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Stability of α-Alumina Nanofluids in Organic Base Fluid

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Highlights

- The thermoacoustic parameters of nanofluids are highly dependent on specific surface area to volume ratio of the nanoparticles in nanofluids.
- α- Alumina nanoparticles were synthesized via sol-gel method.

ABSTRACT

Nanoparticles of alpha alumina (α-Al_2O_3) was prepared via sol-gel method [4-7] from Aluminum isopropoxide [Al ($OC_3H_7)_3$] and aluminum nitrate. Starting solution was prepared by adding aluminum isopropoxide [Al ($OC_3H_7)_3$] gradually in 0.2 M aluminum nitrate and solution continuously stirred for 48 hours. Later, Sodium dodecylbenzen sulfonate (SDBS) was added and stirred for one hour. Now this solution was heated up to 60°C and stirred constantly for evaporation process. Now the paste so obtained was heated at 90°C for 8 hours, we get nanoparticles of alpha alumina (α-Al_2O_3) in powder form. The prepared sample was characterized by X- ray diffraction (XRD), Scanning electron microscopy (SEM), thermal conductivity and Zeta potential. Average particle size has been estimated by using Debye-Scherrer formula [8-9]. It was found to be in the range of 20-30 nm. Nanofluids of α-Al_2O_3 in methanol base fluid were prepared by two step method.

Keywords : α-Al_2O_3 Nanofluids; XRD; SEM; Zeta potential; Thermal conductivity

I. INTRODUCTION

α-Al_2O_3 is one of the most widely used oxide ceramic material. It is used in a variety of plastics, rubber, ceramics, and refractory products. As the α-phase ultrafine Al_2O_3 is a high-performance material of far infrared emission, it is used in fiber fabric products and high-pressure sodium lamp as far-infrared emission and thermal insulation materials. In addition, α-phase nano-Al_2O_3 with high resistivity and good insulation property, it is widely used as the main components for YGA laser crystal and integrated circuit substrates. Recently, advances in manufacturing technology have permitted the production of particles in the 10 nm to 100 nm range.

In the present investigation the synthesis of α-Al_2O_3 nanoparticles by sol-gel method is discussed. Thermal conductivity related to the surface of nanoparticle and nanoparticles surfactant interactions. α-Al_2O_3 nanoparticles with surface areas 30 nm have been prepared, their thermal conductivities and characterization have been investigated.

II. Preparation of Samples

Nanoparticles of alpha alumina (α-Al_2O_3) was prepared by sol-gel method [4-9] from Aluminum isopropoxide [Al (OC_3H_7)$_3$] and aluminum nitrate. Starting solution was prepared by adding aluminum isopropoxide [Al (OC_3H_7)$_3$] gradually in aluminum nitrate and solution continuously stirred for 48 hours. Later, Sodium dodecylbenzen sulfonate (SDBS) were added and stirred for one hour. The obtained solution was heated up to 60°C and stirred constantly for evaporation process. Now the paste so obtained was heated at 90°C for 8 hours, we get nanoparticles of alpha alumina (α-Al_2O_3) in powder form [8-13].

III. Results and Discussion

Spectroscopic Characterization:

The prepared sample was characterized for their phase purity and crystallinity by X-ray powder diffraction (XRD), FTIR and SEM. Formation of the compound confirmed by XRD pattern matched with the standard data available in JCPDS file. Average particle size of α-Al_2O_3 nanoparticles has been estimated by using Debye-Scherrer formula.

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

Where 'λ' is the wavelength of X-ray (0.15460 nm), 'W' is FWHM (full width at half maximum), 'θ' is the diffraction angle and 'D' is particle diameter (size). The estimate size of α-Al_2O_3 nano particles is found to be 30 nm. Nanofluids of α-A l_2O_3 nanoparticles were prepared by two step method in methanol base fluid.

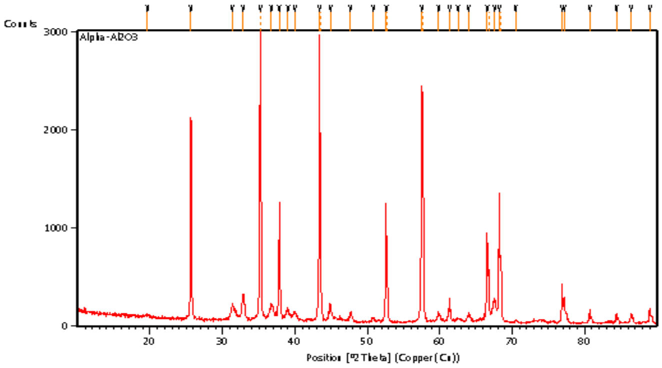

Fig.1 XRD pattern of α-Al_2O_3 nanoparticles

Fig.1 shows the XRD pattern of α-Al_2O_3 nanoparticles. The XRD measurement carried out by using "PAN analytical" X-ray diffractometer keeping the parameter constant at Start Position [°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. It is seen that the materials are well crystalline in nature and well agreed with standard JCPDS file no. 71-1127.

SEM

SEM study is carried out to observe the overall surface morphology and crystallite sizes of the prepared materials. This material has been synthesis by sol-gel method. From the SEM images are observed under 10 micrometer resolutions which show the foam like surface morphology as shown in fig.2. In the depicted images of α-Al_2O_3 materials, it can be clearly seen that the micrograph crystallite sizes may vary from a 10 μm to few microns range if we magnify further. The crystallite looks like having a sharp surface edge as well as crystalline grains and the particles foam like morphology, can be formed from highly agglomerated crystallites. Also, it is confirmed that the crystallite sizes are nearly equal for all sample [14-15].

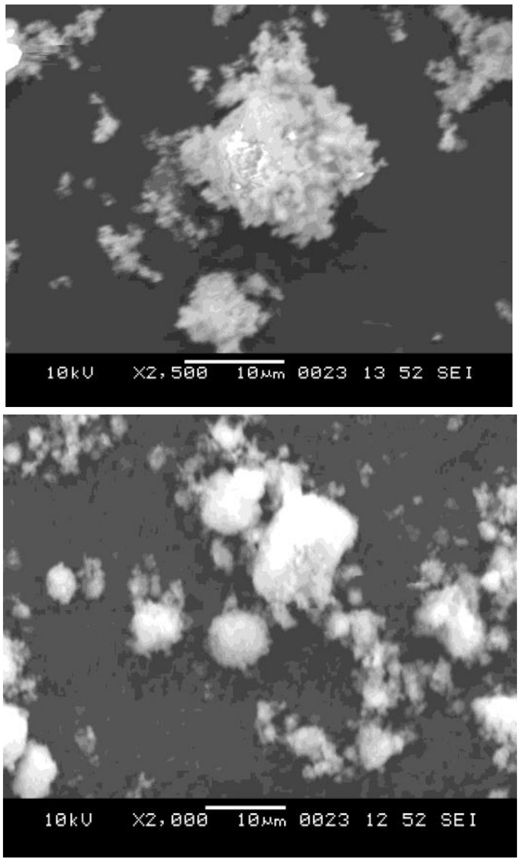

Fig.2 SEM images of α-Al_2O_3 nanoparticles

Zeta potential:

Zeta potential of the prepared α-Al_2O_3 nanofluids was measured by using Zeta potential analyser. It is the potential difference across phase boundaries between solids and liquids. It is observed that zeta potential for molar concentration 0.6 have higher values indicating more stability of α-Al_2O_3 nanofluids indicating in figure 3. Moreever it has less values for other molar concentration indicating less stability. From the graph the values of zeta potential has been greater than 30 either positive or negative exhibit the more stability of the nanofluids.

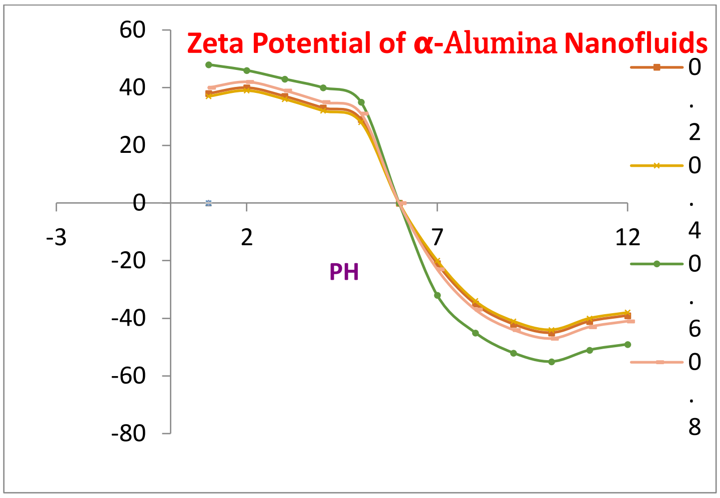

Fig.3 Zeta potential of the prepared α-Al_2O_3 nanofluids

Thermal conductivity:

Fig.4 shows the variation of thermal conductivity with molar concentration of α-Al_2O_3 nanoparticles in methanol base nanofluids. The results clearly show that the effective thermal conductivity of α-Al_2O_3 increases with temperature. It has substantially higher value at molar concentration 0.6 of α-Al_2O_3 in methanol base nanofluids. The thermal conductivity enhancements are highly dependent on specific surface area of nanoparticle, with an optimal surface area for the highest thermal conductivity. The results of Kumar *et al.* and Koo and Kleinstreuer show the strong relationship between Brownian motion and temperature of nanoparticles. Furthermore, the effect of temperature on thermal conductivity is not very well understood and documented.

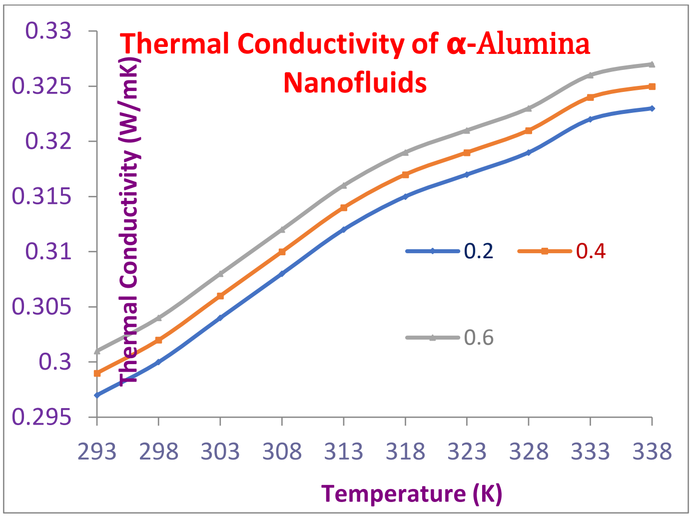

Fig. 4 Thermal conductivity of α-Al_2O_3 nanofluids at 20^{0}C, 25^{0}C and 30^{0}C.

IV. CONCLUSION

1. The structural, optical and thermal properties of the α-Al_2O_3 nanofluids are characterized by XRD, SEM and thermal conductivity.
2. The observed higher values of zeta potential indicate the stability of the α-Al_2O_3 nanofluids.
3. Characterization of α-Al_2O_3 nanoparticles via XRD and SEM shows its nanocrystalline formed.
4. Enhancement in thermal conductivity of α-Al_2O_3 nanofluids is due to the stability of α-Al_2O_3 nanoparticles in dispersion medium.

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