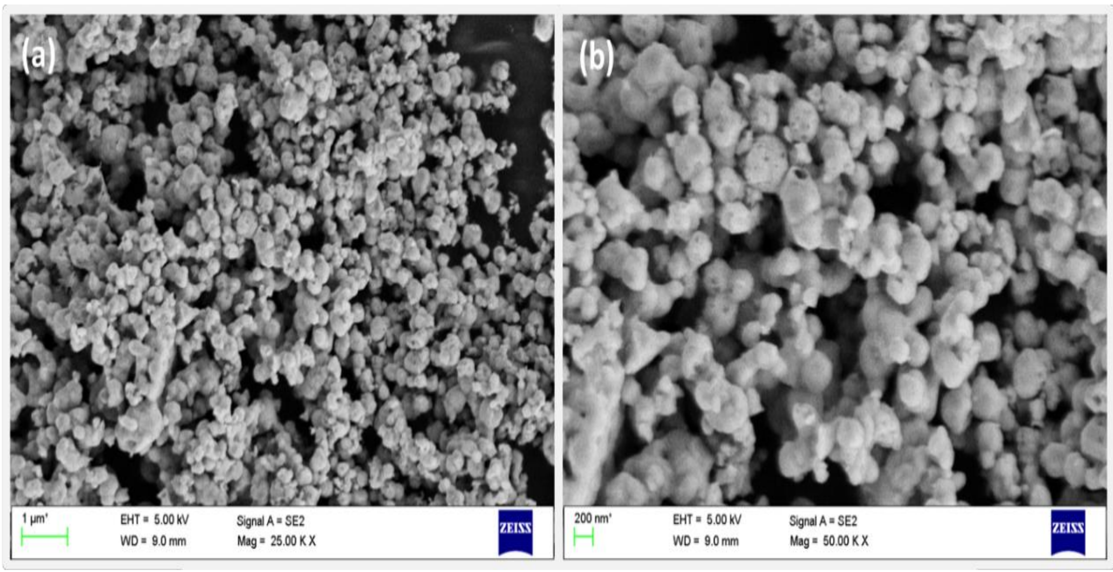

Figure 1: TEM image of spherical silver nanoparticles and its particle size distributions

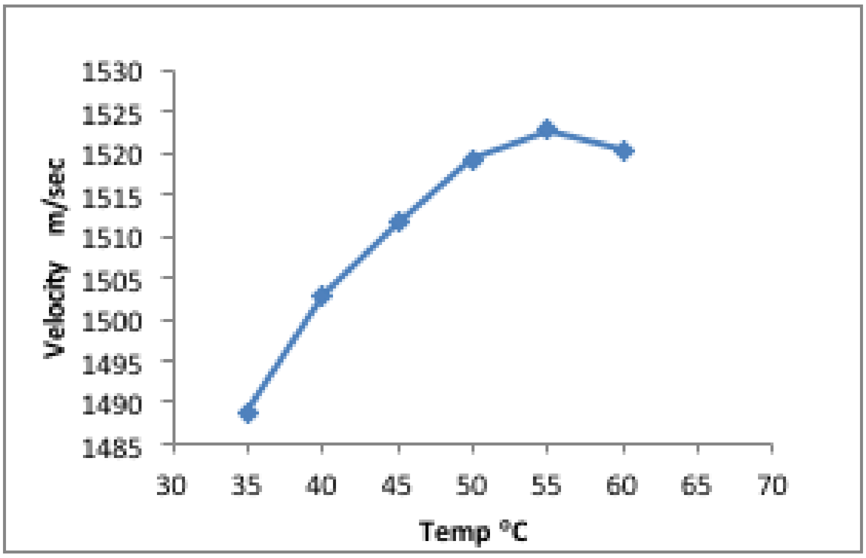

Figure 2: Variation of ultrasonic velocity with temperature in the Au nanofluid

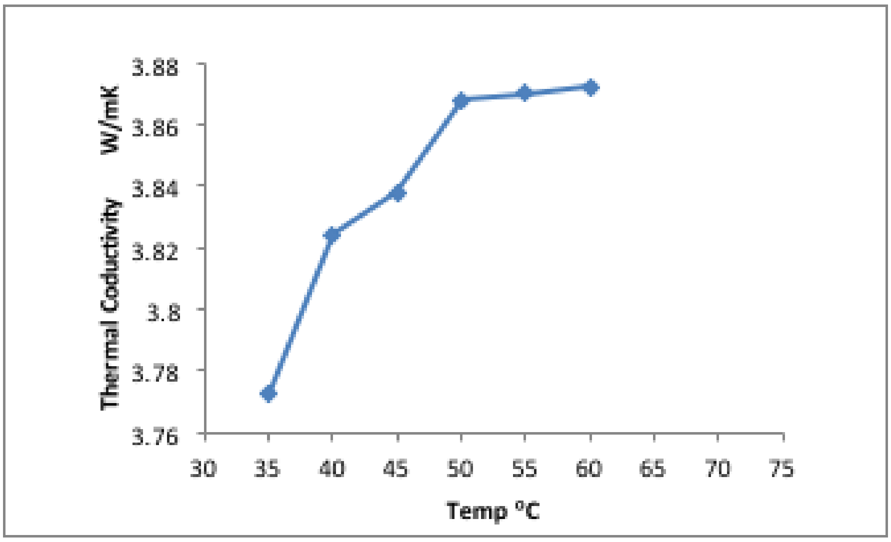

Figure 3: Variation of Thermal Conductivity with different Temperature of Au Nanofluid

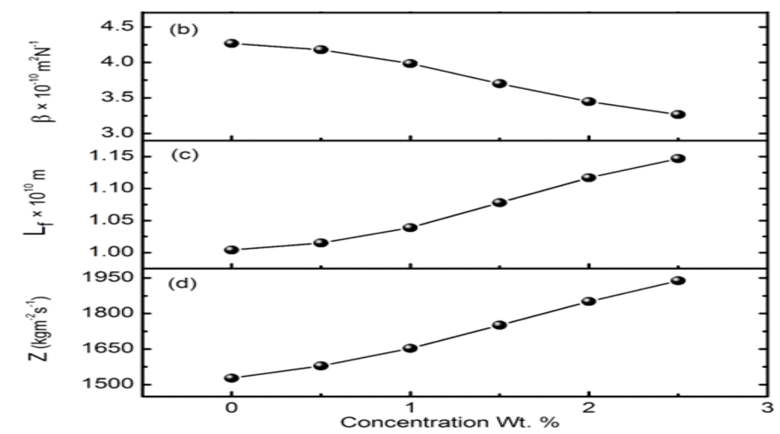

Figure 4: Plots of (d) Acoustical impedance 'Z' (c) Intermolecular free length 'Lf' (b) adiabatic compressibility 'β' verses different concentration of Ag nanofluids

Table 1: Ultrasonic velocity, other acoustical parameters and thermal conductivity measurements of Ag Nanofluid of different concentrations at Temperature 308 K

S.No.	Concentration X	Density ρ kg/m^3	Ultrasonic velocity υ (m/s)	Adiabatic compressibility β×10^{-10} (m^{2}N^{-1})	Inter molecular free length Lf × 10^{10} m	Acoustical impedance Z (kgm^{-2}s^{-1})	Thermal conductivity K x10^{-2} W/mK
1	0.01	0.9956	1485.72	4.267	1.004	1527.52	3.77206
2	0.02	1.0422	1488.25	4.179	1.015	1579.2	3.89549
3	0.03	1.0888	1490.72	3.984	1.039	1653.09	4.01742
4	0.04	1.1354	1492.18	3.703	1.078	1750.98	4.13529
5	0.05	1.1820	1494.91	3.449	1.117	1851.21	4.25545
6	0.06	1.2286	1496.23	3.268	1.147	1938.81	4.37043

Table 2: Ultrasonic velocity, and thermal conductivity measurements of 0.02% concentration of Ag Nanofluid at different Temperatures

S.No	Temperature o C	Ultrasonic velocity m/sec	Thermal Conductivity W/mK
1	35	1488.72	3.77274
2	40	1502.82	3.82417
3	45	1511.62	3.83782
4	50	1519.21	3.86776
5	55	1522.78	3.87012
6	60	1520.25	3.87212

(JEOL, Modal; JEM-201) was used to observe the morphology of the silver particles. A drop of silver nanofluids was carefully placed on a copper grid coated with

Figure 5: TEM image of spherical silver nanoparticles and its particle size distributions

carbon. The sample was dried sufficiently for 24 h and then it was examined. TEM image (Fig.1), show agglomerates of small grains and some dispersed nanoparticles. The histogram of silver particles shows that the particles range in size from 8 nm to 50 nm with mean diameter 26 nm.

Figure; 1 and Figure; 2 shows plots between Temperature Vs Ultrasonic velocity and Temperature Vs Thermal conductivity respectively.

It is clear from this table and figures the acoustical impedance and intramolecular free length increase with the increase of concentration whereas Adiabatic compressibility decrease as concentration increases. It attributes the molecular force of attraction decreases as per Brownian motion. At different concentrations, the ultrasonic velocity, and thermal conductivities are increases. But as temperature increases the ultrasonic velocity increases slowly reaches a maximum at 55^{0}C and then decreases as temperature increases further, whereas thermal conductivity increases as temperature increases.

CONCLUSIONS

The two-step method is used to prepare the required nanofluid. This involves the preparation of nanoparticle and then dispersed into the base fluid of different concentration by using ultrasonication. Wet - chemical method, is a simple method and is used to prepare the Ag nanoparticle. The TEM images analysis indicates that the average size of the silver particle was about 26 nm when the $H_2O/AgNO_3$ ratio greater than 1. Measurement of ultrasonic velocity and its other acoustical parameters gives the valuable information about the physicochemical behavior of the liquid and a liquid mixture; these measurements also provide an important tool to study the liquid state. Such studies have been used to understand the intramolecular interactions of particle-fluid in the liquids mixture; the variations of ultrasonic velocity and thermal conductivity at a different concentration of nanofluid are shown in the figure, it shows ultrasonic velocity is increased with the increase of concentration and but when the temperature increases velocity increases and then slight decrease because of viscosity decreases whereas there an increase of thermal conductivity.

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