

Pluronic F127 stabilized ZnO nanofluid; Investigation of the dispersion stability and thermal conductivity

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Abstract

Nanofluids are suspensions consisting of solid nanoparticles in sizes less than 100 nm and can be used in many research fields. The current research work concentrated on two sections. (1) This part mainly studies the preparation and characterization and colloidal stability of surface modified ZnO nanoparticles disbonded water (ZnO/water) nanofluid (2) estimating thermal conductivity, which was essential for many industrial applications. To study the stability of the F127 stabilized ZnO nanofluid, DLS and zeta potential analysis were used. The polydispersity index, as determined by DLS analysis, is 0.322, and the number-averaged particle size is 110 nm. To achieve this, the dispersant was used for homogeneous solution and the zeta potential value for stabilized ZnO nanofluids in the presence of dispersant was 10.18 mV. The effect of dispersant and temperature on the thermal conductivity of nanofluids was examined. Based on the obtained results, a significant increase in fluid conductivity was observed that had a nonlinear relationship with the volume fraction and an optimized dispersant concentration at 1.5 vol% showed the maximum enhancement of thermal conductivity. The influence of temperature on the thermal conductivity of ZnO stabilized nanofluids was analyzed and compared with ZnO nanofluids.

Keywords: Nanofluid, ZnO, Pluronic F127, Stability, Thermal conductivity

1. Introduction

Nanofluid technology development is a very important study in mathematics, manufacturing, physics, and materials science [1]. Nanofluids widely used to examine practical problems like industrial applications, biomedical engineering, solar thermal applications, and numerous other production fields applied for different physical problems [2]. Nanofluid is critical in a wide range of applications, including chips, refrigerators, hybrid-powered motors, food improvement, heat exchangers, and more [3]. Choi et al. [4] first introduced the concept of nanofluid. This method tries to improve thermal conductivity by integrating a base liquid like water with a solitary kind of nanosized molecule, such as copper, aluminum, carbon nanotubes, etc. For the last few decades, oxide-based semiconductors, specifically Tin dioxide (ZnO), have been in prime focus due to their specific properties (like optical, magnetic, and electrical) [5]. Pavithra et al. [6] investigated thermal conductivity and thermal performance of heat pipes by structurally designed copolymer of amphiphilic poly (styrene-co-2-Acrylamido-2-methylpropane sulfonic acid) poly (STY-co-AMPS stabilized ZnO nanofluid. They reported maximum enhancement at an optimized concentration of dispersant at 1.5 vol% and the thermal resistance and temperature distribution show decreased behaviour by increasing the particle volume fraction and dispersant concentration. Based on these various studies carried out on the ZnO nanofluid, here we prepared ZnO nanofluid stabilized with Pluronic F127 nonionic surfactant. Hence, based on various steps, from preparation to characterization and application, the current paper is divided into various sections. In the section (1) the stability of the prepared nanofluid were characterized with DLS, Zeta potential, AFM analysis. Section (2) presents experimental data obtained from thermal conductivity investigation.

2. Experimental

2.1. Materials

Pluronic® F-127 ((C₃H₆O·C₂H₄O)_x) as non-ionic copolymer surfactant (Polyethylenoxid-Polypropylen-Oxid in einer Triblock-Struktur), CMC of 950-1000 ppm (~25°C), (soluble in water at 10% (w/v)), and ZnO nanoparticles as nanopowder (~80% Zn basis) (<100 nm and 10-25 m²/g) were purchased from Sigma-Aldrich. Double distilled water was purchased from Kiagene Fanavar.

2.2. Nanofluids preparation

To prepare stabilized ZnO nanofluids, a determined volume of ZnO nanoparticles was added to the base fluid and the resulting mixture was then ultrasonicated for nearly 2 h at ambient temperature using an ultrasonicator (Ultrasonic homogenizer (Sonicator, FAPAN Co. Ltd, Iran). The same process was used to create a second batch of nanofluids that contained various F127 surfactant copolymer chains of an amphiphilic polymer as a dispersant agent. In this study, to ensure uniform blending of the dispersant in the water base fluids, the different concentrations of dispersant were first dispersed in the base fluid and constant stirring for an hour. Heating may be necessary to achieve these concentrations. Following the dispersant-base fluid mixture, the measured volume concentration of ZnO nanoparticles was added. This procedure to obtain ZnO nanofluid without surfactant was followed by the same process as above mentioned to produce surfactant stabilized ZnO nanoparticles. The thermal conductivity and dispersion characteristics of water-based ZnO nanofluids were then examined by DLS and Zeta potential analysis. Fig. 1 shows photographs of 1 wt.% ZnO nanofluids without and with F127 copolymer as dispersant agent after 1 day. Due to the strong attraction between the ZnO nanoparticles in absence of surfactant, ZnO nanofluids begin to aggregate and settle at the bottom of the vial after 15 min of preparation. But, the F127 dispersant stabilized ZnO nanofluid are stable for 1 days due to an adsorbed layer of F127 copolymer dispersant on the surface of ZnO nanoparticles creates an effective electrostatic barrier between the ZnO nanoparticles, ensuring greater stability and dispersibility of ZnO nanofiller. So, ZnO nanofluid not stable and nanoparticles (solid phase) removed from base fluid and in presence of F127 surfactant, nanofluid is stable for 1 day.

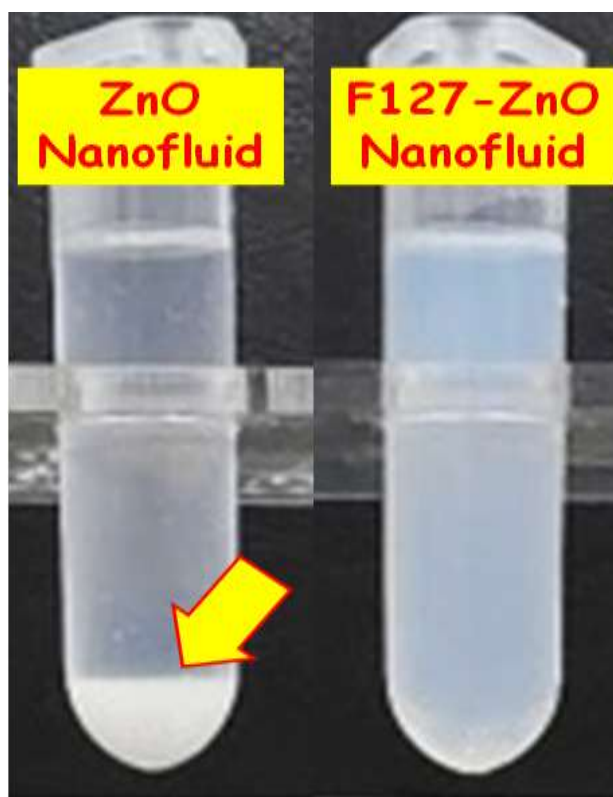


Fig. 1. Photograph of the prepared ZnO nanofluid (1 wt.% ZnO) without surfactant and F127 stabilized ZnO nanofluid after 1 day.

2.3. Thermal conductivity measurement

KD2 Pro (Decagon Devices, USA) (accuracy: ± 5 to $\pm 10\%$, $\pm 10\%$ specific heat, $\pm 10\%$ thermal diffusivity) thermal property analyzer was used to evaluate the thermal conductivity of ZnO nanofluid and surfactant stabilized ZnO nanofluid. It includes a large (10 cm long, 2.4 mm diameter) single needle TR-1 sensor measures thermal conductivity and thermal resistivity. To operate and carry out the measurements, the probe is attached to a microcontroller. The gadget was calibrated using the glycerine that comes with the equipment to determine the experiment's accuracy margin. Fig. 2 shows the set up to measure the thermal conductivity for nanofluid samples at different condition such as different temperature and volume fraction of dispersant.

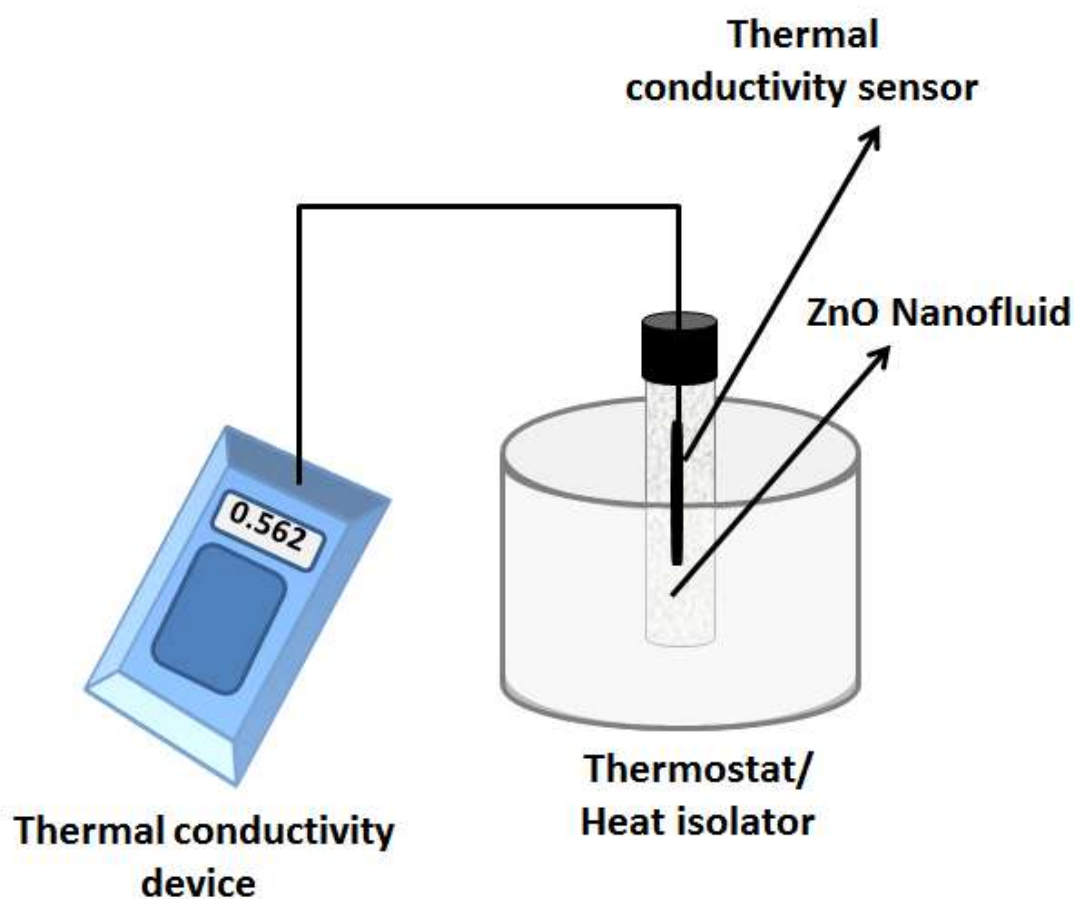


Fig. 1. Setup for thermal conductivity measurement with a KD2 Pro Analyzer

2.4. Characterization

Particle size and zeta potential measurements were conducted using a Zetasizer Nano ZS device (Malvern Panalytical Ltd, Malvern, UK). A freshly prepared, diluted and sonicated sample which the particle concentration to perform the measurements was under 25 mg/mL was used for analysis at 25 °C. The mean dimension or a quantitative assessment of the particle size distribution of colloid of ZnO/water based nanofluids and polydispersity index (ratio of the mass-weighted average particle diameter to the number-weighted average particle diameter) was estimated utilizing dynamic light scattering (DLS).

3. Results and discussion

3.1. DLS and Zeta potential analysis

Fig. 3. depicts the ZnO/water nanofluid's particle size distribution in the presence of the F127 dispersant. As obtained results from DLS analysis, the polydispersity index, as determined by DLS analysis, is 0.302, and the number-averaged particle size is 110 nm. The observed particle size is near the used ZnO nanoparticles (desired nanoparticle size less than 100 nm), This is primarily due to the formation of the thermodynamically stable clusters

of particles. As second reason, suggests that the adsorbed layer of amphiphilic F127 copolymer dispersants on the cationic surface of the nanofluids results in a larger particle diameter. It implies that the F127 dispersant agent can act as an active role in the high dispersion of ZnO nanofluids due to electrostatic hindrance formed between the F127 copolymer's adsorbed layer and the ZnO nanoparticles in the suspension. This result is further confirmed using zeta potential data.

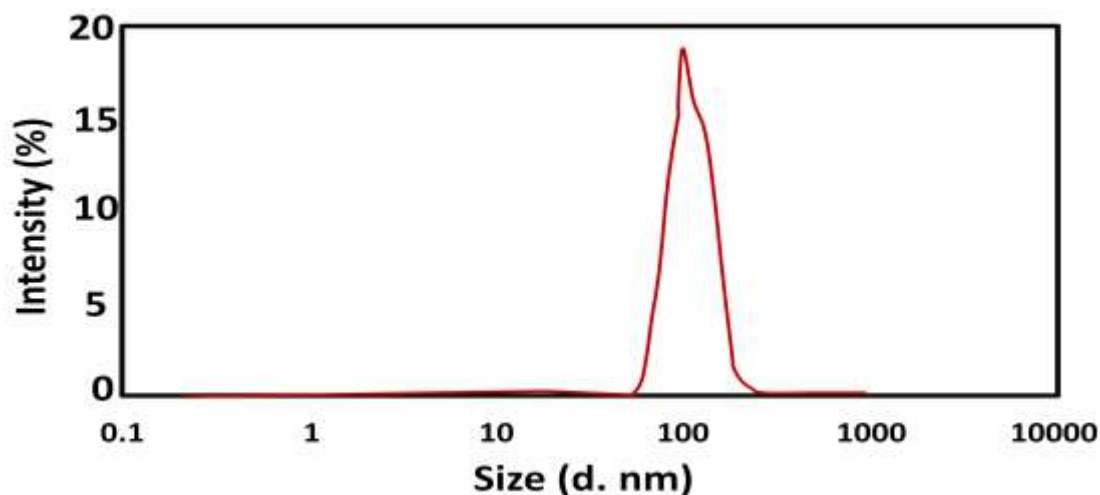


Fig. 3. ZnO/water nanofluid's particle size distribution in the presence of the F127 dispersant, as determined by DLS analysis

To assess the stability of F127 coated ZnO dispersion in the water base fluid shown in Fig. 4. zeta potential analysis was used. depicts the zeta potential value of dispersant stabilized ZnO nanofluids with and without dispersant. The zeta potential value for ZnO/water nanofluid in the presence of F127 dispersant 21.08 mV in Fig. 4. It is obvious that an adsorbed layer of F127 copolymer dispersant on the surface of ZnO nanoparticles creates an effective electrostatic barrier between the ZnO nanoparticles, ensuring greater stability and dispersibility of ZnO nanofiller [7].

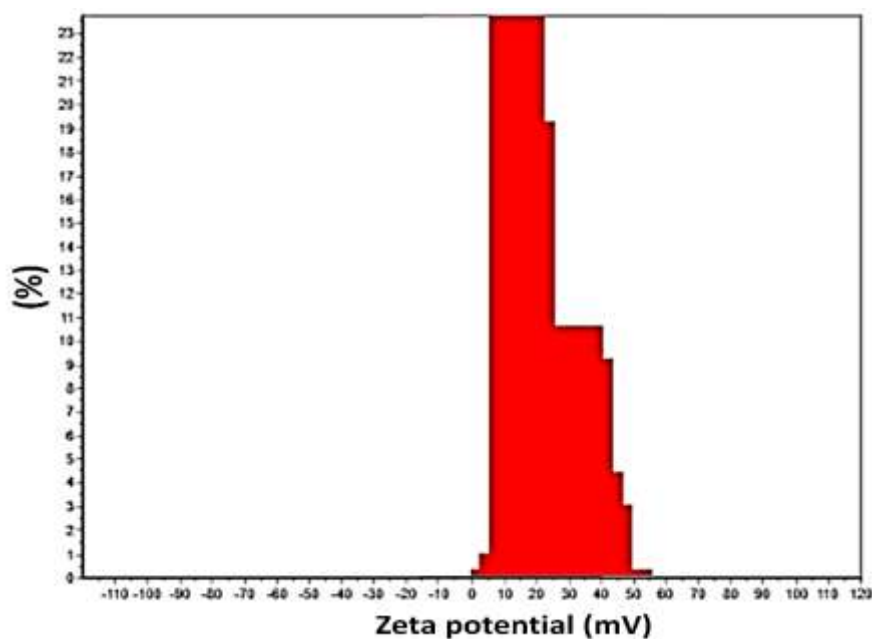


Fig. 4. ZnO/water nanofluid's zeta potential analysis in the presence of the F127 dispersant

3.2. Effect of volume fractions of F127 dispersant on the thermal conductivity

The thermal conductivity of ZnO nanofluids at a various volume fractions of F127 dispersant and ZnO nanoparticles are represented in Fig. 5. The best dispersion and thermal conductivity enhancement of nanofluids (0.879 W/m-K) are observed at 0.5-1.0 vol% ZnO nanoparticles due to proper dispersion of nanofiller leads to more heat transfer with 1.5 vol% F127 copolymer as a nonionic dispersant.

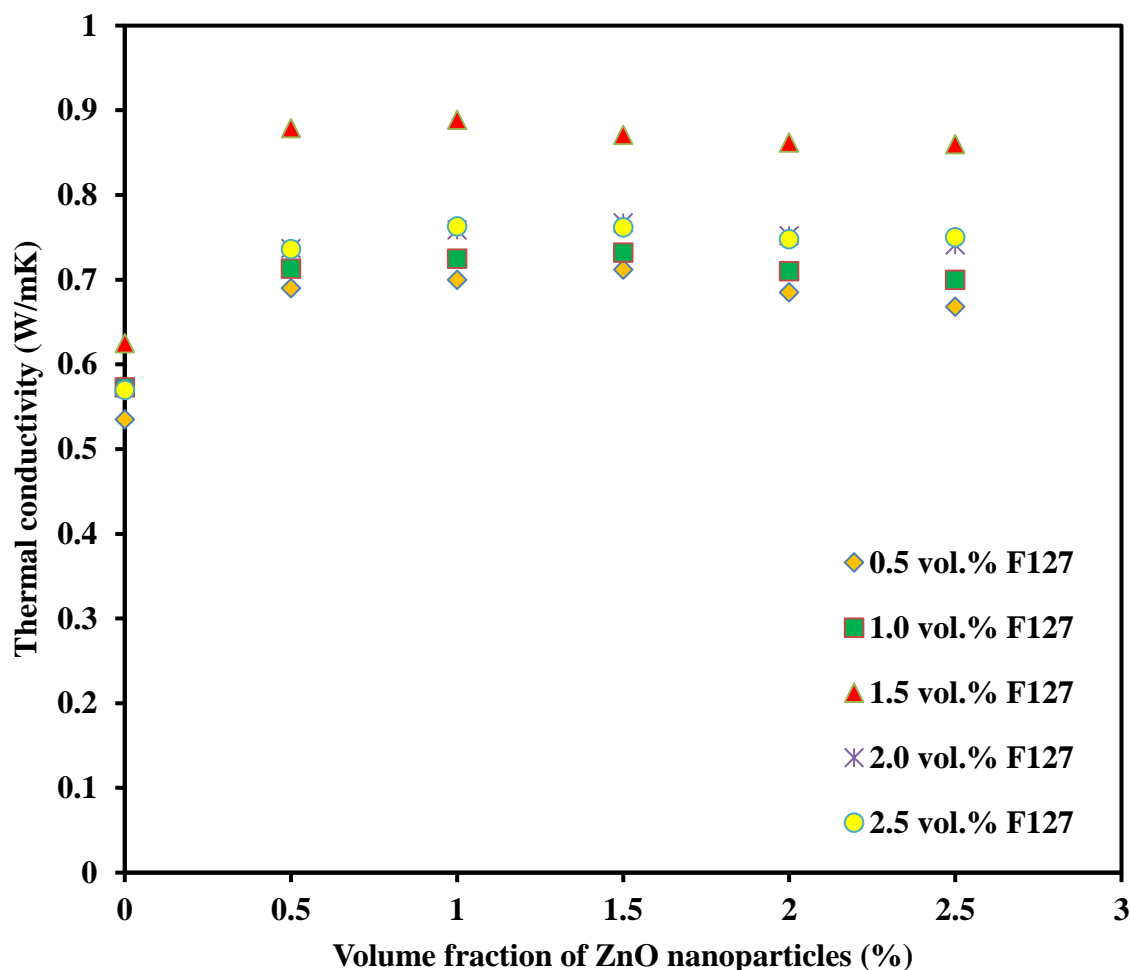


Fig. 5. Thermal conductivity of ZnO nanofluids at various volume fractions

3.3. Effect of temperature on the thermal conductivity of ZnO nanofluid

Fig. 6 depicts the investigation into the effect of temperature on the thermal conductivity of ZnO nanofluids. Error bars on the graph of temperature on the thermal conductivity of ZnO nanofluids indicating the standard deviation over subsequent measurements. As can be seen, thermal conductivity increases with increasing temperature. It is clear that the thermal conductivity gradually decreases with increasing polymer dispersant concentration [8]. This behavior is due to over adsorption of F127 polymer dispersants, which inhibits heat transfer as well as Brownian motion of ZnO nanoparticles [9-12]. Pavithra et al. [6] reported a gradually decreases with increasing polymer dispersant concentration due to the ionic interaction of the highly functionalized hydrophobic styrene moiety adsorbed on the cationic surface of the ZnO nanoparticles and the hydrophilic ionizable sulfonate (SO_3^-) and hydroxyl ($-\text{OH}$) functionalized AMPS moiety extended into the fluids suspension creates an effective electrostatic barrier between the nanoparticles in the base fluids, promoting homogeneous dispersion and stabilization which intern enhances the heat transfer.

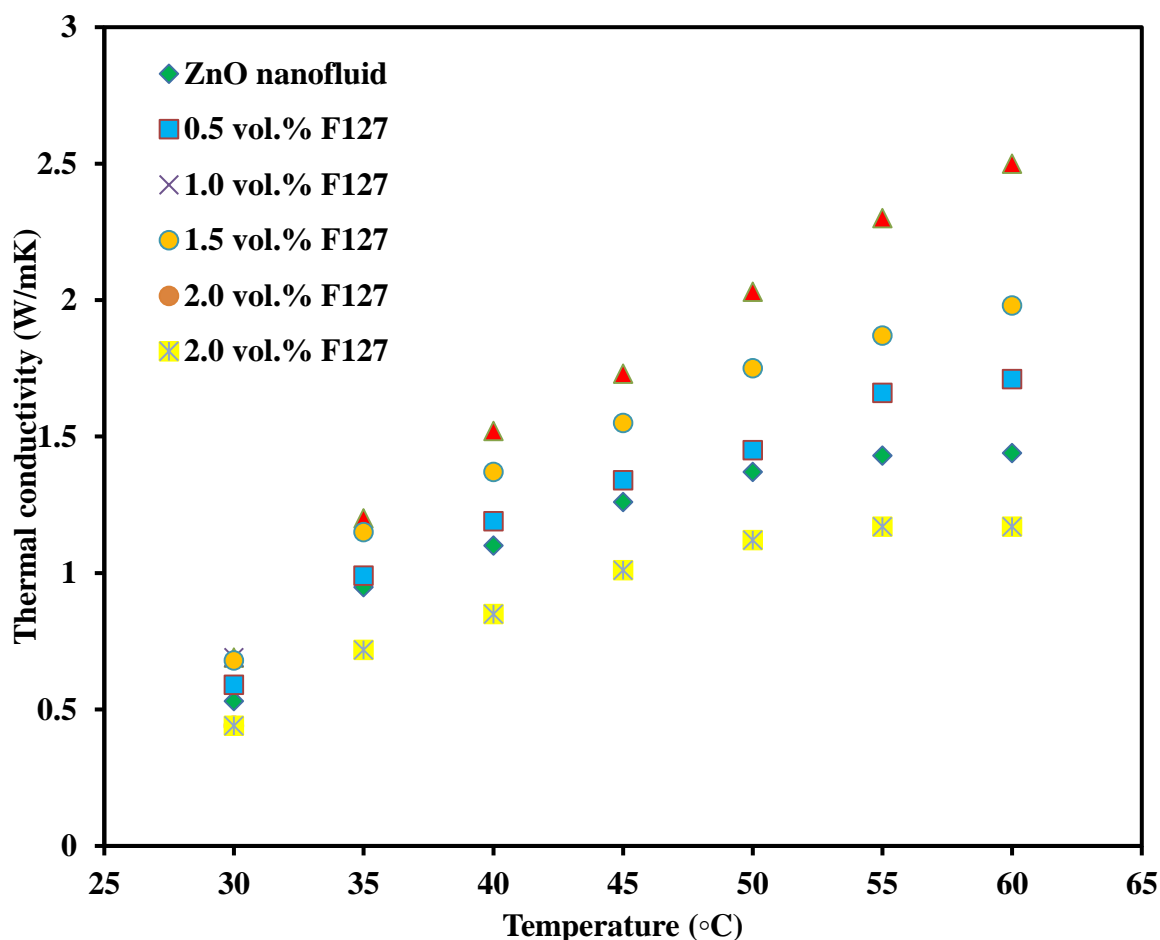


Fig. 6. Thermal conductivity of ZnO nanofluids at different temperatures along with error bars

4. Conclusion

The current research work is focused on two main areas. (1) This part mainly studies the preparation and characterization and the colloidal stability of the surface modified ZnO nanoparticles disintegrated water (ZnO/water) nanofluid (2) the estimation of the thermal conductivity, which is essential for many industrial applications. DLS and zeta potential analysis were used to study the stability of the F127-modified ZnO nanofluid. The polydispersity index, as determined by the DLS analysis, is 0.322 and the number average particle size is 110 nm. In order to achieve this, the dispersing agent was used for a homogeneous solution and the zeta potential value for the stabilized ZnO nanofluids in the presence of the dispersing agent was 10.18 mV. The effect of dispersant and temperature on the thermal conductivity of the nanofluids was investigated. Based on the results obtained, a significant increase in fluid conductivity was observed which had a non-linear relationship with volume fraction. An optimized dispersant concentration of 1.5 vol% showed the maximum increase in thermal conductivity. The influence of the temperature on the thermal conductivity of the ZnO-stabilized nanofluids has been analyzed and compared with that of ZnO nanofluids.

Conflicts of Interest

The author declares no conflict of interest.

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