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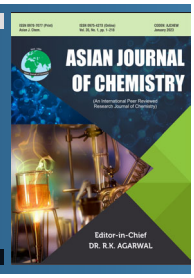

Role of Nanoparticles in Acoustical and Dielectric Measurements using Binary Non-Polar Fluid

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In this work, the experimental values of dielectric constant and acoustical parameters for binary mixture (benzene + diethylamine) and hybrid CuO nanofluid (CuO + diethylamine + benzene) were studied for various molar fraction from 0.01 to 0.06 M with different temperatures ranging from 298 to 318 K. Molecular interaction depends on the concentration, inclusion of CuO nanoparticles and temperature. FTIR analyses also revealed that despite the rise in temperature, no bond breakdown between the molecules is found. The results demonstrate that the weak interaction due to van der Waals forces exist between the unlike molecules due to dipole-induced dipole interactions.

Keywords: Hybrid CuO nanofluid, Acoustical parameters, Dielectric constant and molecular.

INTRODUCTION

Nanofluids is a colloidal mixture of nanosized particles (1-100 nm) in a base fluids and generally applied to increase heat transfer in several applications [1-3] as they exhibit a number of novel thermal transport phenomena. Common examples of base fluids are water, oil, ethylene glycol, *etc*. and when nanoparticles are present, these fluids act more or less like pure fluids, so there is little pressure drop and no need for surfactants [4,5]. The addition of even trace amounts of particles on the nanosize significantly increases the heat conductivity of the nanofluid, which is perhaps its most peculiar characteristic [6,7]. Ultrasonic studies are generally used to explain the intermolecular interaction between the molecules in the several types of liquids like binary liquids, ternary liquids, hybrid fluids, *etc*. [8,9]. In liquid mixtures, changes in the structure are correlated with the variations in the ultrasonic velocity and their related parameters. This hold true for the mixtures with both weakly and strongly interacting components [10].

This study has been made to understand the ultrasonic and dielectric behaviour of binary liquid (benzene + dimethylamine) and hybrid nanofluid (CuO + benzene + dimethylamine). The acoustical parameters (β, L_f and Z) have been calculated from the experimentally measured values of ultrasonic velocity and density. Dielectric constant (ε) was also measured for the same samples using dipole meter. From the results, it is evident that ultrasonic and dielectric studies provide complete information about van der Waals forces between the molecules, intermolecular inter-action between the ions and dipole-induced dipole interaction. The addition of CuO nanoparticles in the binary liquid will not result any breakage of bond between the molecules, which has been competently explained with the FTIR studies.

EXPERIMENTAL

Preparation of binary liquid: The binary mixtures were prepared by mixing the required amount of the pure liquids in a cleaned and dried bottle. In this study, diethylamine (DEA) was employed as solute while benzene as solvent. The binary liquids of various concentrations of DEA ranging from 0.01 to 0.06 M were prepared. To ensure the uniform mixing of binary liquids, the liquid mixture was sonicated in the ultrasonic bath for 5 min.

Preparation of hybrid CuO nanofluid: A pure copper oxide nano powder was purchased from Reinste Plasma Chem GmbH. Rudower chaussee 29; D-12489 Berlin. Six different concentrations of DEA ranging from 0.01 to 0.06 M and CuO nanoparticles weighing from 0.01 to 0.06 g were added in the different varying DEA + benzene binary liquids. After the addition of CuO nanoparticles in to the binary liquid, in order to maintain the uniform suspension, the solution was sonicated for 45 min at room temperature. The stability of the hybrid

CuO nanofluids was maintained for 8 h without adding the surfactant.

Procedure: All the chemicals procured for the experiment are of analytical grade and used without further purification. The liquid mixture of various concentration was prepared with the specific mole fraction in an air tight containers to avoid the evaporation and contamination of the organic liquid. The ultrasonic velocity of the binary liquid and hybrid CuO nanofluid have been measured for various molar concentration from 0.01 to 0.06 M using an Ultrasonic Interferometer working at a fixed frequency of 2 MHz supplied by Mittal Enterprises, New Delhi. The density was measured in 5 mL gravity bottle with accuracy of ± 2 parts in 10^4. In this work, the adiabatic compressibility (β), free length (L_f), acoustical impedance (G) were evaluated from the measured values of ultrasonic velocity and density. The liquid mixture immersed in a temperature controlled water bath at various temperature ranges from 25 to 45 ºC. The dielectric constant values of the binary liquids and hybrid CuO nanofluids were measured using a dipole meter (supplied by Mittal enterprises, New Delhi) for the same molar concentration and temperature.

RESULTS AND DISCUSSION

When added the CuO nanoparticles to the binary mixture of benzene + diethylamine, the ultrasonic velocity values were higher at all the concentrations compared with the velocity values obtained in the respective binary liquids. This may due to the suspension of nanoparticles, which induces the particle-fluid interaction, which in turn increases the ultrasonic velocity values of hybrid nanofluid compared to the binary liquid (Fig. 1). As temperature increases, the ultrasonic velocity values decrease for CuO + DEA + benzene nanofluid systems. This may be due to the rapid movement of the molecules of fluids [11]. In the case of acoustical parameters of hybrid nanofluid, values of the acoustical impedance (Z) follows the same trend as ultrasonic velocity values and the reverse trend is followed by the values of adiabatic compressibility (β) and intermolecular free length (L_f).

Many researchers have also studied the dielectric properties of the nanofluid in terms of frequency [12]. Herein, the value of the dielectric constant (ε) in terms of concentration and temperature were also evaluated. When diethylamine (DEA)

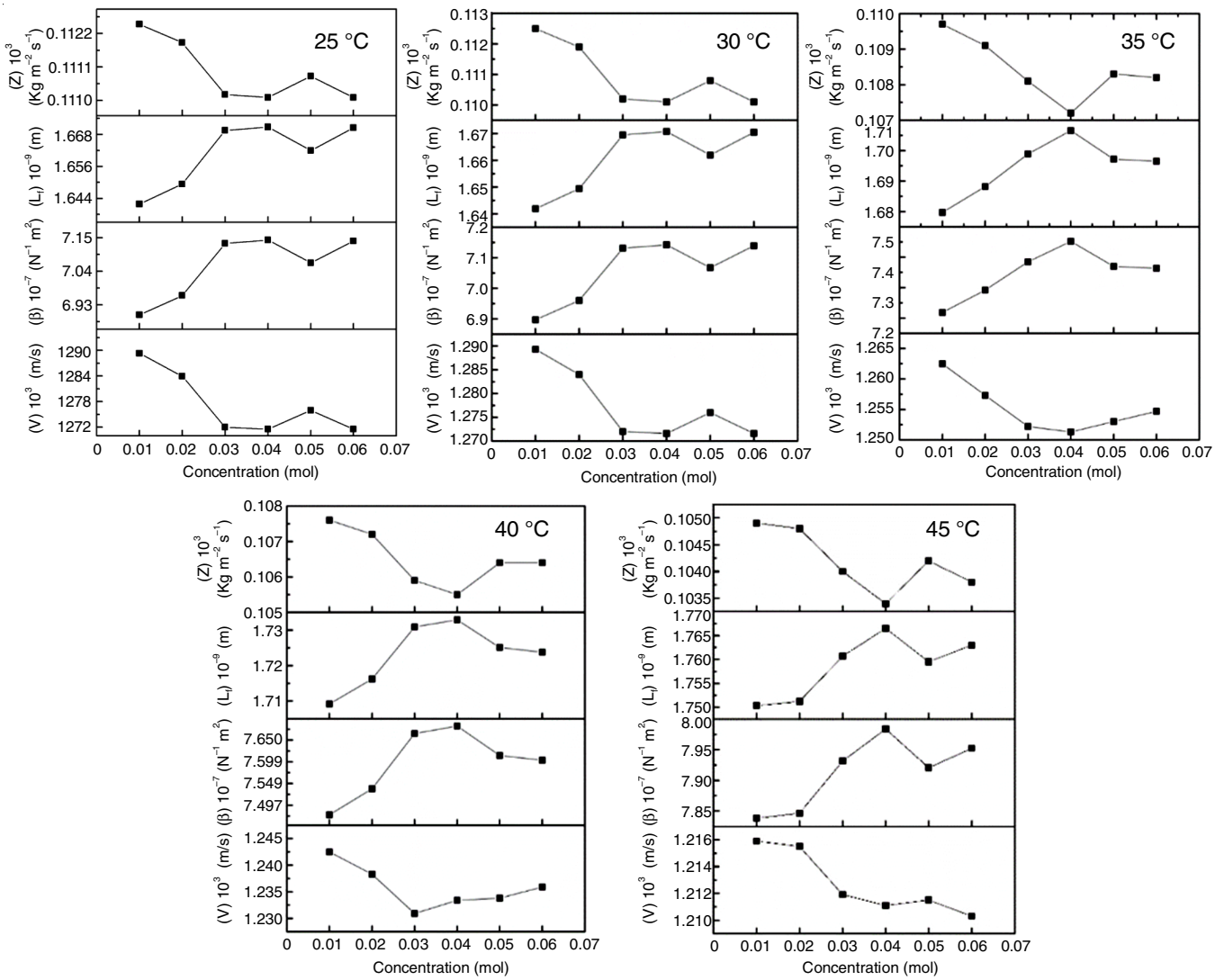

Fig. 1. Variation of ultrasonic velocity (v), acoustical parameters (β, L_f, Z) with the concentration of CuO nanofluid at different temperature

as solute was added to benzene, the dielectric constant value increases as the concentration increases but decreases with the increase of temperature. It is due to the N-H bonding in diethylamine. The addition of DEA has no effect on the value of ε in the binary liquid, but results in the weak molecular interactions, however, this weak bonding gets altered when increasing the temperature.

The dielectric investigations of the non-polar hybrid nanofluids (CuO + DEA + benzene) show the very low dielectric constant value (Fig. 2). Thus, there is no possibility for the dipole-dipole interaction between the non-polar molecules, but compared to it corresponding binary liquids, it is evident that the addition of CuO nanoparticle may produce the induced dipole interaction between the molecules of liquid and the nanoparticle. The weak interaction is existing due to the van der Waals force between the molecules.

FTIR studies: The FTIR spectra (Fig. 3) confirmed that no chemical reaction takes place in the prepared non-polar hybrid CuO nanofluid [13]. However, as compared to the peaks observed between 2800-1000 cm^{-1} for the binary liquid,

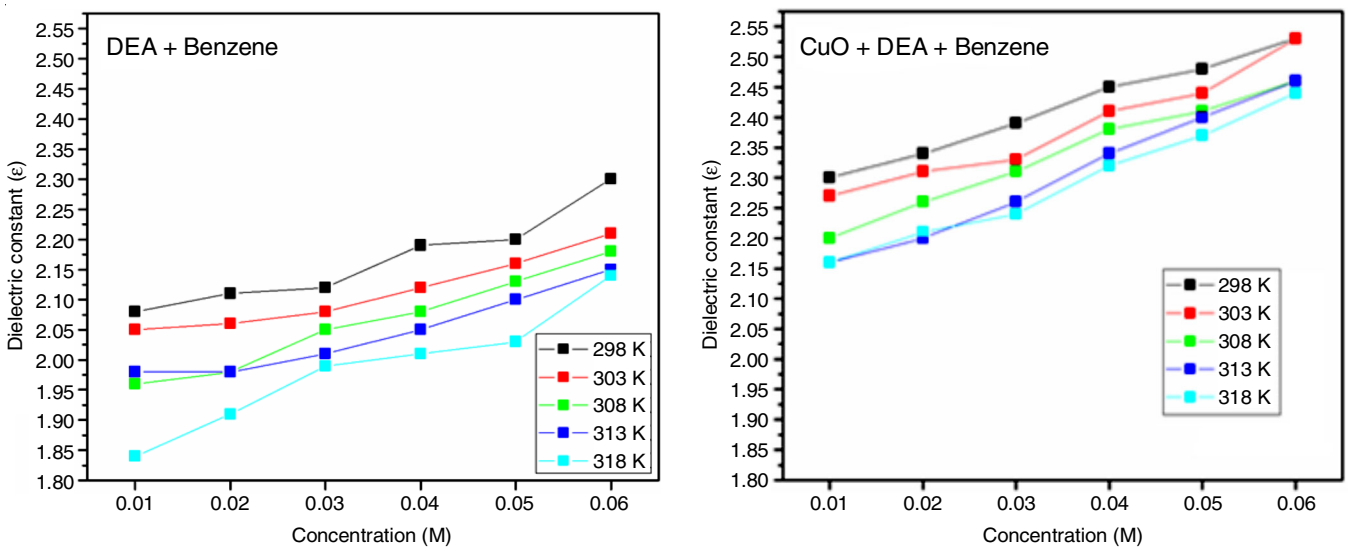

Fig. 2. Molar concentration *versus* dielectric constant for binary liquid (benzene + DEA) and hybrid CuO nanofluid (benzene + DEA) (298 K to 318 K)

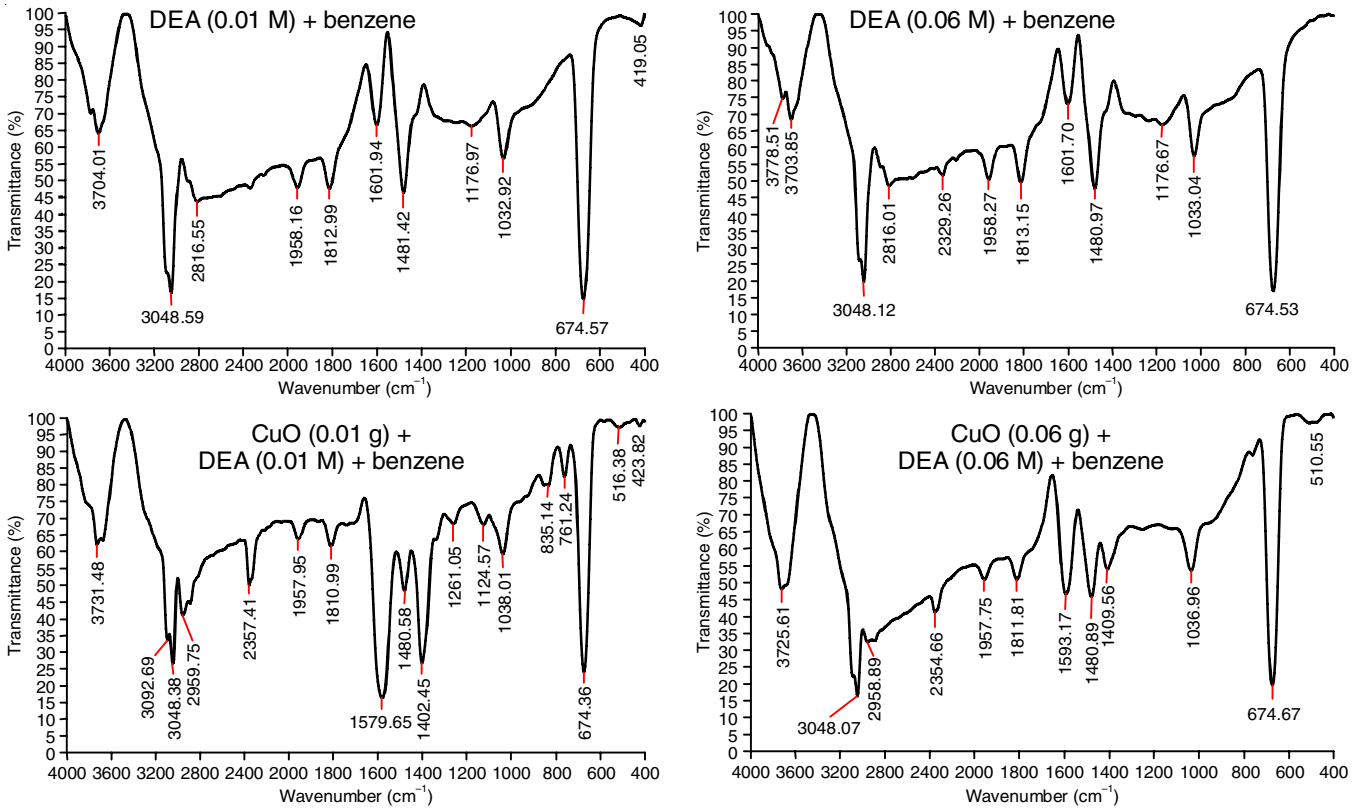

Fig. 3. FTIR spectra of binary liquid and hybrid nanofluid (CuO + benzene + DEA)

the slight shift of peaks was observed in case of hybrid CuO nano-fluid and also the greater number of peaks presence confirms the interaction of CuO nano particle with the fluid.

Conclusion

The ultrasonic and dielectric studies are the effective tool to understand the physico-chemical behaviour of the molecules in the liquid mixtures. This work has been proposed to study about the physical properties of the nanofluid and perceive the mechanism of fluid flow in nano level. The acoustical parameters using ultrasonic velocity and dielectric constant were calculated for the CuO nanofluid in benzene and diethylamine system at various temperatures with different mole fractions. The variation of the parameters predominant due to the addition of CuO nanoparticles. This information confirms the particle-fluid interaction between the molecules. The value of dielectric constant (ε) increases with the increase in temperature and concentration. Addition of the CuO nanoparticles in the binary liquid (diethylamine + benzene), a significant increase in the value of dielectric constant (ε) in hybrid CuO nanofluid was observed. A shift in the C-C and C-H bonds confirmed the induced dipole interaction exist in the nanofluid system as supported by FTIR spectra. In addition, the absence of changes in the FTIR peaks demonstrated that the nanofluids were not contaminated during the study.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interests regarding the publication of this article.

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