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Optimization of Bath Ultrasonication to Improve Thermal Conductivity of CuO Dispersion in Ethylene Glycol

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Abstract: Copper oxide nanoparticles of particle size range 25-30 nm were synthesized and its morphology was characterized using scanning electron microscope. The crystallite size of CuO nanoparticle was 10.21 nm which was calculated from 2 theta values using Scherrer's formula. Copper oxide – ethylene glycol (EG) with low particle concentration of 0.1 vol % using bath sonication was formulated and its transport properties like thermal conductivity and viscosity were measured. The thermal conductivity enhancement was about 2.4 % and viscosity reduction was about 12.7 % at room temperature and makes it suitable for cooling applications.
Keywords: Copper oxide, ethylene glycol, thermal conductivity, viscosity.

Introduction

Most of the conventional coolants have limitations in their transport properties like low thermal conductivity, low thermal diffusivity, and low convective heat transfer coefficients [1]. Maxwell (1881) suggested that dispersing solid particles in such coolants would improve their thermal conductivity. Dispersion of milli/micron meter sized particles in base fluids have limitations like rapid settling of particles. Choi and Eastman (1995) [2] invented 'Nanofluids' which are referred as stable colloidal suspension of nanometer-sized particles in suitable base fluids. Generally, metals [3,4], metal oxides [5–7], CNTs [8–10], graphene [11,12] etc are used as nanomaterials. Commonly used base fluids are water [13–15], ethylene glycol [16], ethylene glycol-water mixture [17,18], mineral oil [19–21], propylene glycol [22–24] and propylene glycol-water [25] mixture. Nanoparticles have an advantage of having high surface to volume ratio and higher surface area. On dispersing it to the base fluid, the thermal conductivity enhancement is higher. Brownian motion, particle clustering and layering of base fluids molecules over particles contribute to thermal conductivity of nanofluids. Many nanofluids possess higher viscosity when nanoparticles added to the base fluids. In contrast, properly prepared glycol based nanofluids have reduction in viscosity due to addition of nanoparticles. Above all, nanofluid must also possess excellent colloidal stability [26,27].

In this present work, CuO nanoparticles were synthesized and CuO-EG nanofluids were formulated. Attempts have been also made to optimize the thermal conductivity and viscosity of CuO-Ethylene Glycol (EG) nanofluid using bath sonication.

Materials and methods

Materials

Copper acetate monohydrate was purchased from Merck, India. Sodium hydroxide and acetic acid were obtained from Fisher Scientific, India and Emplura®, India respectively. Ethylene glycol was procured from Vetec™, India. All the chemicals were used without any further purification.

Preparation & characterization of CuO nanoparticle

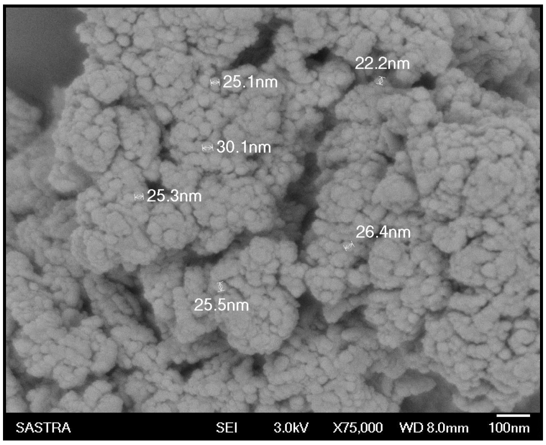
Copper oxide nanopowder was prepared using wet chemical precipitation method [28,29]. About 0.2 M copper acetate monohydrate precursor and acetic acid was stirred and heated up to boiling. 8 M NaOH solution was added to the boiling solution in a drop-wise manner and heated continuously for 2 hours. The color of the solution gradually changed from blue to black and a precipitate was obtained. This final solution was cooled to room temperature and was then filtered and dried in a hot air oven maintained at 100°C for about 8 hours. The black CuO powder obtained was then characterized using scanning electron microscopy and X-ray diffractometer to check its morphology, particle size and nature of crystallinity respectively.

Preparation and characterization of nanofluid

Two step method was adopted for the preparation of CuO-ethylene glycol (EG) nanofluid. A known quantity of CuO nanopowder was dispersed into a known volume of ethylene glycol and was homogenized for 20 minutes and sonicated it using bath sonication (Supersonics, 35±3 kHz, India). Nanofluid of 0.1 vol % was prepared and transport properties like thermal conductivity and viscosity were measured as a function of bath sonication time.

Thermal conductivity of the nanofluids and base fluid were measured using thermal property meter which utilizes the principle of transient hot wire (KD2 Pro, Decagon Devices, USA). The experimental setup consists of a thin metallic wire made up of stainless steel of 60 mm in length and 1.27 mm in diameter which was immersed into the sample. This wire acts both as the thermocouple and a line heat source. Viscosity of the nanofluids and the base fluid (EG) were measured using a rotational viscometer (LVDV-II + Pro, Brookfield Engineering, USA) of spindle size S-18 over a shear rate ranging from 20 – 200 rpm. All the measurements were carried out at least three times and the obtained results are of the form average ±standard deviation.

Results and Discussion



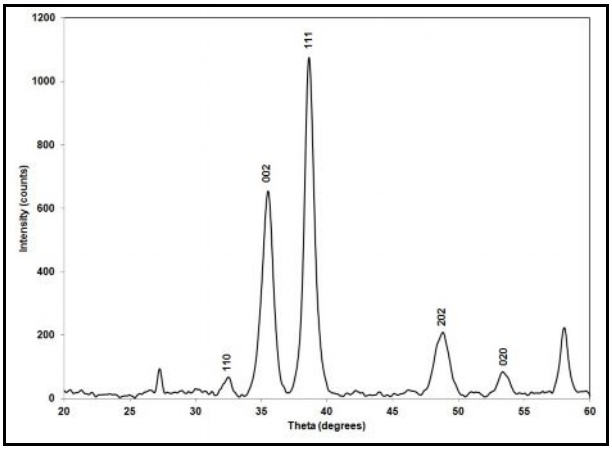


Figure 1. Scanning Electron Microscope image of CuO **Figure 2. XRD of CuO**

Scanning electron microscope image of the synthesized CuO nanoparticle was shown in figure 1. The morphology of the nanoparticle was found to be spherical with a particle size ranges between 25-30 nm. X-ray diffractogram (Figure 2) results had confirmed that synthesized nanoparticle was CuO with monoclinic structure by comparing the obtained results with the JCPDS database. The narrowness of the peaks represents the crystalline nature of the CuO nanopowder. The crystallite size of the synthesized CuO nanoparticle was found to be 10.21 nm which was calculated using Scherrer's formula.

Effect of sonication time on thermal conductivity

When nanoparticles were added directly to the base fluid, due to its higher surface area to volume ratio and higher surface energy, they tend to agglomerate each other. Many methods are in practice in order to separate the agglomerated nanoparticles. In this study we chose bath sonication for particle disintegration. Figure 3 shows the thermal conductivity of CuO-EG nanofluids of 0.1 vol % as a function of sonication time. As the bath sonication time increases, the thermal conductivity of nanofluid was found to increase gradually above the base fluid's thermal conductivity at room temperature and tends to remain constant after few hours of sonication. The thermal conductivity gets saturated at 6 hours for 0.1 vol % of CuO-EG nanofluid. The increase of CuO-EG nanofluid concentrations 0.1 vol % was found to increase by 2.4 %. From these results, it shows that the effective dispersion of nanofluid was obtained at saturated thermal conductivity values. A complete dispersion of nanoparticle in base fluid is required for many heat transfer applications in order to obtain higher thermal conductivity and excellent colloidal stability.

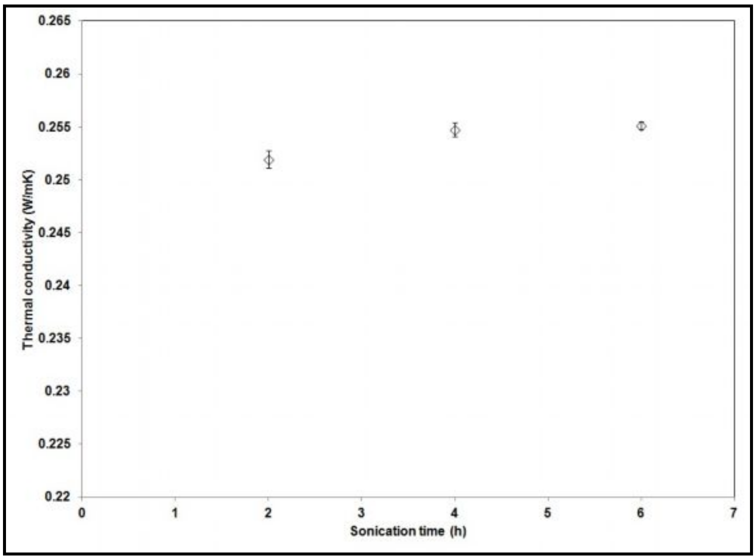


Figure 3. Effect of sonication time on thermal conductivity

Effect of sonication time on viscosity

Figure 4 shows the viscosity measurement plot of CuO-EG nanofluids of 0.1 vol % as a function of sonication time. As the bath sonication time increases, the dispersion viscosity of both the nanofluids gets decreased at room temperature when compared with the viscosity of the base fluid. The percentage reduction in viscosity of CuO-EG nanofluid of concentrations 0.1 vol % with respect to base fluid viscosity at room temperature was 12.7 %.

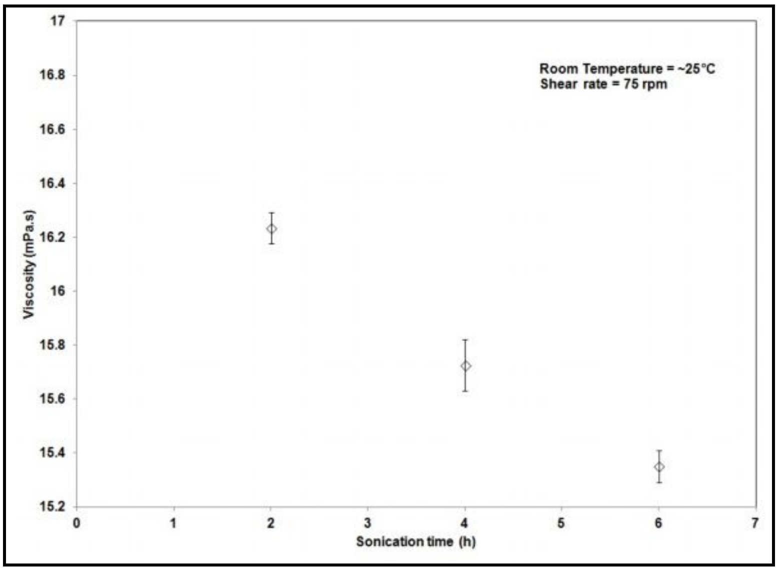


Figure 4. Effect of sonication time on viscosity

Conclusion

CuO nanoparticles were synthesized using wet chemical method and were characterized using SEM and XRD. The synthesized CuO nanopowders were dispersed in base fluid (EG) by using two step method and very low concentration of CuO-EG nanofluid (0.1 vol %) was prepared. Transport properties such as viscosity and thermal conductivity were measured at room temperature. The enhancement of thermal conductivity for 0.1 % CuO-EG nanofluid was 2.4 % and percentage reduction in dispersion viscosity was 12.7 % due to reduction in aggregate size. Hence bath sonication can be used to prepare low concentration CuO-Ethylene glycol nanofluids.

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