International Journal of Science and Research (IJSR)
ISSN (Online): 2319-7064, Impact Factor (2013): 4.438
www.ijsr.net

Ultrasonic and Thermal Properties of Nanofluids Containing Copper Nanoparticles

Giridhar Mishra*[1], Meher Wan[2], Vimal Pandey[3], Devraj Singh[1] and R.R. Yadav[2] and B. Mishra[3]

[1]Department of Applied Physics, Amity School of Engineering and Technology, Bijwasan, New Delhi-110061, India

[2]Ultrasonics NDE Lab., Department of Physics, University of Allahabad, Allahabad-211002, India

[3]Department of Physical Sciences, Mahatma Gandhi Chitrakoot Gramodaya Vishwavidyalaya, Satna-485334, India

Abstract: ***Nanofluids are colloidal suspensions obtained by dispersing nanoparticles in any base fluid. These new type of fluids have attracted wide interest in recent years as nanofluids have significantly higher thermal conductivity than the base fluids. In this work nanofluids containing copper nanoparticles have been developed using a novel chemical method in our laboratory. Nanofluids so-prepared were characterized by UV-Visible spectroscopy, X-ray diffraction (XRD) and transmission electron microscopy (TEM). The measurements of ultrasonic velocity and ultrasonic attenuation in the prepared samples were made as function of temperature and concentration of the copper nanoparticles in the PVA. The obtained results were analyzed taking into account the ultrasonic and thermal behavior of matrix and particles. The thermal conductivity of synthesized nanofluids was measured with Hot Disk Thermal Constant Analyser and 20-35% enhancement was found in the thermal conductivity of Cu-PVA nanofluids having different concentrations of copper nanoparticles in PVA solution. Present ultrasonic investigation accounts for the enhancement in the thermal conductivity of the colloidal solutions.***

Keywords: Copper nanoparticles, Nanofluid, UV-Visible spectroscopy, TEM, Ultrasonic properties, Thermal properties.

1. Introduction

Nanofluids are colloidal suspensions obtained by dispersing nanoparticles in any base fluid have attracted wide interest in recent years after Choi and his coworkers observed that they have much higher thermal conductivity than predictable from the effective medium theories [1-7]. Nanofluids, produced by dispersing nanoparticles into conventional heat transfer fluids like water, ethylene glycol, poly vinyl alcohol etc., are proposed as the next generation heat transfer fluids due to the fact that their thermal conductivities are significantly higher than those of the base liquids [8]. Hong *et al.* suggested that suspensions containing small nano-particle clusters are more efficient in improving thermal conductivity than that of individual dispersed nanoparticles because the clustered nanoparticles may provide a longer path for heat transfer [9]. Nanofluids containing a small amount of metallic or nonmetallic nanoparticles like Cu [10], Al_2O_3 [11], CuO [12], SiC nanoparticles or nanotubes [13] are synthesized and studied by several research groups. It has been found that the thermal conductivity of a nanofluid having 0.3vol% Cu nanoparticles dispersed in ethylene glycol increased by up to 40% over that of pure ethylene glycol [14]. Cu nanofluids can be prepared by dispersing Cu nanoparticles into base liquids either by step-by-step method or by one-step methods that combine the preparation of nanoparticles with the preparation of nanofluids, so that the processes of drying, storage, transportation, and redispersion of Cu nanoparticles are avoided hence agglomeration of nanoparticles may not take place in this method. Recently, Yadav *et al*. [15-18] have measured ultrasonic attenuation in nanofluids having various concentrations and correlated it to thermo-physical property of the nanofluid. Biwa *et al.* studied the ultrasonic wave attenuation and ultrasonic velocity in suspensions containing metallic or non-metallic solid particles of micrometer and millimeter size, aiming to find out the mechanism that can be correlated to particle size, concentration and mechanical properties of the constituents.

2. Experimental

$CuCl_2.2H_2O$ and PVA were received from M/s Merck Chemicals & Reagents. The freshly prepared homogeneous colorless solutions of PVA in water have been used for nanofluids containing Cu nanoparticles. Ultraviolet-Visible (UV-VIS) spectroscopy, X-ray diffraction (XRD) and Transmission Electron Microscopy (TEM) are the main characterization tools used to study the formation of metal nanoparticles. The absorption spectrum of nanofluids was recorded using a Lambda 35, Perkin-Elmer double beam UV-visible absorption spectrometer, using a 1 cm quartz cell. A thick film of the nanofluid was dried on the glass plate for X-ray diffraction analysis. XRD measurement was done by X'Pert-Pro, PANalytical (with CuKα radiation λ=1.5406 Å) operating at room temperature. The particle size and its distribution were analyzed with E.M.-C.M.-12 (Philips) transmission electron microscope operating at 200 KeV. The samples for TEM measurements were prepared by dropping the colloidal solution onto a copper grid.

3. Result and Discussion

The absorption spectra and XRD pattern of Cu-PVA nanoparticles-liquid suspension are shown in Figs. 1 and 2 respectively.

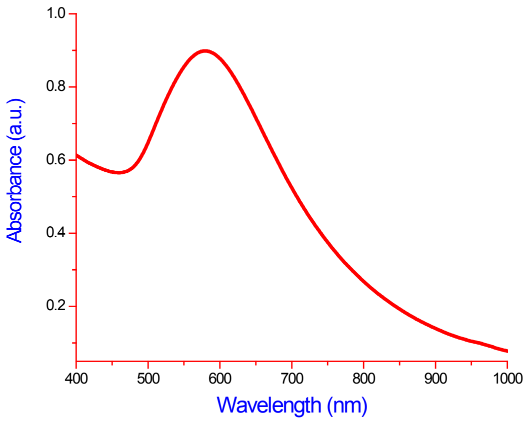

Figure 1: UV-Visible spectrum of 0.2wt% Cu nanoparticles-PVA suspension

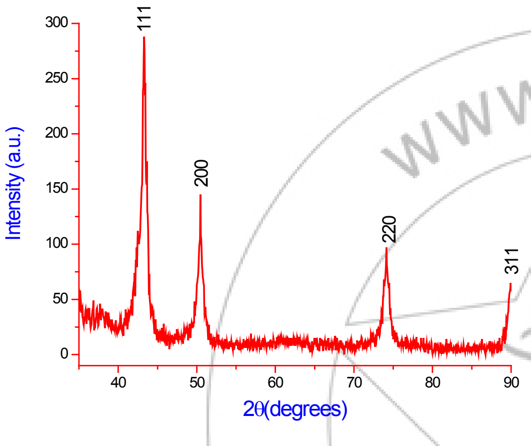

Figure 2: XRD pattern of 0.2 wt% Cu nanoparticles- PVA suspension

The UV-visible spectrum shows strong absorption peaks at 580 for 0.2 wt% Cu-PVA nanofluids. The sharp absorption peak indicated narrow size distribution of Cu metal nanoparticles in PVA. All the nanofluid samples showed symmetrical peaks due to the surface plasmon resonance of metal nanoparticles. The peaks typically represent the formation of small metal nanoparticles in the solution. The UV-visible spectrum suggests that Cu salts have been reduced by PVA. The XRD analysis of the nanofluids has confirmed the formation of metallic copper nanoparticles in the solution. XRD results reveal that the Cu metal nanoparticles are cubic crystalline (F_{m3m} space group).

Fig. 3 shows the TEM image of the Cu-PVA nanofluid. The average size is seen to be about 10 nm. The selected area electron diffraction pattern (SAED) patterns of Cu metal nanoparticles in PVA is shown in Fig. 4 showing the crystalline structure of Cu metal nanoparticles. The copper nanoparticles are well dispersed in colloidal solution as evinced by TEM micrographs.

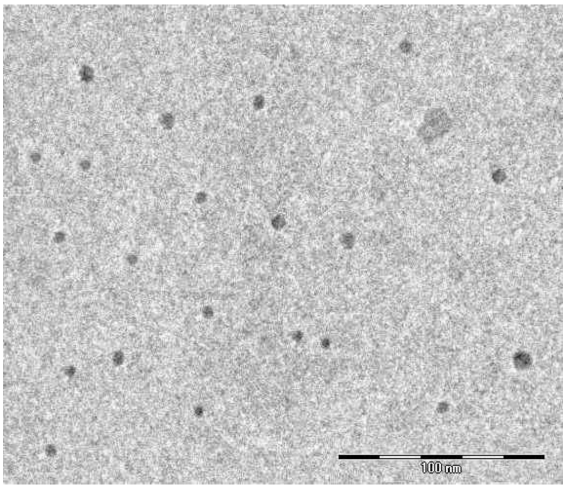

Figure 3: TEM micrograph of 0.2 wt% Cu nanoparticles-PVA suspension

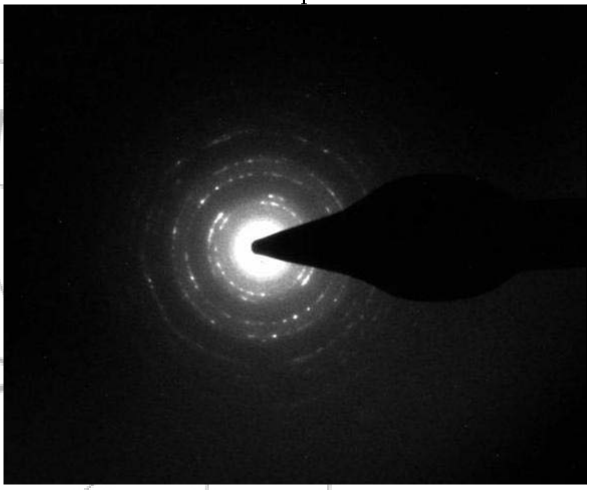

Figure 4: SAED pattern of 0.2 wt% Cu nanoparticles- PVA suspension

Figs. 5 and 6 show the temperature dependent ultrasonic velocity and ultrasonic absorption for different samples of Cu-PVA nanoparticles-liquid suspensions respectively.

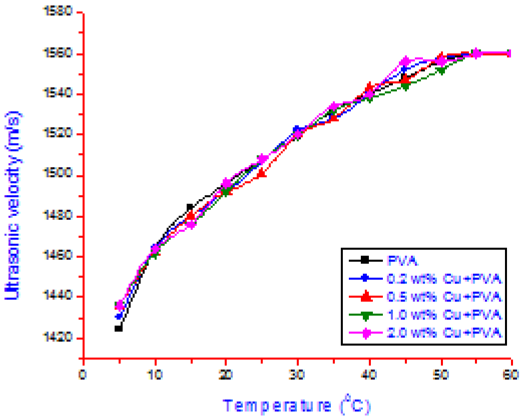

Figure 5: Temperature dependent ultrasonic velocity in Cu-PVA nanofluids

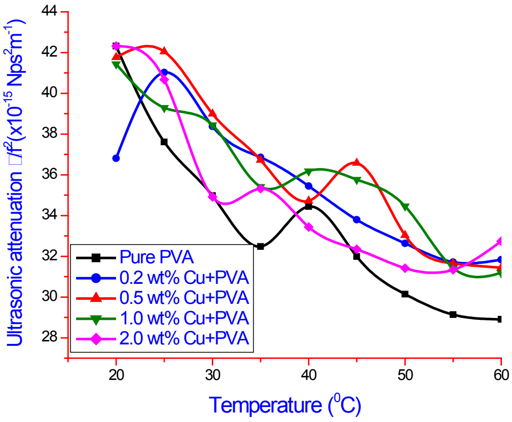

Figure 6: Temperature dependent ultrasonic attenuation in Cu-PVA nanofluids

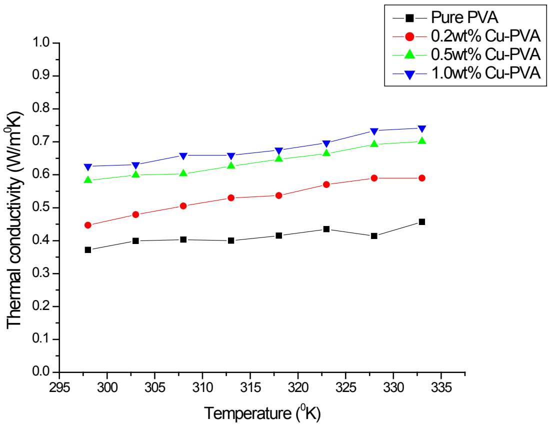

Figure 7: Thermal Conductivity of Cu-PVA nanofluid at different temperatures.

The variation of ultrasonic velocity with temperature is almost same for all concentrations of Cu metal nanoparticles. For Cu-PVA, there is no distinct minimum in ultrasonic velocity with temperature. Now the ultrasonic absorption is measured for the Cu-PVA colloids. The measurement is done for different concentration/ temperature of the sample. Fig. 6 shows that the maximum attenuation appears in 0.5 wt% Cu nanoparticles-suspended in PVA.

In general, as in other materials [19], both the ultrasonic velocity and attenuation are quite sensitive to the particle size, morphology and dispersion of the particles. The effective attenuation in the Au-PVA colloidal nanofluid can be expressed as

$$\alpha = \alpha_p + \alpha_m + \alpha_{pm}$$

where α_p is the contribution from the Cu- metal, α_m is the counterpart contribution from the polymer matrix, α_{pm} describes the change in the final α- value owing to a macroscopic interaction between the two components in Cu-PVA nano-colloid structure and associated modified thermo-physical properties of the nanofluid. S. Biwa and coworkers [20] analyzed the ultrasonic absorption in millimeter sized particles- reinforced polymers by a differential scheme and found good agreement between the theory and experiments. The wave attenuation in these composites is a complex process where the viscoelastic loss and the scattering loss coexist.

Fig. 7 shows the thermal conductivity of the nanofluid due to dispersion Cu nanoparticles in base fluid PVA.

Nanofluids have anomalously high thermal conductivities at very low nanoparticles concentrations [14, 21, 22]. To date, the exact mechanism of thermal transport in nanofluids is not fully known, and several possible mechanisms based on theoretical models, experiments and previous heat transfer theory have been suggested to describe experimental results on thermal conductivity of nanofluids. Brownian motion of suspended nanoparticles is attributed as one of the key factors of the greatly enhanced thermal conductivity performance and it was not considered in conventional thermal transport theory. U. S. Choi *et al.* proposed the theoretical model that accounts for the fundamental role of dynamic nano particles in the nanofluids [1]. They have derived a general expression for the thermal conductivity of nanofluids involving different modes of energy transport in the nanofluids. The important mode is thermal interaction of dynamic or dancing nanoparticles with base fluid molecules. Even though the random motion of nanoparticles is zero when time averaged, the vigorous and relentless interactions between liquid molecules and nanoparticles at the molecular and nanoscale level translate into conductions at the macroscopic level, because there is no bulk flow. Moreover, the thermal conductivity model not only captures the concentration and temperature dependent conductivity, but also predicts strongly size-dependent conductivity. As we have seen the thermo-elastic ultrasonic attenuation (dissipative type attenuation) is directly proportional to the thermal conductivity of the composite and the attenuation due to scattering for the nanoparticles is almost negligible. Further, the observed anomalous enhancement in thermal conductivity is also justified with another model by Das *et al.* [23], which is the composite model consisting stationary particle model approach and moving particle approach to calculate effective thermal conductivity of nanofluids. In stationary particle model approach, it is assumed that the heat conduction happens by two paths as through highly conducting nanoparticle medium and through liquid medium. This assumption explains the thermal conductivity enhancement due to particle concentration. According to this assumption, the thermal conductivity enhancement will be directly proportional to ratio of thermal conductivities and volume fraction of nanoparticles and liquid matrix and inversely proportional to particle radius. From Das *et al.*, it can be written as-

$$\left(\frac{K_{eff}-K_m}{K_m}\right)=c.\bar{u}_p\,\frac{\varepsilon r_m}{K_m(1-\varepsilon)r_p}\ ,$$

where $(K_{eff} - K_m)/K_m$ is enhancement factor of thermal conductivity in nanofluids. It is also evident from this model that the thermal conductivity of inhomogeneous liquid mixtures is inversely proportional to viscosity of the liquid medium. Since the viscosity of the liquid medium *i.e.,* base fluid decreases with increase of temperature and results in further increase in particle velocity and thus thermal conductivity. This model is better in molecular size regime and may not be considered better when the concentrations of the nanoparticles are much higher so that the inter-particle interactions become important. Thus it may reflect better correlation with our experimental data for smaller particles. As we have used small amounts of nanoparticles in preparation of nanofluids, the fluidic properties of liquid are almost unaffected for the easy flow of liquids in order to better transfer of heat from one place to other. The low dimensional copper nanoparticles reinforced nanofluids have much higher thermal conductivity and stability for heat transfer applications because of smaller dimension of nanoparticles. Therefore, we predict that the effective enhanced thermal conductivity of the nanofluid has such an impressive effect as the excess attenuation on the total ultrasonic attenuation behaviour.

4. Conclusions

- We have successfully synthesized the nanofluids containing copper nanoparticles.
- UV-visible, XRD and TEM measurements confirms the formation of Cu nanoparticles in PVA.
- Ultrasonic absorption in nanofluids shows interesting behavior.
- Experimental results show that the behavior of ultrasonic attenuation is well related to the enhancement in the thermal conductivity of PVA due to Cu nanoparticles.

References

[1] S.U.S. Choi, in: D.A. Siginer, H.P. Wang (Eds.), Developments and Applications of Non-Newtonian Flows, vol. FED 23, American Society of Mechanical Engineers, New York, 1995, pp. 99-105.
[2] S.K. Das, S.U.S. Choi, W. Yu, T. Pradeep, Nanofluids: Science and Technology, J. Wiley & Sons, Hoboken, NJ, 2008.
[3] M. Chandrasekar, S. Suresh, A Review on the Mechanisms of Heat Transport in Nanofluids, Heat Transfer Engineering 30 (2009) 1136-1150.
[4] S. Özerinc¸, S. Kakac¸, A.G. Yazıčgolu, Enhanced thermal conductivity of nanofluids: A state-of-the-art review, Microfluidics andNanofluidics 8 (2009) 145-170.
[5] J.H. Lee, S.H. Lee, C.J. Choi, S.P. Jang, S.U.S. Choi, A Review of Thermal Conductivity Data, Mechanisms and Models for Nanofluids International Journal of Micro-Nano Scale Transport 1 (2010) 269-322.
[6] V. Trisaksri, S. Wongwises, Critical review of heat transfer characteristics of nanofluids, Renewable and Sustainable Energy Reviews 11 (2007) 512-523.
[7] X.Q. Wang, A.S. Mujumdar, Heat transfer characteristics of nanofluids: a review, International Journal of Thermal Sciences 46 (2007) 1-19.
[8] Y.M. Xuan, Q. Li, W.F. Hu, Aggregation structure and thermal conductivity of nanofluids, AIChE J. 49 (2003) 1038.
[9] T.K. Hong, H.S. Yang, C.J. Choi, Study of the enhanced thermal conductivity of Fe nanofluids, J. Appl. Phys. 97 (2005) 064311.
[10] Y. Xuan, Q. Li, Heat transfer enhancement of nanofluids, Int. J. Heat Fluid Flow 21 (2000) 58-64.
[11] S. Lee, S.U.S. Choi, S. Li, J.A. Eastman, Measuring Thermal Conductivity of Fluids Containing Oxide Nanoparticles, ASME J. Heat Transfer 121(1999) 280.
[12] H.Q. Xie, J.C. Wang, T.G. Xi, Y. Liu, Journal of Chinese Ceramic Society, 29 (2001) 361.
[13] S.U.S. Choi, Z.G. Zhang, W. Yu, F.E. Lockwood, E.A. Grulke, Anomalous thermal conductivity enhancement in nanotube suspensions, Appl. Phys. Lett. 79 (2001) 2252.
[14] J.A. Eastman, S.U.S. Choi, S. Li, W. Yu, L.J. Thompson, Anomalously increased effective thermal conductivities of ethylene glycol-based nanofluids containing copper nanoparticles Appl. Phys. Lett. 78 (2001) 718.
[15] G. Mishra Ph.D. Thesis Titled “Non Destructive Evaluations of Advanced Functional Materials”, in Allahabad University (2009).
[16] R.R. Yadav, Giridhar Mishra, P.K. Yadawa, S.K. Kor, A.K. Gupta, Baldev Raj, Ultrasonic properties of nanoparticles-liquid suspensions, Ultrasonics 48 (2008) 591.
[17] D.K. Singh, D.K. Pandey, R.R. Yadav, Devraj Singh, Characterization of CrO_2-poly-vinyl pyrrolidone magnetic nanofluid, Journal of Magnetism and Magnetic Materials 324 (2012) 3662.
[18] MeherWan, R.R. Yadav, K.L. Yadav, S.B. Yadav, Synthesis and experimental investigation on thermal conductivity of nanofluids containing functionalized Polyaniline nanofibers, Experimental Thermal and Fluid Science 41 (2012) 158.
[19] Mougin, D. Wilkinson, K.J. Roberts, R. Jacks, P. Kippax, Powder Techno. 134 (2003) 243.
[20] S.Biwa, Y. Watanabe, S. Motogi, N. Ohna, Ultrasonics 43 (2004) 5.
[21] S.P. Jang, S. U. S. Choi, Appl. Phys. Lett. 84 (2004) 4316.
[22] J. Garcia-Serrano, A.G. Galindo, U. Pal, Solar Energy Materials & Solar Cells 82 (2004) 291.
[23] D. Hemanth Kumar, Hrishikesh E. Patel, V. R. Rajeev Kumar, T. Sundararajan, T. Pradeep, and Sarit K. Das; Model for Heat Conduction in Nanofluids 93 (14) (2004) 144301-4