Stability and Thermal conductivity of SiC Nanofluids

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Abstract- *This article reports thermo stability and thermal conductivity of Silicon carbide (SiC) nanofluids in methanol base fluids. SiC nanoparticles has been synthesized via sol-gel method and SiC nanofluids were prepared by two step method. Stability of SiC nanofluids were studied by zeta potential measurement and thermal conductivity has discussed with help of experimental results. Average particle size has been estimated by using Debye-Scherrer formula, which is found to be 30 nm. The molecular properties of ultrasonic waves in nanofluids undergo changes in highly associated systems and dependent on the cohesive properties of nanofluids. In this study we have carried out an investigation on stability and thermal conductivity study of prepared SiC nanofluids in methanol.*

Keywords- SiC nanoparticles; Sol-gel technique; Zeta potential; thermal conductivity.

I. INTRODUCTION

It is well known that demand of nanofluids in different fields is continuously increasing due to rapid development of nanotechnology in current century. The nanofluids can helpful to enhance the thermal conductivity as well as use to increase the heat transfer coefficient of the fluid [1], which is applicable in many areas such as nuclear systems, electronic devices, heat exchanger systems, chemical industries and automobiles etc [2]. Dr. Choi [3], was the first who proposed the term nanofluids which is a colloidal suspension of nano-sized particles (1–100 nm) dispersed in base fluids to improve their thermal performances [4]. Therefore, this concept received great attentions from the researchers to study the superior heat transfer properties of nanofluid [5-8]. Nanofluid is the name presented by Argonne National Laboratory to describe the suspension of nanoparticles in a base fluid. The water, ethylene glycol and engine oil are use as base fluids which has a low thermal conductivity and the thermal conductivity of nanoparticles particles is typically of the order of magnitude higher than that of the base fluids. Thus, the addition of nanoparticles in the base fluid at lower concentrations shows the significant increases in thermal performance [9, 10]. Masuda et al. [11] studied the thermal conductivity of nanofluids using Al_2O_3(13 nm), SiO_2 (12 nm), and TiO_2(27 nm) nanoparticles suspended in water-based fluids. Recently, nanofluids also used as solar heat exchangers to improve heat transfer properties. Moreover, adding nonmaterial to conventional heat transfer fluids improves their thermal properties [12]. Hence nanofluid exhibit improvement in heat transfer properties compared to conventional fluids use in solar heat exchangers [13]. Use of nonmaterial in fluids provides a higher surface area than that of conventional fluids. Therefore, researchers find the potential scope of adding these nonmaterials to fluids and applications in heat transfer mechanism [14]. In this article we have reported the synthesis SiC nanoparticles and SiC nanofluid in methanol by two step chemical route and studied their thermal conductivity successfully.

II. EXPERIMENTAL DETAILS

2.1 Preparation of SiC nanofluids

For the preparation of SiC nanofluids, first we have synthesized the SiC nanoparticle, using the mixture of SiO_2:Mg in the molar ratio 1:2 which is heated in the furnace at 650°C for 6 hours. Latter for an acid etching process of the prepared product for 5 hour we have used a mixture of HF 10% wt and HNO_3 4 M respectively. Then this mixture is washed with the help of distilled water and dried at room temperature, finally we get SiC in powder form [15-17]. After then nano powder of SiC were well dispersed in methanol base fluid using a magnetic stirrer for 30 min. The surfactants were used to enhance the stability of nanoparticles in nanofluids. The mixture is kept in microwave heating upto the completion of reaction and the color of the mixture get changes. The final product obtained is SiC nanofluid [18].

III. RESULTS & DISCUSSION

X-Ray Diffraction (XRD) was obtained with a diffractometer 'PAN analytical,' Model: Xpert PRO, equipped with Cu Kα1 radiation. Zeta potential of SiC nanofluids was measured by means Zeta Potential Analyzer. Thermal conductivity was measured by Thermal conductivity meter model DTC-300.

3.1 X-Ray Diffraction (XRD)

Figure 1 shows the XRD pattern of Silicon carbide (SiC) nanoparticles reporting some silicon and carbon phases centered at 2θ = 350. The XRD measurement carried out using standard parameter such as [°2Th.]: 10.0154 End Position [°2Th.]: 89.9834, Step Size [°2Th.]: 0.0170, Scan Step Time [s]: 5.7150, Scan Type: Continuous, Measurement Temperature [°C]: 25.00 Anode Material: Cu, K-Alpha1 [Å]: 1.54060. From the observed pattern it is seen that reported pattern is well agreed with standard JCPDS file number 00-004-0756. To confirm the nanoscale nature, we have carried out the average crystallite size of the SiC nanoparticles using Debye Scherrer formula as indicated in the following equation (1), which is found to be approximately 30 nm.

$$D = \frac{0.9\lambda}{\beta Cos\theta} \quad \text{--} \quad (1)$$

In above equation β is the broadening caused by nanoparticles size, θ is the Bragg's angle and λ is the wavelength of X-ray beam.

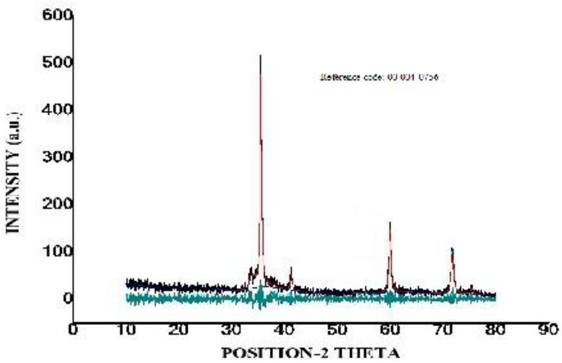

Fig. 1 X- ray diffraction pattern of Silicon carbide (SiC) nanoparticles

3.2 Zeta potential

Zeta potential of the prepared SiC nanofluids was measured by using Zeta potential analyser. It is the potential difference across phase boundaries between solids and liquids. It is used to measure the electrical charge of nanoparticles that are suspended in liquid and also measured the stability of the dispersion formed due to the reaction. It also applicable to study the surface charge in the dispersion medium. Hence, Zeta potential measurements is an important characterization method for surface stability of nanofluids. The positive or negative values of zeta potential are necessary to ensure the stability of nanofluids. It is used to avoid the aggregation of nanoparticles in nanofluids by varying the stabilizar concentration or by surface modification. Genearlly, the higher values either positive / negative or more than 30 indicates good stability. Zeta potentioal of SiC nanofluids in methanol with molar concentration is shown in figure 2. It is observed that zeta potential for molar concentration 0.3 and 0.6 have higher values indicating more stability of SiC nanofluids at these concentrations. Moreever it has less values for other molar concentration indicating less stability. The values of zeta potential has been greater than 30 either positive or negative for number of concentration exhibit the more stability of synthesized nanofluids.

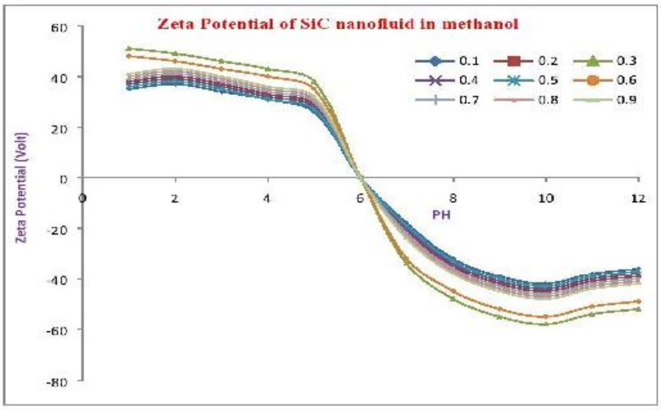

Fig. 2 Zeta potential of SiC nanofluids in methanol

3.3 Thermal Conductivity

Experimental studies show that thermal conductivity of nanofluids highly dependent on many factors such as particle volume fraction, base fluid material, particle shape and size, mixture combinations and slip mechanisms, surfactant, temperature and acidity of the nanofluid are effective in the thermal conductivity enhancement. Review of studies showed that the thermal conductivity increases by use of nanofluid compared to base fluid. Thermal conductivity can be represented as

$$T = 3 \left(\frac{N}{Vm}\right)^{\frac{2}{3}} K_B \, u \quad \text{..................................} (2)$$

Where, N is Avogadro's number (N= 6.02214078 x 10^{23}), Vm is the molar volume, K_B is the Boltzmann's constant (K_B = 1.3807 x 10^{-23} JK^{-1}) and u is sound velocity.

Figure 3 shows the variation of thermal conductivity with molar concentration of SiC nanofluids in methanol. The results clearly show that the effective thermal conductivity of nanofluid increases with temperature. It has substantially higher value at molar concentration 0.4 indicating more stability of nanofluids because of high specific surface area and therefore more heat transfer surface between nanoparticles and fluids. The thermal conductivity enhancements are highly dependent on specific surface area of nanoparticle, with an optimal surface area for the highest thermal conductivity. The strong relationship between Brownian motion and temperature of nanoparticles are also responsible for the nonlinear behavior of the nanofluids [19-29].

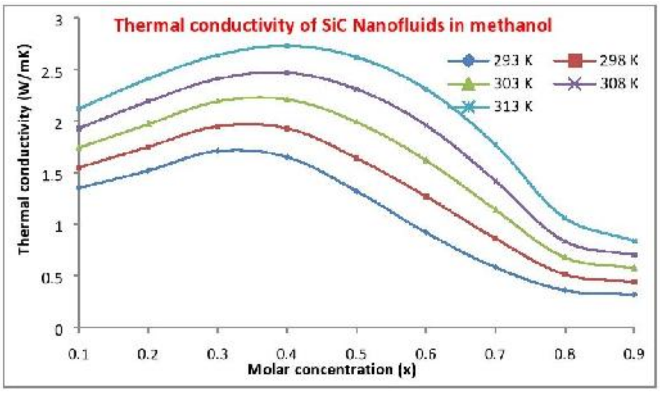

Fig. 3 Thermal conductivity of SiC nanofluids in methanol

IV. CONCLUSIONS

From the present study it is seen that the addition of nanoparticles into the base fluids has produced a considerable augmentation of the heat transfer coefficient that clearly increases with an increase of the particle concentration. The phase purity of the prepared nanoparticles and the thermal conductivity of the prepared nanofluid has been clearly indexed. The observed higher values of zeta potential indicate the stability of the SiC nanofluids.

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