RESEARCH ARTICLE OPEN ACCESS

Transport properties of Gum mediated synthesis of Indium Oxide (In_2O_3) Nano fluids

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ABSTRACT
Two- Step method has been applied to prepare stable In_2O_3 nano fluids in Ethylene Glycol with PVP (Polyvinyl pyrrolidone) used as stabilizing agent having In_2O_3 concentrations of 1% by volume, where the In_2O_3 nano particles are obtained by biosynthesis of Indium (III) Acetyl Acetonate and Gum Acacia. Since the two-step method is more versatile as it provides the opportunity to disperse a wide variety of nano particles in different types of base fluids. The nano fluids were characterised by UV-vis spectroscopy, FTIR, SEM, EDAX, and TEM, and systematically investigated for Thermal conductivity (TC), density, viscosity, specific gravity and electrical conductivity for different polymer concentrations. The size of nano particles was found to be in the range of 5-30nm for two different nano particle to PVP ratios. For higher concentration of polymer in nano fluid, nano particles were 20nm in size showing increase in Thermal conductivity but a decrease in density and viscosity which is due to the polymer structure around nano particles. It is observed that the viscosity, density & specific gravity increases with the increase in PVP concentration and decreases with temperature. The thermal conductivity measurements of nano fluids show substantial increment relative to the base fluid (Ethylene glycol). Effect of PVP Polymer on viscosity, density, specific gravity can have a significant effect on magnitude and behaviour of the Thermal conductivity enhancement confirming the Newtonian behaviour of nano fluid. This offers tremendous scope for developing compact and effective heat transfer equipment. An enhancement of 20-25% for 1:5 volume concentration are observed at an average voltage of 60V when compared with EG (Ethylene glycol) at the same voltage. This method is simple, fast and reliable for the synthesis of Newtonian nano fluids containing In_2O_3 nano particles.

I. Introduction

Nano fluid is a term proposed by Choi in 1995 of the Argonne National laboratory U.S.A. In recent years, nano fluids have attracted more and more attention [1-5]. Research in nano fluids has many potential applications [6-11]. Most of the reviews are concerned of the experimental and theoretical studies of the thermo physical properties of nano fluids [12-17]. The two-step method is extensively used in the synthesis of oxide based nano fluids and it is the most economic method to produce nano fluids in large scale. Nano particles have the tendency to aggregate due to their high surface area and surface activity. The important technique to enhance the stability of nano particles in fluids is the use of surfactants. Several authors have argued that large TC increase is due to hydrodynamic effect of nanoparticles brownian motion [18,19]. Nano fluids have shown large enhancements in TC as compared to base fluid [20] temperature and particle size dependence [21, 22] reduced friction coefficient [23] and significant increase in critical flux [24]. In_2O_3 nano fluids are very stable due to the protective role of PVP, as it retards the growth and agglomeration of nano particles by steric effect. PVP is an efficient agent to improve the stability of suspension [25]. The steric effect of polymer dispersant is calculated by the concentration of the dispersant.

II. Experimental

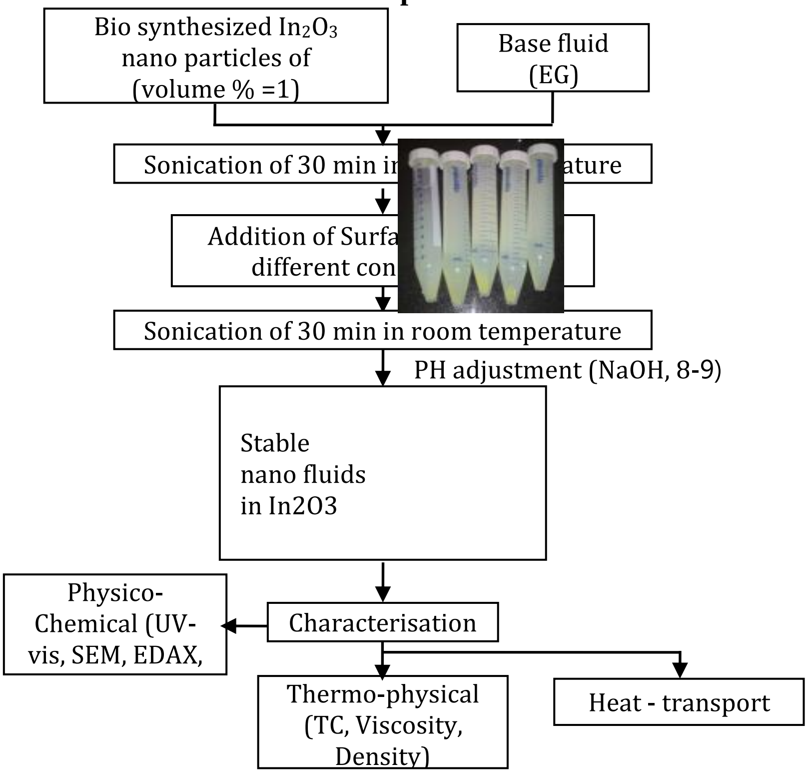


Fig.1 ***Flow chart of preparation of In_2O_3 nanoparticles***

Phase change materials (Indium nano particles) in Polyalphalefin [26] have been synthesized using a one step.

Table 1 Parameters for synthesis of In_2O_3 nano fluids

In_2O_3 : PVP weight ratio	**Description**
1:2	0.2g of In_2O_3 with 0.4g of PVP in 200 ml EG
1:3	0.2g of In_2O_3 with 0.6g of PVP in 200 ml EG
1:4	0.2g of In_2O_3 with 0.8g of PVP in 200 ml EG
1:5	0.2g of In_2O_3 with 1g of PVP in 200 ml EG

III. Characterization of nano fluids

UV-vis absorption spectrum (SHIMADAZU) has been recorded on Nano drop 1000 1-mm column in the wave length range (200-600 nm) at room temperature. SEM & EDX of In_2O_3 nano fluids on glass substrate is taken using HITACHI. TEM images have been taken by placing the nano fluid directly on copper grid and allowing the sample to evaporate naturally. FTIR spectrum was taken with a PerkinElmer Spectrometer. For this purpose, nano fluid is spread on NaCl crystal to form a film and subsequently dried in an oven for 15 minutes under low power allowing EG to evaporate. ANTON–PAAR Density Meter has been used to measure density and specific gravity of nano fluids in the temperature range of 30^{o}C–60^{o}C. CANNON-FENSKE kinematic viscometer bath is used to measure the viscosity in the temperature range of 30^{o}C-60^{o}C. Electrical conductivity measurements were done with Microprocessor-based conductivity meter at room temperature for different concentrations. Steady state parallel method (*Hilton Thermal Conductivity of liquids and gases Unit H471*) is used to measure the thermal conductivity of nano fluids. The thermal conductivity can be expressed as

$$K = \frac{Q_c \Delta r}{A \Delta t}$$

where, Q_c – Heat transfer by conduction through the base fluid; Δr – Radial Clearance, A – Area of conduction path, and Δt – Temperature difference.
so that the heat transfer coefficient is in linear behaviour with reference to the temperature difference/voltage.

IV. Results and Discussion

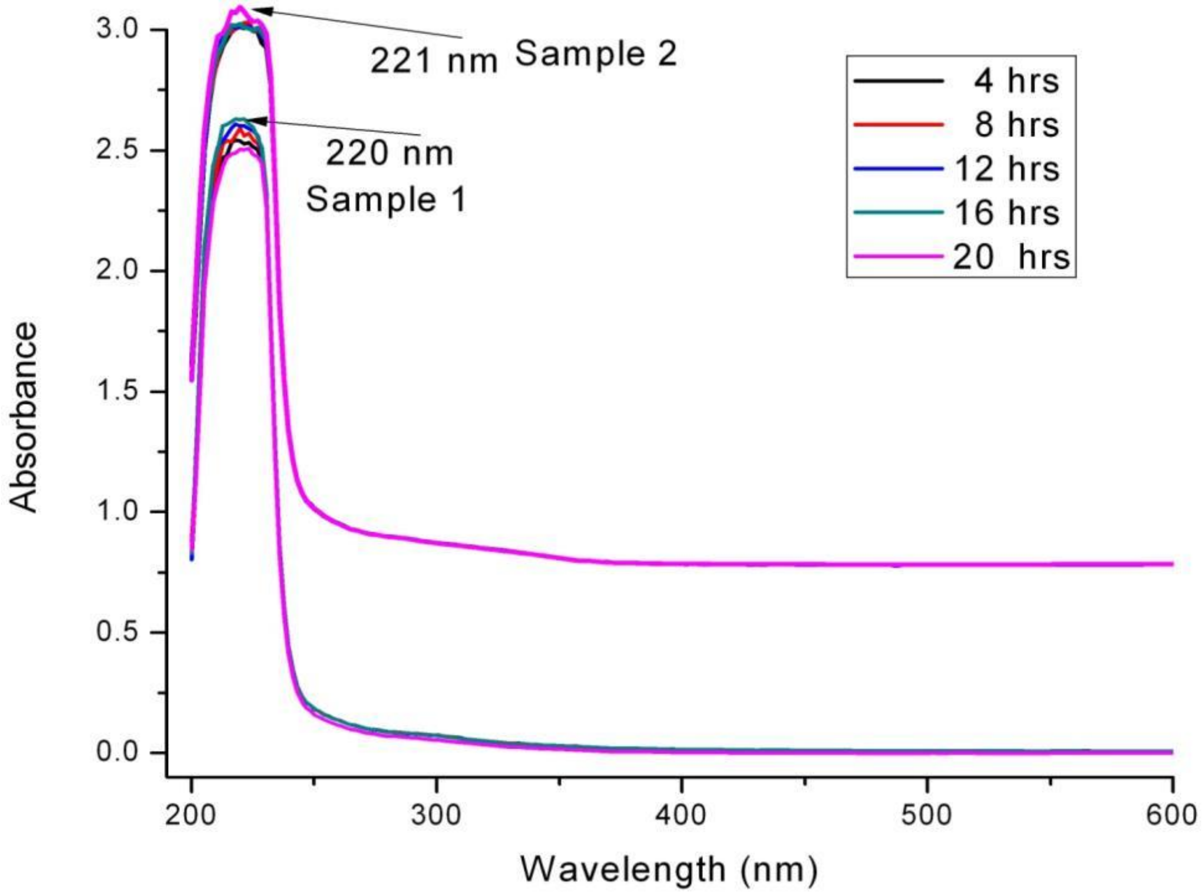


Fig.2 ***UV-Vis absorption Spectrum of 1:2 (Sample1) and 1:5 (Sample 2) of In_2O_3 nano fluids***

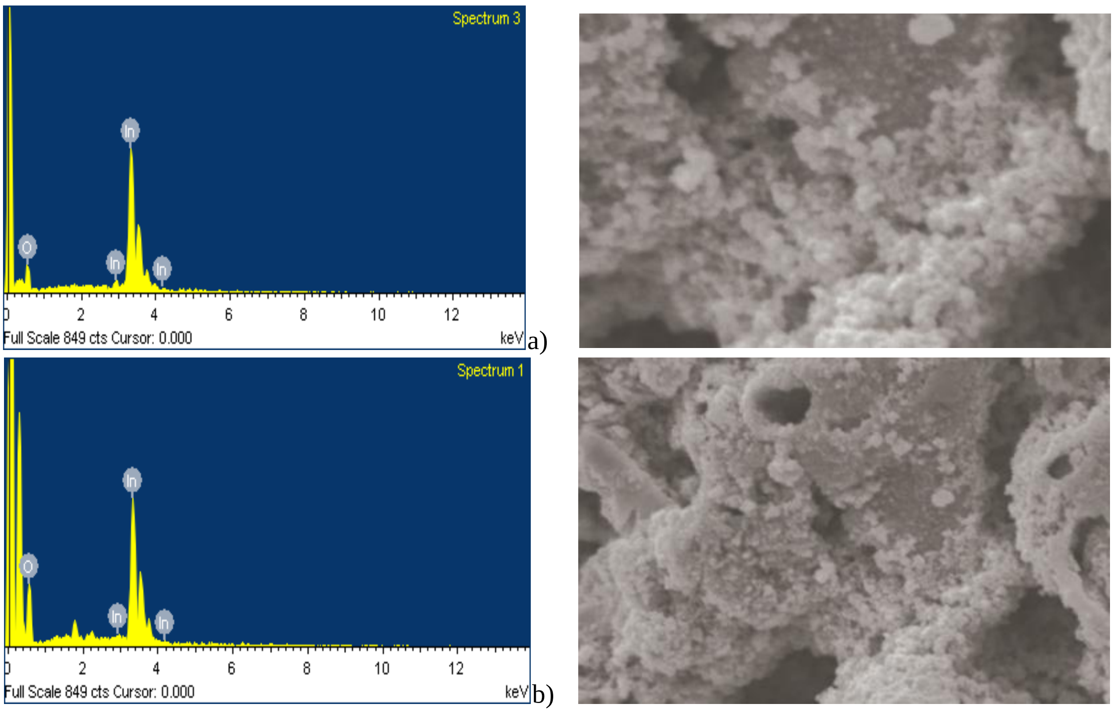


Fig.3 ***EDAX and SEM of (a) 1:2 (Sample 1) and (b) 1:5 (Sample 2) of In_2O_3 nfs***

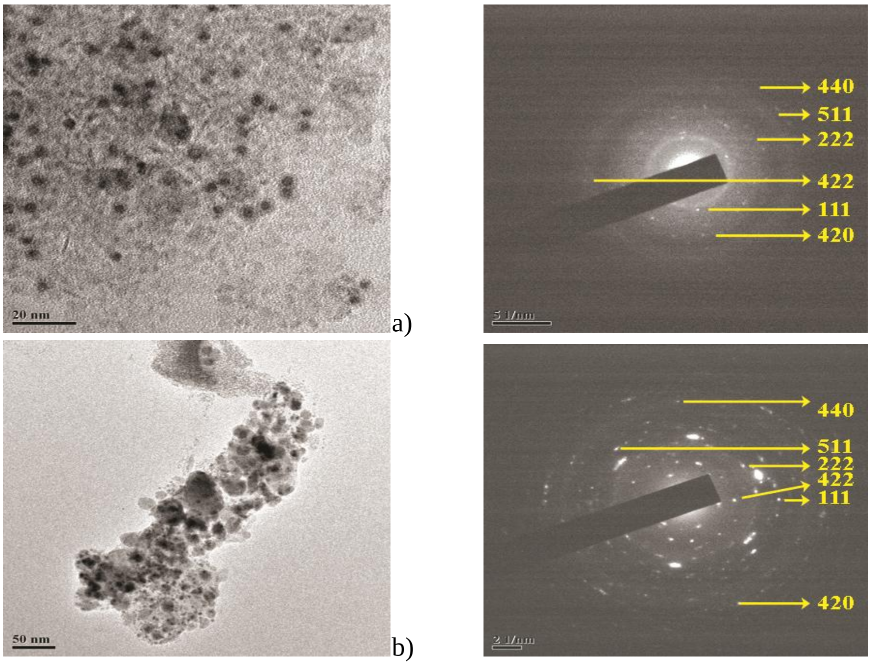
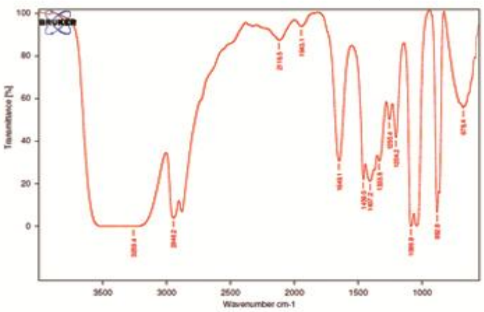


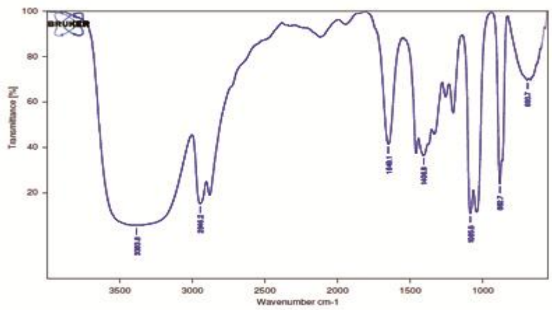
Fig.4 ***TEM and SAED pattern of (a) 1:2 (Sample 1) and (b) 1:5 (Sample 2) of In_2O_3 nfs***

The position of the surface Plasmon absorption peak of In_2O_3 nano particles depends on the refractive index of the surrounding medium, particle size, absorbed polymer on the particle surface etc. figure 1 shows the UV-vis spectrum of the polymer stabilised In_2O_3 nano fluid in the wave length range of 200 to 600nm. A strong absorption is observed at 220 nm and 22 nm for samples (1:2 and 1:5) respectively as shown in fig.2 indicates the particle size dependence and PVP entrapment of In_2O_3 nano particles. It is observed that there is slight shift of curve for sample (1:5) at 221nm. Stabilization of nano fluids [27] has been studied at room temperature for every 4 hours in 24 hours and it has been found that the obtained nano fluids are stable for more than 3 months in the stationary state. Excellent stability of the prepared nano fluid is due to the protective role of PVP as it retards the growth and agglomeration of nano particles[28] as shown in fig.2.

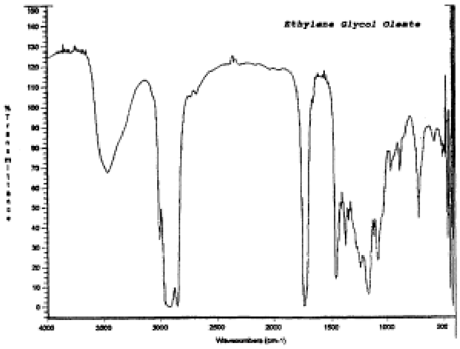
Figure 3 shows the SEM and EDAX of In_2O_3 nano fluids taken by preparing a film on glass substrate[29] confirming the presence of In_2O_3 nano particle in the nano fluid. SEM analysis shows the spherical morphology of In_2O_3 nano particles. Analysis of EDAX shows *In* and *O* peaks located between 2 KeV and 4 KeV [30]. The chemical composition and purity of the products are also examined using EDAX. The EDAX spectrum revealed *In* and *O* as the only detectable elements, indicating that the sample is without any contamination and slightly carbon due to presence of PVP in the nano fluid. Their atomic ratio is close to 2:3 confirming that the nano particles are of In_2O_3. The corresponding SAED pattern is displayed in Fig.4 showing the poly crystalline structure of In_2O_3 nano particles. The SAED pattern of the nano fluids and TEM images of the In_2O_3 nano particles PVP suspensions in the samples (1:2 and 1:5) with corresponding particle size distributions are shown in fig.4. The TEM images reveal that the nano particles are spherical in shape with size distribution between 5 to 10nm. The In_2O_3 nano particles are dispersed in colloidal solution as seen in TEM micro graph and the inter-planar spacings for different hkl values are coincident with the JCPDS standard data (06-0416) as shown in Table 2.



a) Sample 1



b) Sample 2



c) EG

Fig.5 ***FTIR Spectra of (a) 1:2 (Sample 1), (b) 1:5 (Sample 2) of In_2O_3 nano fluids and (c) EG***

The FTIR spectra of sample 1:2, 1:5 and EG as shown in fig.5(a), 5(b) and 5(c) respectively showing strong band due to amide carbonyl (present in PVP monomer) stretch vibration but shifts to 1649.1 cm-1 [31, 32]. Band displacement indicates attachment of amide carbonyl oxygen with Indium. Ethylene Glycol oxidised products are not detectable in (a) and (b) indicating the presence of In_2O_3. The two spectra resemble one another for the appearance of a prominent band at 2946 cm-1.

Table 2: Interplanar spacing (dhkl) of nano fluid samples calculated from SAED (Selected Area Electron Diffraction) patterns in Fig 3 compared with the reference values in the standard data (JCPDS :06-0416)

S. No.	Sample 1:2 Nano fluid d_{hkl}(^{O}A)	Sample 1:5 Nano fluid d_{hkl}(^{O}A)	Standard data (JCPDS: 06-0416)	
			d_{hkl}(^{O}A)	h k l
1	3.163	2.9368	3.1234	111
2	2.757	2.686	2.7056	200
3	1.9124	1.901	1.9134	220
4	1.218	1.286	1.2414	420
5	1.592	1.5496	1.5622	222

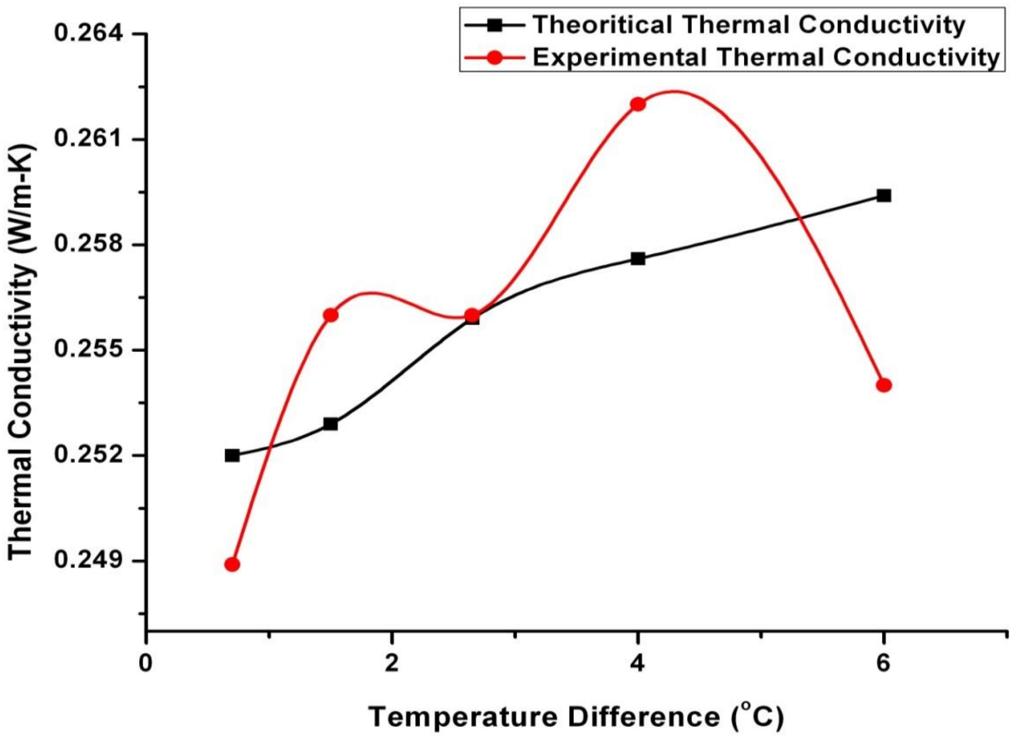


Fig.6 Thermal Conductivity of Ethylene Glycol

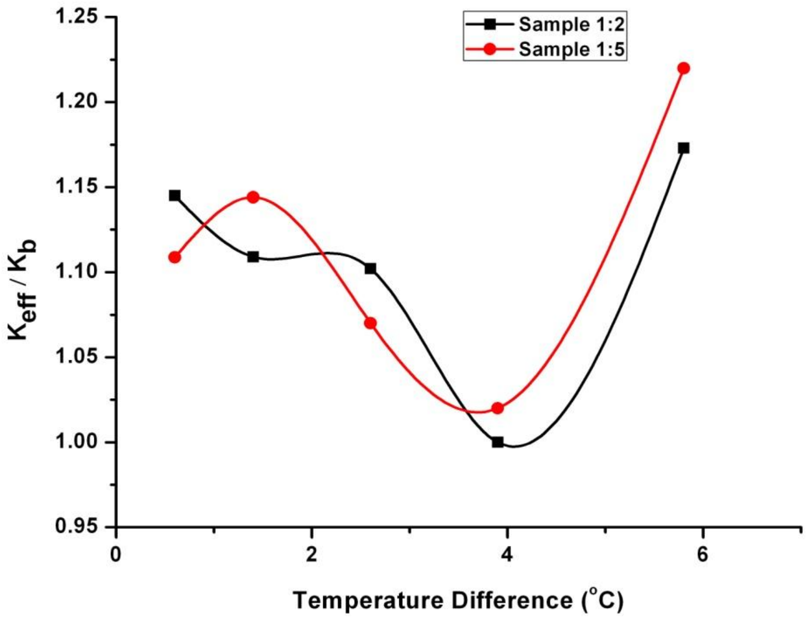


Fig.7 Thermal Conductivity enhancement ratio for In_2O_3 nano fluids

Measured and reported Thermal conductivity of Ethylene Glycol with temperature difference are presented in fig.6. There is a close agreement between the observed and reported values of EG as can been seen from the fig.6. It is observed that the Thermal conductivity of EG decreases with temperature as reported [33, 34]. Measurement system has been calibrated before use by measuring TC of water at room temperature. Hence the smaller size and higher stability of the fluid lead to the enhanced TC. Fig.7 represents the thermal conductivity ratio for In_2O_3 nano fluid (TC normalised by that of base fluid (EG) with temperature difference). The variation of thermal conductivity ratio (K_{eff}/K_b) with temperature seems to be sigmoidal in nature showing slow to sharp increase with increase in temperature difference.

This variation is similar to the variation of (Keff/Kb) with volume % of particles [35]. This non linear behaviour in Keff/Kb can be explained on stochastic motion (Brownian motion) [36] of the nano particles freed from PVP binding as the temperature difference increases. With increase in temperature nano particles diffuse through the polymer matrix. This also increases Brownian motion of nano particles causing convection to increase significantly with temperature causing thermal conductivity enhancement. Enhancement in TC of nano fluid cannot be explained by classical models. Differences between the experimental and classical model estimation have been reported earlier by many researchers [37, 38].

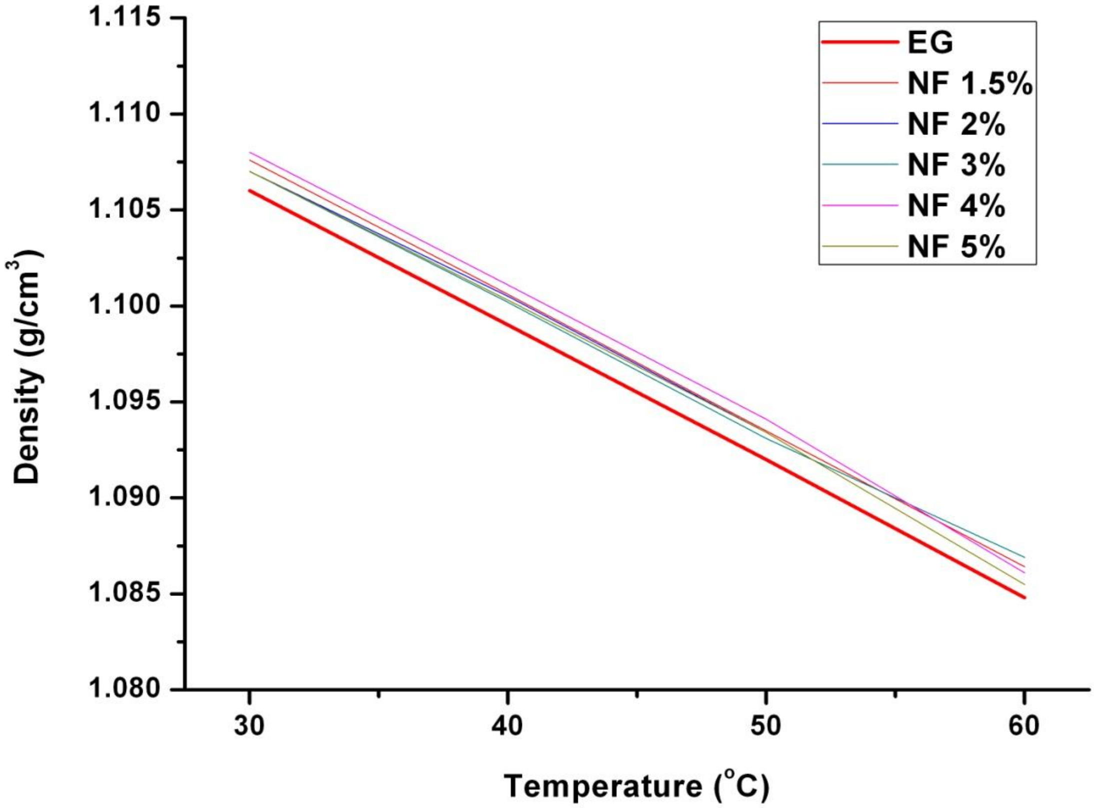


Fig.8 Temperature vs. Density of In_2O_3 nfs

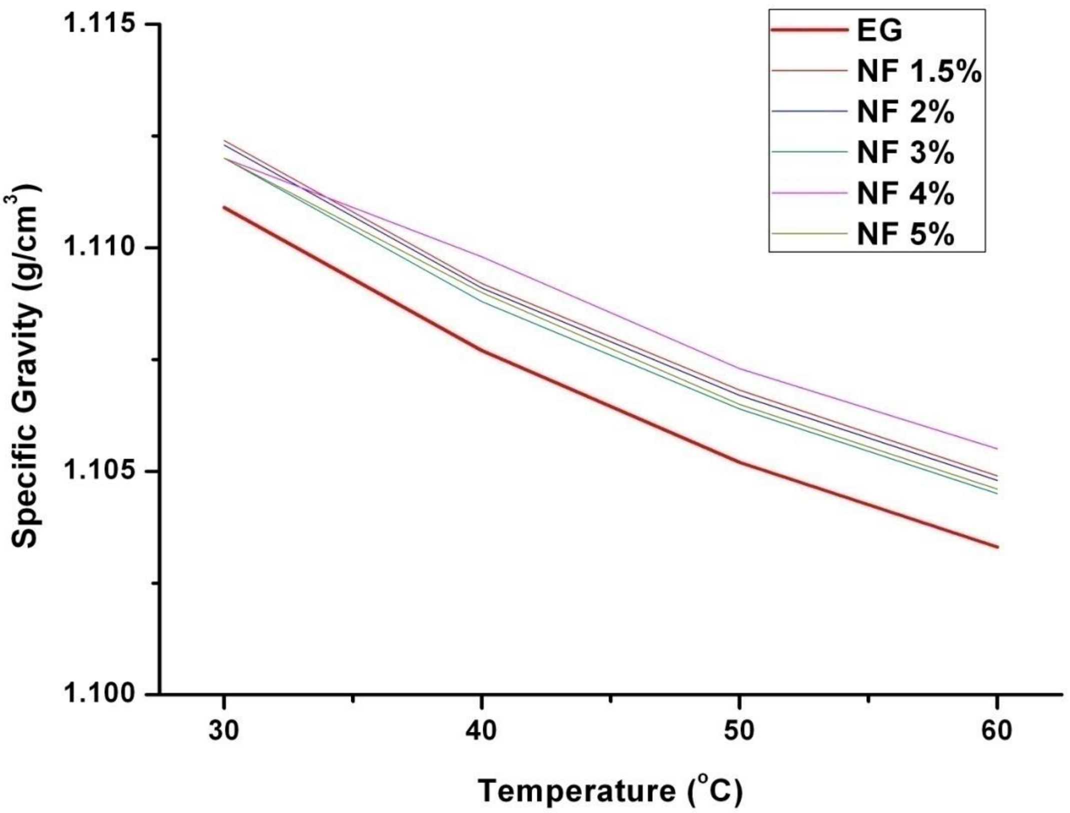


Fig.9 Temperature vs. Specific Gravity of In_2O_3 nfs

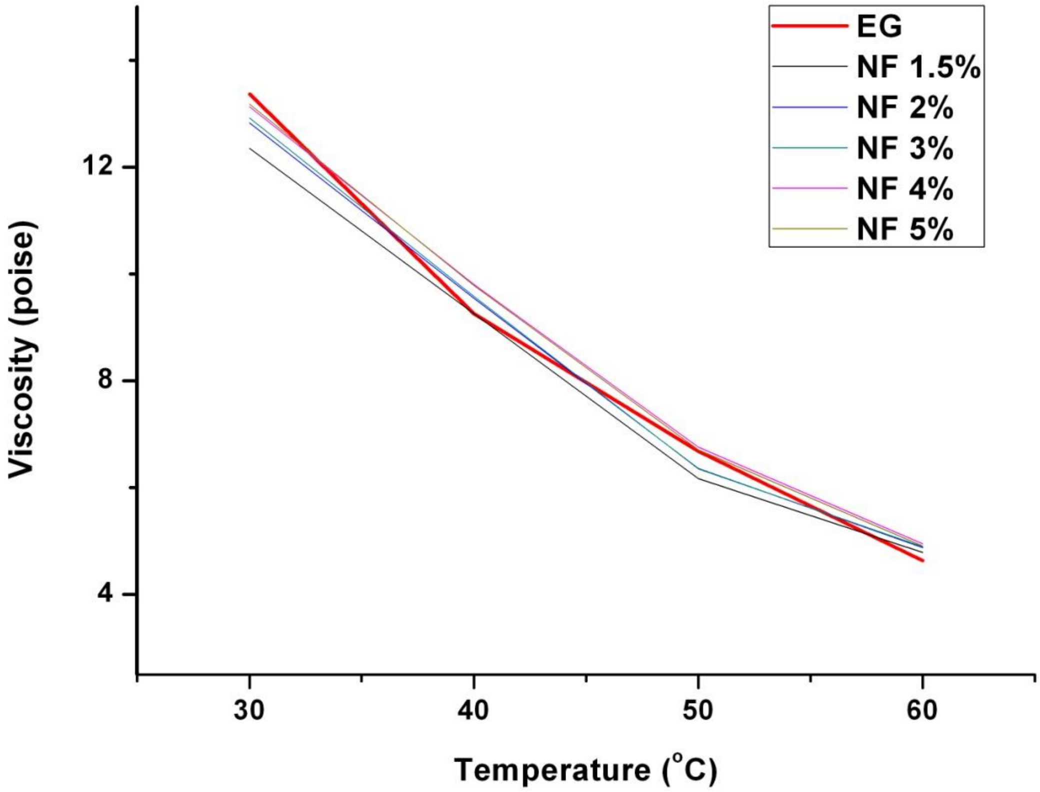


Fig.10 Temperature vs. Viscosity of In_2O_3 nano fluids

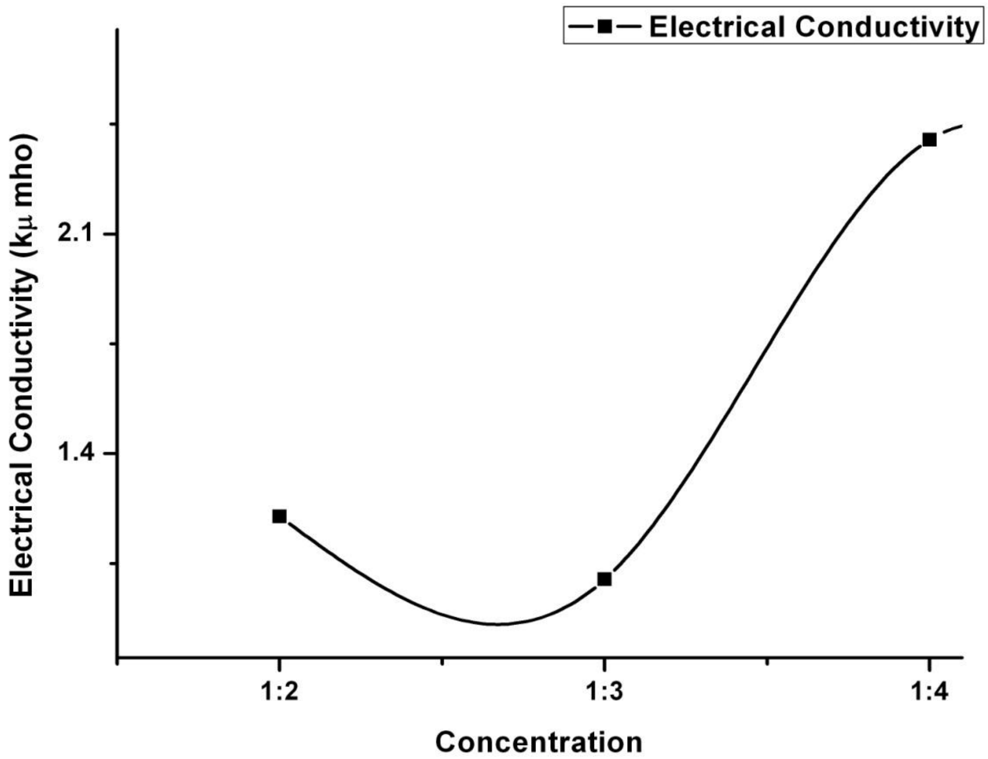


Fig.11 Concentration vs. Electrical Conductivity of In_2O_3 nfs

Fig. 8 and fig. 9 represents the density and specific gravity at temperatures ranging from 30°C to 60°C. The viscosity of nano fluids depends on shear rate, nano particle size, surface area, surface potential, polymer dispersed and temperature [39]. Fig. 10 shows that the viscosity increases with increased particle concentration and decreases with temperature [40]. It is observed that 1:2 and 1:5 nano fluid samples viscosity decreases than the viscosity of base fluid which shows good heat transfer for these fluid concentrations. Hence the higher polymer concentration increases electrical conductivity, thermal conductivity and decreases viscosity.

Also it is observed that the high TC and low viscosity, of samples (1:2 and 1:5) reveals that the In_2O_3 nano particles formed are stable. Hence the In_2O_3 nano fluids being polymer capped have shown low viscosity and high thermal conductivity.

V. Conclusions

We have successfully synthesised In_2O_3-PVP nano fluids having different concentration of PVP in room temperature by two-step method. The UV-vis spectra, TEM image, SEM and SAED pattern confirms the formation of In_2O_3 nano particles dispersed in PVP. Enhancement of Thermal conductivity, Electrical conductivity and decrement in viscosity are also in good agreement with the base fluid and it is suitable for large scale production. Nano fluid thermal study shows that a small amount (1% by vol) of In_2O_3 nano particle enhances the Thermal conductivity of base fluids substantially by 25%. High polymer concentration increases Thermal conductivity and decreases viscosity. The result presented here makes nano fluids more attractive as cooling fluid for devices with high energy density.

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