Experimental investigation of thermal and electrical conductivity of silicon oxide nanofluids in ethylene glycol /water mixture

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Abstract

In this paper, the thermal conductivity and electrical conductivity of SiO_2 nanofluids using mixture of ethylene glycol (EG) and water (H_2O) as the base fluid are investigated. The two-step method was used to prepare SiO_2-EG/H_2O nanofluids with a mass concentration of 0.3%. The variations in thermal conductivity and electrical conductivity as functions of EG concentration (0–100%, v/v) and temperature (25–45 °C) are present. Experimental results showed that the thermal conductivity and electrical conductivity of SiO_2-EG/H_2O nanofluids both decreased as the EG content percentage increases in the EG/H_2O mixture. At a specific EG content percentage, thermal conductivity and electrical conductivity both increased with the increase in temperature. To better evaluate the enhancement performance of SiO_2-EG/H_2O nanofluids, the relative electrical conductivity was introduced and studied explicitly. The mechanism of electrical conductivity enhancement in SiO_2-EG/H_2O nanofluids was analyzed in detail. Meanwhile, the ratio of thermal conductivity and electrical conductivity was also discussed.

Keywords: Thermal conductivity; Electrical conductivity; SiO_2 nanofluids; Electrical

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conduction mechanism; Thermo-electrical conductivity ratio

1. Introduction

The generation of heat energy has a negative effect on lots of machines and instruments. Thus, heat transmission is very important to majority of the fields of industrials engineering such as electric generation, solar collector, air-condition, and automobile [1–4]. The common and traditional fluids used in heat exchanger are water, ethylene glycol (EG), etc. In the past decades, more and more research has been performed to improve the heat transfer performance of these traditional fluids. Among these, preparing nanofluids based traditional fluids is an attractive study direction. The nanofluids are low-concentration suspensions of metallic or nonmetallic nanoparticles with sizes typically of 1–100 nm in a base fluid, e.g. water, oil and alcohol [5].

Murshed *et al.* [6] investigated the thermal conductivity of titanium dioxide (TiO_2) nanofluids and aluminum (Al) nanofluids. They found that the thermal conductivity of TiO_2/EG nanofluids (particle volumetric loading 5%) exhibited 18% enhancement compared with that of base fluid. And the enhancement is 45% for Al/EG nanofluids with the same concentration. Hong and co-workers [7] made a study about thermal conductivity of Fe/EG nanofluids. Research results showed that the thermal conductivity of Fe nanofluids (0.55 vol.%) was increased to 118% compared with that of base fluid. Sundar *et al.* [8] conducted an experiment to research the thermal conductivity and viscosity of Al_2O_3 nanofluids. They employed EG/H_2O (20:80%. v/v) as a base fluid, and they discovered that at a particles concentration of 0.3 vol.%, the thermal conductivity enhancement reached to 11% at a temperature of 20 °C. The work of Li and co-workers [9] also achieved a noticeable thermal conductivity enhancement by applying 50-nm ZnO nanoparticles and EG as the base fluid. To further employed this nanoparticle for natural heat transfer study, the thermal conductivity of ZnO-EG/H_2O nanofluid was also studied under different EG and H_2O ratios (v/v) [10]. In addition, there are still lots of articles about thermal conductivity of various nanofluids, such as CuO [11], Cu [12], and ZrO2 [13] etc. These articles commonly declared that nanofluids could effectively increase thermal conductivity of based fluids. As is well-known, the key technology to improve the heat transfer properties of traditional fluids is increasing the thermal conductivity [14]. Nanofluid has a more superior heat transfer performance when compared with pure liquids and promises to be a new heat transfer medium [15–18]. More investigations and research need to be performed before commercialization and industrialization for nanofluids.

Recent few decades, nanofluids have attracted increasing attention and the reported properties about various nanofluids mainly involve thermophysical properties, natural convection capability, boiling heat transfer performance, etc. A major goal of our research is to assess the effect of temperature and the proportion of EG on thermal conductivity of SiO_2 nanofluids. SiO_2 nanofluid was chosen because it is of a lot of excellent performances, such as stable chemical properties, insulation, easy to synthesis, and economy. There are a lot of literatures about the variety of properties of SiO_2 nanofluids including the thermal conductivity. In the study of Pang *et al.* [19], the SiO_2 nanofluids using methanol as the base fluid were prepared and the thermal conductivity increased in an increase of the nanoparticle volume concentration. According to the experimental results of Zhu *et al.* [20], the thermal conductivities of SiO_2 nanofluids were higher than those of base fluids, and increased with the increase of volume fraction and temperature. Other research about the thermal conductivity of SiO_2 nanofluids all drew basically the same conclusion. Although there are some literatures reporting the influence factors of thermal conductivity of SiO_2 nanofluids, e.g., nanoparticle concentration, temperature, diameter of nanoparticle, there are few literatures concerning to the effect of composition of the base fluid.

In addition to the thermal conductivity of SiO_2 nanofluids, electrical conductivity is another important property of nanofluids. The electrical conductivity of nanofluids is related to the ability of charged particles in the nanofluids to carry the charges toward respective electrodes when an electric potential is applied [21]. The ratio of thermal conductivity and electrical conductivity is considered as an essential index to evaluate the feasibility of a certain nanofluid to be implemented in an electrically active heat transfer application [22]. The stability of a suspension depends on its electrostatic characteristics such as iso-electric point (IEP) and zeta potential which play a critical role in the electrical conduction process [23]. Thus, the electrical conductivity of nanofluids is well worth studying because it is related to the stability of nanofluids and might provide valuable information about the stability of nanofluids. However, few literatures about the electrical conductivity of nanofluids were published. The experimental work concerning to the electrical conductivity of SiO_2 nanofluids is rare.

To the best of our knowledge, although the thermal conductivities of SiO_2 nanofluids are widely investigated, the effect of the composition of base fluid on thermal conductivity of SiO_2-EG/H_2O nanofluids is few or not comprehensively mentioned in the literatures. And almost no research concerns the electrical conductivity of SiO_2-EG/H2O nanofluids. In this work, SiO_2-EG/H_2O nanofluids were prepared by the two-step method with the help of magnetic stirring and ultrasonic oscillation. The morphology and structure of the SiO_2-EG/H_2O nanofluids were characterized by X-ray diffraction (XRD) and transmission electron microscopy (TEM). The objective of this work was to experimentally investigate the effect of temperature and the mix ratio of H_2O and EG on the thermal and electrical conductivity of SiO_2-EG/H_2O nanofluids. What's more, the electrical conduction mechanism of SiO_2-EG/H_2O nanofluids was discussed.

2. Experiment

2.1 Preparation of nanofluid

SiO_2 nanoparticles (Beijing Dk Nano technology Co. LTD, China) with an average diameter of 30nm and purity of 99.9% were used in this work. Base fluids were prepared by mixing both distilled water (Robust Co. Ltd, China) and EG (Aladdin Industrial Co. Ltd, China) to yield a 40 -mL base fluid. The purity of EG is 99.9% and it was used without any purification. The SiO_2-EG/H_2O nanofluids were prepared by the two-step method without using any surfactant. The mass fraction of nanofluids was calculated from the weight of dry SiO_2 powder and the total weight of the suspension using the Eq. (1).

$$\varphi = m_{\mathrm{p}} / (V_{\mathrm{EG}} \cdot \rho_{\mathrm{EG}} + V_{\mathrm{H_2O}} \cdot \rho_{\mathrm{H_2O}} + m_{\mathrm{p}}) \quad (1)$$

where m_{p} means the mass of the SiO_2 nanoparticles, the V_{EG} and $V_{\mathrm{H_2O}}$ represent the volume of EG and H_2O respectively, and the ρ_{EG} and $\rho_{\mathrm{H_2O}}$ represent the density of EG and H_2O respectively. By using a sensitive electronic balance (BSA423S, Sartorius Scientific Instruments Co. LTD, Germany) with an accuracy of 1 mg, nanoparticle sample preparation was carried out. Then nanoparticles were dispersed into the base fluid with a mass concentration of 0.3%. The electrical conductivities of the H_2O and EG at 25 °C are 5.44 μS/cm and 0.33 μS/cm by measurement. With a magnetic stirring (HJ-6, Jintan JIERUIER electric appliance Co. LTD, China) for 6 h and an continuous ultrasonic oscillation (40 kHz, PS-100A, Jie kang ultrasonic cleaning machine Co. LTD, China) for 2 h, the nanofluid mixture was well blended.

2.2 Characterization

The structural property of the dry SiO_2 nanoparticles was evaluated by using X-ray diffraction (XRD, D8 ADVANCE, BRUKER AXS GMBH, Germany). The TEM analysis of the SiO_2 nonoparticles sample was used to illustrate the descriptive details about SiO_2 nonoparticles. An UV-visible spectrum (TU-1810, Beijing Purkinje General Instrument Co. LTD, China) was performed to show the stability of SiO_2-EG/H_2O nanofluids.

The thermal conductivities of the nanofluids were measured using a transient hot-wire apparatus (TC 3020L, Xi'an Xiatech Electronic Technology Co. LTD, China).

The accuracy of this transient hot-wire apparatus is ±2–3% and its measuring range is 0.001–20 W/m·K. The operating temperature range of this instrument is between -160 and 150 °C. For the measurement of the electrical conductivity of nanofluids, an electric conductometer (3175-307, Jenco Instruments Inc., America) with a pair of electrodes (Model No. 109 L, Serial No. JC03345) was applied. The accuracy and measuring range of the device are ±0.5% and 0.0–199.9 μS/cm, respectively. It has two conductivity resolutions: 0.01 μS/cm for conductivity range from 0.00 to 19.99 μS/cm and 0.1 μS/cm for conductivity range from 2.00 to 199.9 μS/cm. To ensure that the stability of the sample did not impact the measurements and results, each sample needs a continuous ultrasonic oscillation before any measurements. During the measuring process of thermal and electrical conductivity, a T-type thermocouple (SMCL-1, Zenith International Trade CO. LTD, China) with an accuracy of ±0.5% and a data acquisition instrument (Agilent 34972A, USA) were used to detect the temperature of nanofluids. In addition, a temperature-controlled bath was used to keep constant temperature of every nanofluids sample during measurements. To ensure the uniformity of temperatures between the thermal conductivity and electrical conductivity, all measurements were started at a temperature of 25.0 °C and increasing to 45 °C in a 5 °C interval.

2.3 Calibration of devices

To ensure the accuracy of the devices to measure the thermal conductivity, pure drinking water (Cestbon Co. Ltd, China) was measured as standard sample. Calibration result of the thermal conductivity measuring instrument is available in Ref

[9]. To further ensure the precision and repeatability of the electrical conductometer, electrical conductivity of standard sample [0.1 mM potassium chloride (KCl) solution] was measured 10 times. The standard electrical conductivity of the solution at 25 °C should be 14.94 μS/cm [24,25]. Results of the measurement are within the limits of 14.9–15.0 μS/cm. Table 1 shows the measuring values of electrical conductivity of the standard KCl solution at 25 °C. The maximum error is ±0.40%, which proved the reliability of the conductometer.

Table 1 Summaries of electrical conductivities of 0.1 mM KCl

Times	Value (μS/cm)	Absolute error (%)	Times	Value (μS/cm)	Absolute error (%)
1	15.0	0.40	6	14.9	0.27
2	15.0	0.40	7	15.0	0.40
3	15.0	0.40	8	15.0	0.40
4	14.9	0.27	9	14.9	0.27
5	14.9	0.27	10	15.0	0.40

3. Results and discussion

3.1 Characterization

Fig. 1 shows the optical images of SiO_2-EG/H_2O nanofluids samples with different EG content percentages (v/v%, φ_v) after 5 h standing. As seen that there is no visible precipitation besides the sample with a φ_v of 0%, suggesting the feasibility of SiO_2-EG/H_2O nanofluids for experimental study.

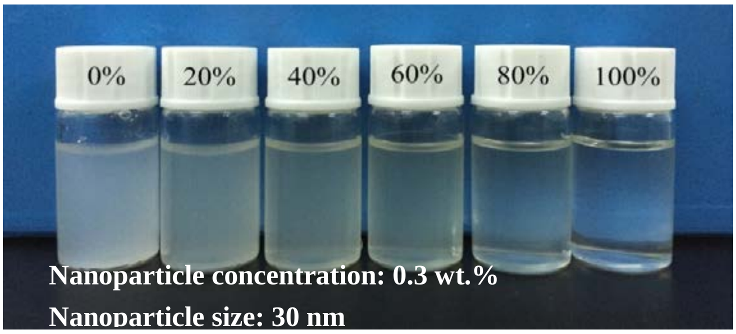

Fig. 1. SiO_2-EG/H_2O nanofluids samples with different φ_v.

The XRD spectrum of SiO_2 nanoparticles is present in Fig. 2. No crystalline peaks are found in the XRD spectrum, indicating that the nanoparticles are amorphous. Further, the XRD spectrum reaches its peak at an 2θ angle of 22 °. This value is the characteristic peak of amorphous SiO_2 (JCPDS card No. 29-0085). No more diffraction peak proves the high purity of the nanoparticles.

Fig.3 shows the TEM image of the SiO_2 nanoparticles. It can be seen that the nanoparticles are sphere with a diameter of ~30 nm. Aggregated structures prompt the long-time ultrasonic concussion (2 h in this work) during nanofluid preparation to break down the connection between nanoparticle interfaces.

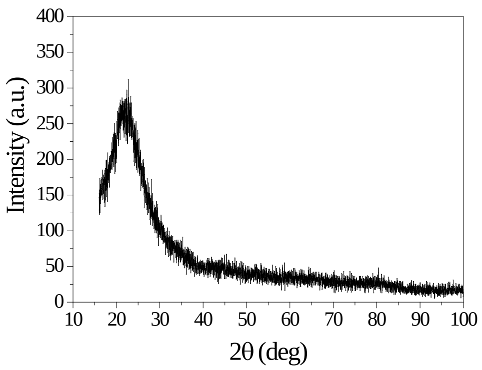

Fig. 2. XRD spectrum of SiO_2 nanoparticles.

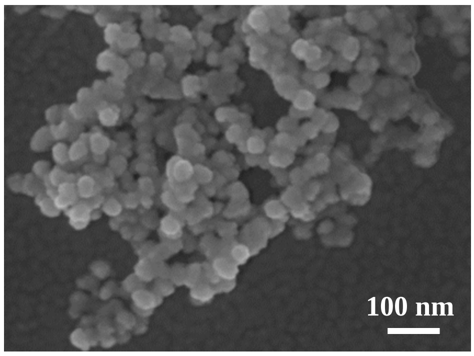

Fig. 3. TEM image of the SiO_2 nanoparticles.

There are some instruments and methods that can characterize the stability of nanofluids, UV–Vis measurements have been widely used to quantitatively characterize colloidal stability of nanofluids [26]. The working principle of UV–Vis spectrophotometer is that the intensity of light becomes different when the light absorbs and scatters passing through a fluid. This apparatus is applicable for almost all base fluids. Herein, nanofluids with four different φ_v, namely 0, 20, 80 and 100%, were tested. Fig. 4 illustrates the UV–Vis spectrum of the SiO_2-EG/H_2O nanofluids at wavelengths of 450–550 nm. Each sample was detected in three different times after preparation in 0, 1 and 2 h. In this detection, it can be seen that as the φ_v becomes higher, the variation of absorbance within two hours grow smaller; namely, the nanofluids sample grow more stable. It can also be found that for the nanofluids whose φ_v is equal or greater than 20%, the variation value of absorbance over the entire range of wavelength was smaller than 3%. Thus the UV–Vis spectrums did not appear much difference for these SiO_2-EG/H_2O nanofluids samples, which illustrates that these SiO_2-EG/H_2O nanofluids were basically stable in the first two hours after preparation. However, for the nanofluids whose φ_v is equal to 0%, the maximum variation value of absorbance was 10% approximately. That means when the base fluid is water, the SiO_2 nanofluids sample has lower stability.

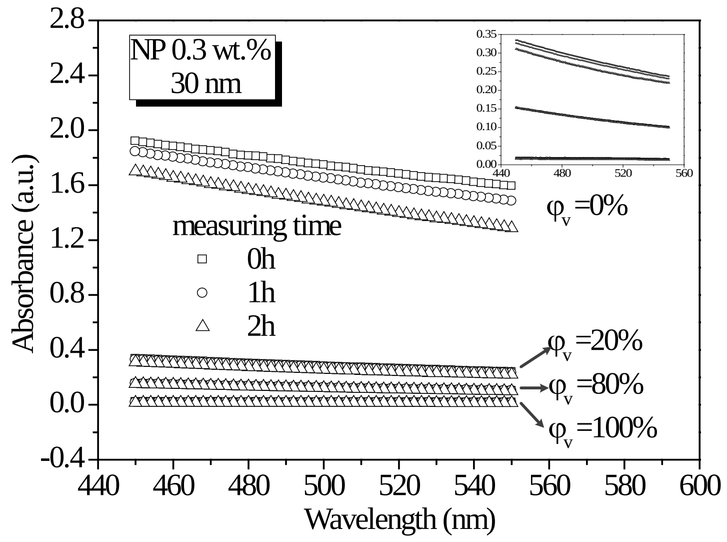

Fig. 4. UV–Vis spectrum of SiO_2-EG/H_2O nanofluids.

3.2 Thermal conductivity of nanofluids

Thermal conductivities of SiO_2-EG/H_2O nanofluids with different φ_v were measured at different temperatures from 25 to 45 °C. The base fluids were comprised with different φ_v ranging from 0% to 100%. The results are summarized in Table 2.

Fig. 5(a) and 5(b) shows the distribution of the thermal conductivities of SiO_2-EG/H_2O nanofluids as a function of φ_v and temperature respectively. From Fig. 5(a), one can observed that thermal conductivity decreases with increasing φ_v in an approximately linear manner. For example, the thermal conductivity had gone from 0.613 to 0.262 W/(m·K) when φ_v was changed from 0 to 100% at 25 °C, and the percentage decline reached to 57%. That is mainly because the thermal conductivity of a mixture of H_2O and EG decreases linearly with the increase of φ_v. From Fig. 5(b), it can be seen that thermal conductivity of SiO_2 nanofluids posted a small increase by raising the temperature. The thermal conductivity of nanofluids had been increased from 0.613 to 0.635 W/(m·K) when the temperature of the sample (φ_v=0%) was raised from 25 to 45 °C, and the percentage increase is only 3.6%. Through the comparative analysis of Fig. 5(a) and 5(b), it is found that φ_v has a more obvious effect on thermal conductivity of SiO_2 nanofluids than temperature. Furthermore, it is well known that φ_v can represent the thermal conductivity of base fluids. In other word, the thermal conductivity of base fluids has a significant influence on the thermal conductivity of SiO_2 nanofluids.

Table 2 Thermal conductivities of SiO_2 nanofluids for different temperatures and φ_v (W/(m·K))

	φ_v (%)					
T(°C)	0	20	40	60	80	100
25	0.613	0.526	0.442	0.368	0.310	0.262
30	0.617	0.534	0.446	0.370	0.310	0.262
35	0.626	0.539	0.449	0.372	0.312	0.263
40	0.632	0.544	0.453	0.375	0.313	0.263
45	0.635	0.549	0.457	0.378	0.315	0.264

Table 3 Thermal conductivity values of base fluids (W/(m·K))

	φ_v (%)					
T(°C)	0	20	40	60	80	100
25	0.587	0.503	0.419	0.352	0.299	0.246
30	0.594	0.509	0.424	0.355	0.301	0.247
35	0.602	0.515	0.428	0.358	0.303	0.248
40	0.609	0.520	0.431	0.360	0.304	0.248
45	0.615	0.525	0.435	0.363	0.306	0.249

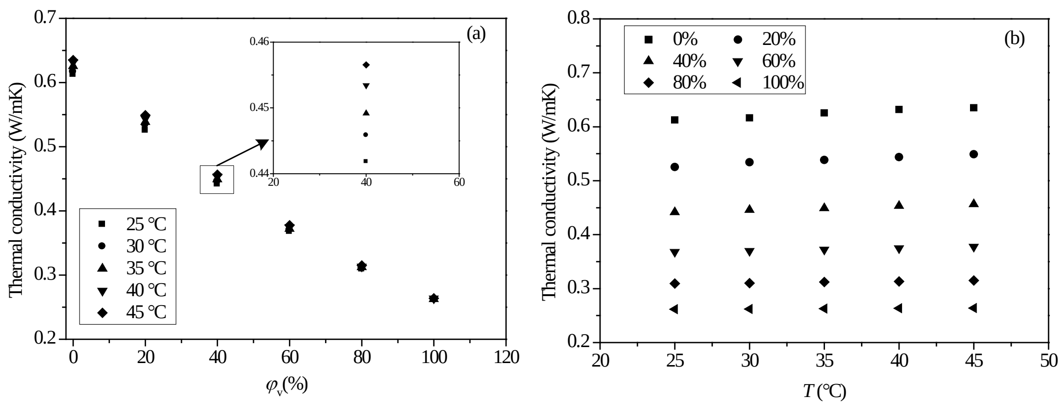

Fig. 5. Thermal conductivity distributions of SiO_2 nanofluids dispersed in mixture of EG and H_2O as functions of (a) φ_v and (b) temperature

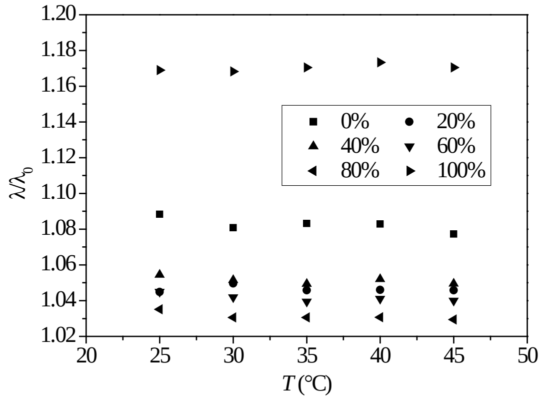

Fig. 6. Relative thermal conductivity of SiO_2-EG/H_2O nanofluids.

The relative thermal conductivity of SiO_2-EG/H_2O nanofluids is best presented by Fig. 6. λ/λ_0 represents the relative thermal conductivities where λ_0 and λ represent the thermal conductivity of base fluids and SiO_2-EG/H_2O nanofluids, respectively. The thermal conductivity values of base fluids are listed in Table 3. The highest relative thermal conductivity appeares at the 100% of φ_v which is around 1.17 in average, and the lowest appeared at 80% of φ_v which is around 1.03 in average. This result means that adding nanoparticles can enhance the thermal conductivity of base fluids at any φ_v.

3.3 Electrical conductivity of nanofluids

The electrical conductivities of SiO_2-EG/H_2O nanofluids with different φ_v (0% –100%) were measured at different temperatures from 25 to 45 °C. Table 3 shows the specific electrical conductivity measured values for different temperatures and φ_v. Fig. 7(a) presents the variation of the measured electrical conductivity of SiO_2-EG/H_2O nanofluids for different φ_v over the temperature interval of 25–45 °C. It can be seen that the electrical conductivity decreases with increasing φ_v in this temperature range, but the reduction rate slowed at higher φ_v. A similar trend has been observed before in 0.1%, 0.3 % and 0.5% particle volume concentrations of Al_2O_3 nanofluids (13 nm) [27]. The experiment results of [27] also show that there is a negative correlation between the electrical conductivity of Al_2O_3 nanofluids and EG concentration, and the correlation weakens as the EG concentration becomes higher. Although H_2O is a kind of very weak electrolyte, it can ionize few ions. In contrast, EG is a kind of organic matter and it does not have the ability to carry electric charges. Thus, the electrical conductivity of H_2O is higher than the electrical conductivity of EG. Therefore, the electrical conductivity of base fluid will decrease as the EG content percentage of base fluid increases. In other words, the electrical conductivity of base fluid has a negative correlation with φ_v. And that is the main reason to contribute to the result of Fig. 7(a). Fig. 7(a) also shows that the highest and the lowest electrical conductivities are observed at the 0% and 100% of φ_v respectively. These results suggest that the influence of temperature on electrical conductivity is less than that of φ_v when the test temperature is between 25 °C and 45 °C. Fig. 7(b) shows the electrical conductivity of SiO_2-EG/H_2O nanofluids as a function of temperature at different φ_v. As plotted, a slight enhancement of the electrical conductivity on temperature during 25 and 45 °C is disclosed. A similar trend has been observed before in Al_2O_3 [28], graphene [14], palladium [29]and TiO_2 nanofluids [30].

Table 4 Summaries of electrical conductivity values of SiO_2 nanofluids (μS/cm)

	φ_v (%)					
T(°C)	0	20	40	60	80	100
25	49.2	32.7	21.7	13.47	6.50	2.91
30	50.0	34.0	21.9	14.17	6.79	3.08
35	50.9	35.7	23.9	14.95	7.55	3.52
40	52.8	36.8	25.2	16.32	8.02	3.89
45	54.0	37.9	26.6	17.40	8.74	4.44

Table 5 Electrical conductivity values of base fluids (μS/cm)

	φ_v (%)					
T(°C)	0	20	40	60	80	100
25	5.44	4.22	1.9	1.47	1.36	0.33
30	5.53	4.26	2	1.48	1.39	0.36
35	5.73	4.77	2.18	1.74	1.56	0.42

40	5.85	4.93	2.28	1.98	1.68	0.46
45	6.05	5.4	2.52	2.21	1.85	0.53

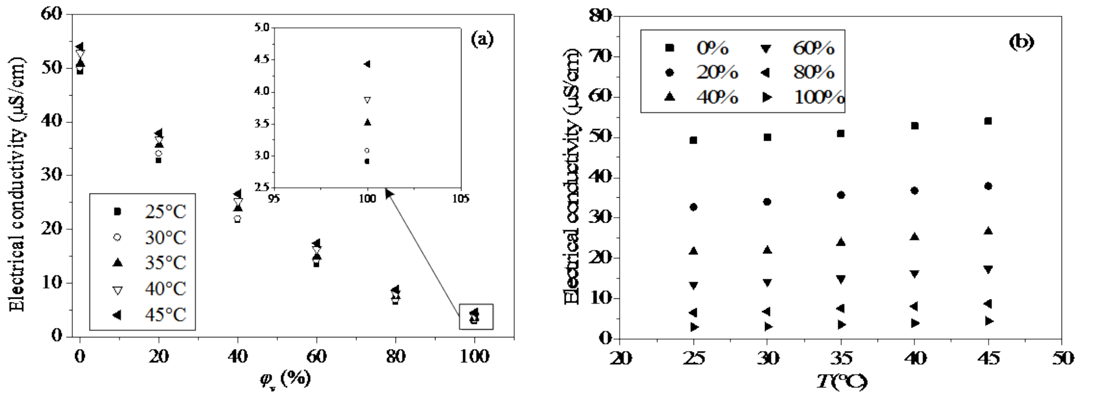

Fig. 7. (a) Electrical conductivity of SiO_2 nanofluids for different φ_v and (b) electrical conductivity of SiO_2 nanofluids for different temperatures.

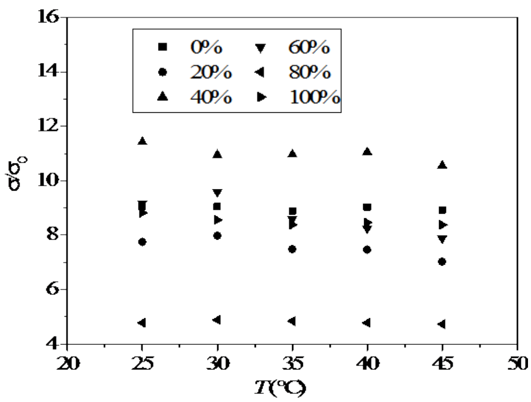

Fig. 8. Relative electrical conductivity of SiO_2-EG/H_2O nanofluids.

Fig. 8 shows the relative electrical conductivity of nanofluids under the condition of this study. In this figure, σ/σ_0 is the relative conductivity where σ_0 and σ correspond to the electrical conductivity of base fluids and SiO_2-EG/H_2O nanofluids, respectively. The electrical conductivity values of base fluids are listed in Table 5. It is of interest to point out that the relative electrical conductivity does not have an approximatively linear relationship to temperature as displayed by electrical conductivity property in Fig. 7(b). The highest relative electrical conductivity is observed at the 40% of φ_v which is around 11 in average, and the lowest is observe at

80% of φ_v which is around 5 in average. That means, whatever the φ_v is, the electrical conductivity of SiO_2-EG/H_2O nanofluids always has an enhancement compared with the electrical conductivity of the base fluid.

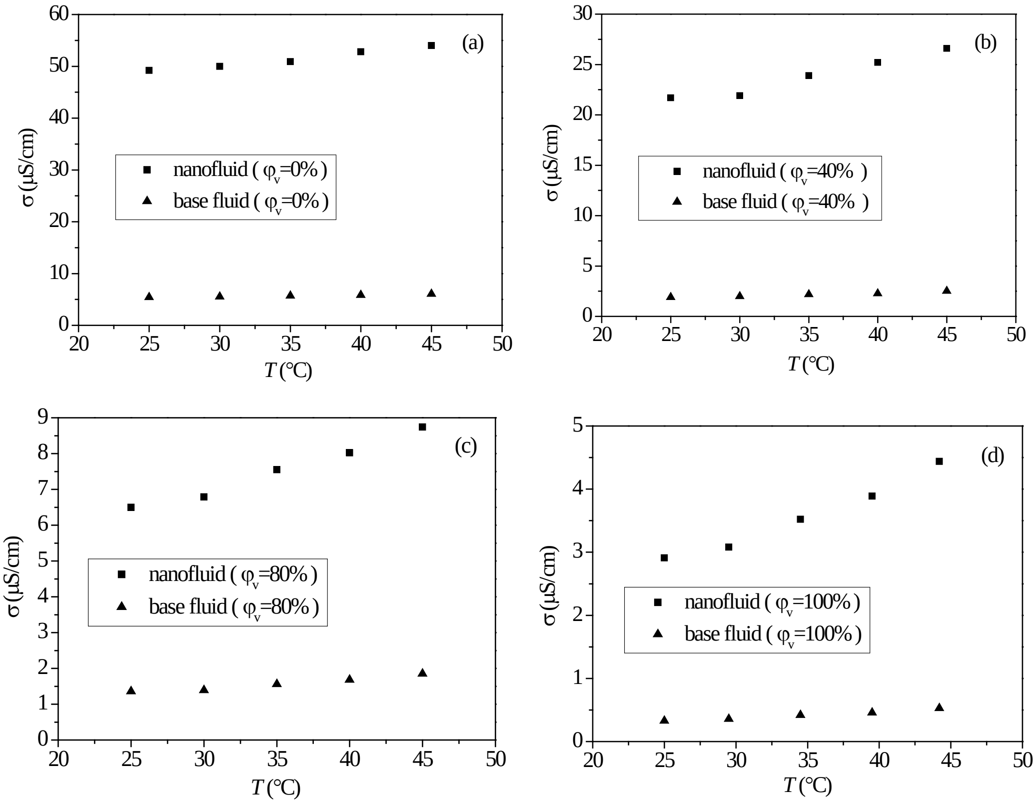

Fig. 9. Comparison of electrical conductivities between SiO_2-EG/H_2O nanofluids and base fluids for (a) φ_v= 0%, (b) φ_v= 40%, (c) φ_v= 80% and (d) φ_v= 100%.

Fig. 9 shows the effective electrical conductivity of SiO_2-EG/H_2O nanofluids and base fluids with different φ_v (0%, 40%, 80% and 100%). From Fig. 9, the contrast of the electrical conductivity of SiO_2-EG/H_2O nanofluids and base fluid is more obvious. It is observed that the electrical conductivity has a great enhancement when the nanoparticles are added into the base fluid. There are several reasons leading to this phenomenon. Though the SiO_2 nanoparticles cannot dissociate in the suspension, they can selectively adsorb charged ions. Thus, the surface of SiO_2 nanoparticles is charged.

On the one hand, the presence of uniformly disperse particles of which surface is charged leads to an enhancement of electrophoretic mobility undoubtedly. Hence, the electrical conductivity of the suspension enhanced significantly. On the other hand, when the surface of the particles is charged, ions of opposite charge to that of the particles surface are attracted, causing the development of a charged diffuse layer surrounding the particles [31]. The layer is known as electrical double layer (EDL) [31]. The EDL can actively contribute to the electrical conductivity of the suspension. Moreover, the electric double layer (EDL) thickness becomes thinner with the increasing temperature, which can enhance the electrical conductivity of nanofluids [31]. Future more, there is a negative correlation between liquid viscosity and temperature [32]. The electrophoretic mobility increases when the viscosity decreases, which leads to the enhancement of electrical conductivity [32].

3.4 Thermo-electrical conductivity ratio of nanofluids

The importance differs from one base fluid to another and it would be affected by properties of thermal conductivity and electrical conductivity. However the ratio can be described as thermo-electrical conductivity ratio (TEC, %) [27]. TEC is expressed as,

$$TEC = \frac{5\lambda}{\sigma\lambda_{EG}} \times 100\% \qquad (2)$$

λ_{EG} is referring to the thermal conductivity of pure ethylene glycol. Number 5 is utilized in the equation as that symbolizes the allowable value of electrical conductivity by Zakaria et al. [27].

TEC can represent the feasibility of one nanofluid to be applied in an electrically active heat transfer fields. The higher the TEC of one nanofluid, the more it is adaptive for this nanofluid to be applied in the electrically active heat transfer application such as fuel cell [27]. Fig. 10 demonstrates the TEC of SiO_2-EG/H_2O nanofluids with different φ_v at different temperatures. The results in Fig. 10 showed that the TEC ratio can be affected by both φ_v and temperature. The TEC ratio of SiO_2 nanofluids varies inversely to its temperature and varies directly to φ_v. The maximum value of TEC turned up in the SiO_2 dispersed in pure EG nanofluid at 25 °C, and the value is 79.9%.

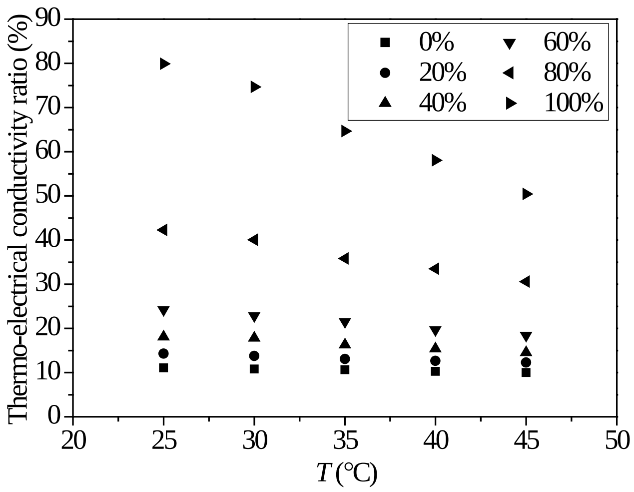

Fig. 10. Thermo-electrical conductivity ratio (TEC) distribution of SiO_2-EG/H_2O nanofluids as a function of temperature.

4. Conclusions

In this article, the thermal and electrical conductivity of SiO_2-EG/H_2O nanofluids was investigated. The experiment was conducted with SiO_2-EG/H_2O nanofluids containing different EG content percentage (φ_v = 0, 20, 40, 60, 80 and 100%) within the temperature range from 25 to 45 °C. The following conclusions are obtained:

i. The thermal conductivity of SiO_2-EG/H_2O nanofluids decreases with increasing EG content percentage at fixed temperature and it increases with increasing temperature at fixed EG content percentage. However, the effect of EG content is much more than the effect of temperature.

ii. The electrical conductivity of SiO_2-H2O nanofluids also shows the similar variation trend with the thermal conductivity. The highest and lowest relative electrical conductivity can be confirmed, which is at the 40% of EG content and the 80% of EG content, respectively.

iii. Because of the ionic adsorption capacity of SiO_2 nanoparticles, the electrical conductivity of SiO_2-EG/H_2O nanofluids has an obvious enhancement compared with that of the base fluids. Moreover, it also leads to the development of EDL. EDL can further enhance the electrical conductivity of the suspension.

iv. The thermo-electrical conductivity ratio of SiO_2 nanofluids is related to its EG content and temperature. The highest value of TEC ratio can be obtained when the temperature is 25 °C.

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