p-ISSN 2089 – 0133 e-ISSN 2477-6416
URL : https://jurnal.uns.ac.id/ijap/article/view/74558

DOI : https://doi.org/10.13057/ijap.v14i1.74558

THE EFFECT OF TETRAETHIL ORTHOCILICATE (TEOS) ON Fe_3O_4 NANOPARTICLES ADDITION IN ELECTRICAL

Indri Dayana*[1], Habib Satria[1], Martha Rianna[2]
[1] Engineering Faculty, Universitas Medan Area, Medan, Indonesia
[2]Department of Physics, Universitas Sumatera Utara, Medan, Indonesia
*dayanaindri@gmail.com

Received 05-06-2023, Revised 26-10-2023, Accepted 23-04-2024,
Available Online 25-04-2024, Published Regularly April 2024

ABSTRACT

Magnetite Nanoparticles of pure (Fe_3O_4) and Fe_3O_4 with TEOS addition have been successfully synthesized from natural iron sand using the coprecipitation method. The purpose of this study is to provide information on the effect of TEOS to Fe_3O_4 on the electrical properties. The effect of TEOS addition to Fe_3O_4 indicates that the increase in true density results is 4.95 gr/cm^3. The stability of nanolubricant on Fe_3O_4 nanoparticles with the addition of TEOS 1.2 ml was dispersed homogeneously. The value of thermal conductivity also increases due to TEOS addition on Fe_3O_4 nanoparticles in a volume fraction of 0.8% of 1,631 W/m.K and the heat of the type produced was 718.44 J/kg.K. The effect of TEOS addition on Fe_3O_4 nanoparticles produces good electrical properties of stability in the nano-lubricant.

Keywords: Fe_3O_4 nanoparticles, TEOS, thermal conductivity, electrical properties.

Cite this as: Dayana, I., Satria, H., & Rianna, M. 2024. The Effect of Tetraethil Orthocilicate (TEOS) On Fe_3O_4 Nanoparticles Addition In Electrical. *IJAP: Indonesian Journal of Applied Physics, 14*(1), 202-208. doi: https://doi.org/10.13057/ijap.v14i1.74558

INTRODUCTION

Magnetite (Fe_3O_4) nanoparticles, a common magnetic iron oxide, have a cubic inverse spinel structure with oxygen forming an FCC closed packing and Fe cations occupying the interstitial tetrahedral and octahedral sites [1]. The electrons can hop between Fe^{2+} and Fe^{3+} ions in octahedral sites even at room temperature, rendering magnetite an important half-metallic material [2].

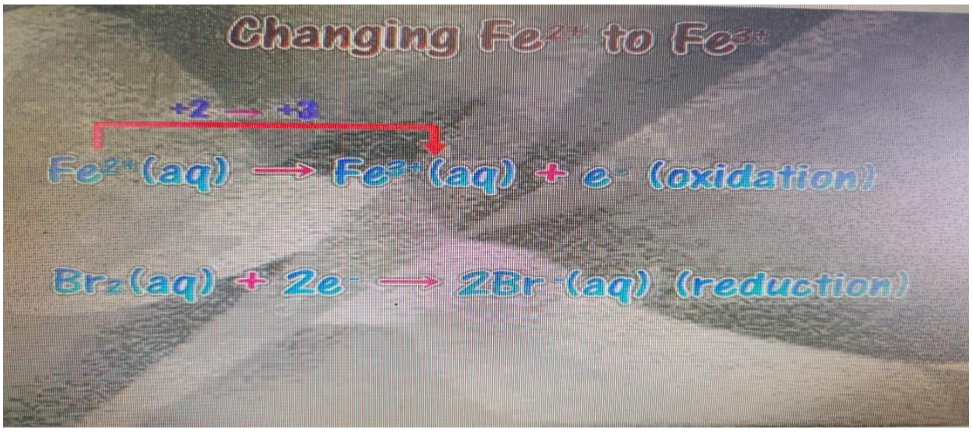

Figure 1. Sketches related to electrons moving between Fe2+ and Fe3+ ions

Figure 1 shows a sketch of the ability to transfer electrons Fe2+ and Fe3+ due to oxidation and reduction processes [2]. Magnetite (Fe_3O_4) nanoparticles are used in several applications, such as nanofluid for heat transfer applications [3-4], thermal conduktivity, density and adsorbent materials [5-8].

Fe_3O_4 nanoparticle synthesis has been carried out using various methods, including the coprecipitation method [9-11], high energy milling [12], sol gel [13] and others. The coprecipitation method is the most effective method because this method can be carried out under normal environmental conditions. The synthesis method of Fe_3O_4 nanoparticles used in this study is the coprecipitation method. Synthesis of inorganic compounds is based on the deposition of more than one substance together when it passes the saturation point. This means that coprecipitation is a method that can precipitate metals together during the formation of a precipitate. When a precipitate separates from a solution, the precipitate is not always perfectly pure, it may contain various amounts of impurities, depending on the nature of the precipitate and the conditions of deposition dissolving or precipitating a solid in a solution is determined by the saturation condition or the limit of a solid substance that can dissolve in a liquid[13]. The advantages of the coprecipitation method are using room temperature and easily controlling particle size so that the time needed is relatively shorter [14].

This study was conducted with the aim of dispersing Fe_3O_4 nanoparticles with the composition of TEOS into the lubricant and knowing the density before mixing TEOS and after mixing TEOS and potential zeta testing that affects nano-lubricant stability viewed from the electrical properties.

METHOD

The process of coating magnetite Fe_3O_4 nanoparticles with Tetraethyl Orthosilicate (TEOS) and then the characterization of these results were obtained. Aquades solution and Ethanol solution act as solvents, Ammonia solution acts as sedimentary solution and Tetraethyl Orthosilicate (TEOS) acts as coating material. In the research, 0.2 grams of Fe_3O_4 powder was combined into 60 ml of Aquades, 240 ml of Ethanol, and 7.5 ml of Ammonia 18%. Then, TEOS was added with variations of 0.9 ml, 1.2 ml, 1.5 ml, and 2.5 ml. Then it was stirred using a magnetic stirrer for 6 hours with a speed of 500 rpm and a temperature of 25 C to produce a homogeneous solution. Then, the results of the mixture will produce powder in the form of a precipitate. The precipitate was separated from the solution using a permanent magnet and washed using Aquades, and then the precipitate of washed wet powder was then dried in the oven for 24 hours at a temperature of 60 C. After the sediment dries, the dried powder was mashed using mortar. To produce Fe_3O_4 nanoparticles powder, 0.2 gram of Fe_3O_4 nanoparticles was mixed into 100 ml of lubricating oil and stirred using a spatula until homogeneous. The Nano-lubricant was further analyzed using several measurements and characterizations. The thermal conductivity and specific heat of the nano-lubricant were measured using C-Therm, TCi thermal conductivity analyzer. Heat Type (HT, Linseis, STA PT 1600). The densities of nano-lubricants were measured using a Pycnometer. Transmission Electron Microscopy (TEM, Tecnai G2 S20 twin) was used to analyze the magnetite particle size and distribution. The magnetite particles' thermal behavior at two different conditions: with and without silica (TEOS) coating.

RESULTS AND DISCUSSION

Nano-lubricant Thermal Conductivity Model

The thermal conductivity of a nanofluid is an important data used in the application of nanofluid. The ratio as reference data increases the thermal conductivity of the nanofluid compared to the base fluid. Measurement of thermal conductivity was carried out to determine the effect of TEOS variation and stability of nanoparticles that have been tested with potential zeta. The sample used was to see the effect of TEOS on the thermal conductivity of nanofluid in which samples of Fe_3O_4 nanoparticles coated with TEOS with a variation of 1.2 ml of conductivity can be seen in Figure 2. The calculation was taken from the theory of the Maxwell model of solid-liquid mixture.

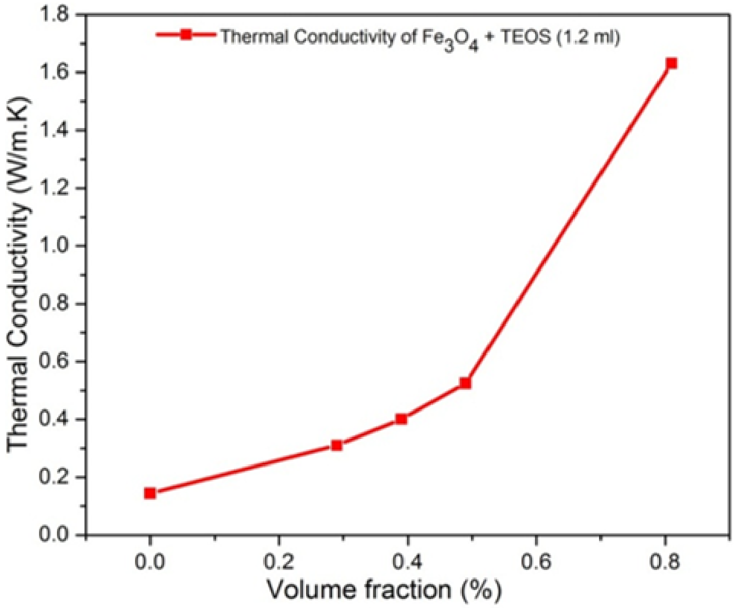

Figure 2. Value of thermal conductivity of Fe_3O_4+TEOS (1.2ml) sample to the variation in volume concentration

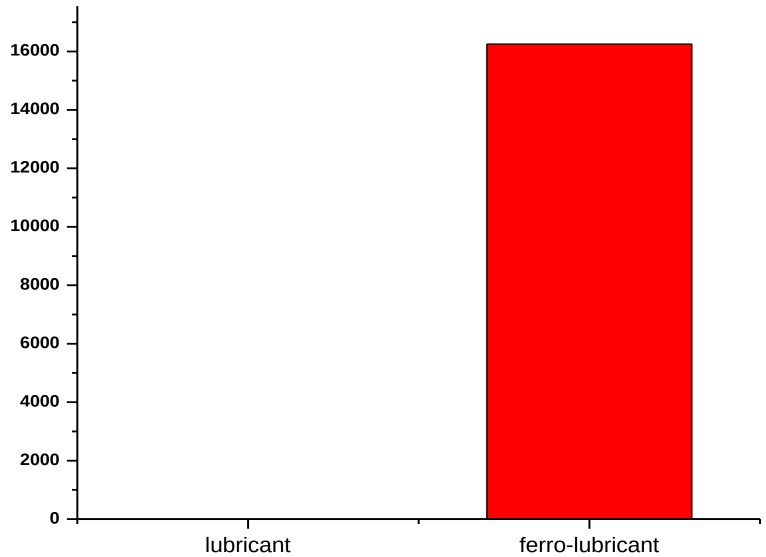

Figure 3. Sketch of the thermal conductivity measurement

Figure 2 and Figure 3 show that there is an increase in the value of thermal conductivity from a volume concentration of 0% (pure Fe_3O_4) of 0.144 W/m.K, while Fe_3O_4 with the addition of TEOS 1.2 ml with a volume concentration of 0.81% is 1,631 W/m.K. These results indicate that the effect of TEOS addition increases the value of thermal conductivity in Fe_3O_4. The greater the volume concentration of the sample, the greater the value of thermal conductivity [17, 18]. The conductivity value increases due to the effect of volume concentration because the nanoparticles are suspended in the base fluid, causing heat transfer in suspension in the solid-liquid phase on the surface of the particles [19], consequently the heat transfer properties in the sample are more efficient. In addition, another cause is the occurrence of Brownian movement in the base fluid [20-21].

Heat Type Model of Nanofluid

Heat type is one of the properties that affect nanofluid. Figure 4 explains the effect of TEOS addition on samples of Fe_3O_4 nanoparticles on the heat of their type. The heat value was obtained from the calculation using a model that was previously used in the study conducted by Ping Zhou et al. in (2010) [26].

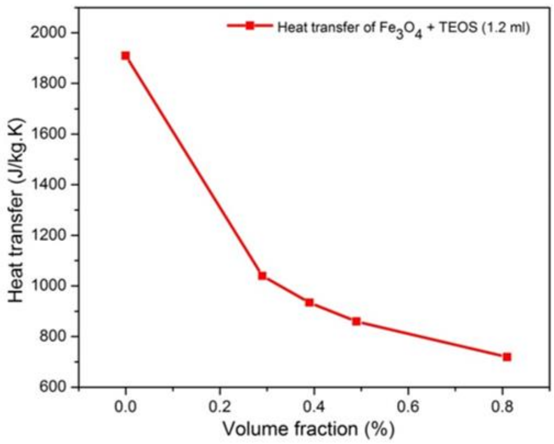

Figure 4. Heat value of Fe_3O_4 + TEOS (1.2ml) sample to the variation in volume concentration

Table 1. Heat value of the sample with TEOS volume concentration

Concentration (% vol)	Heat Type (J/kg.K) Literature, Ping Zhou et al. (2010) [26]	Heat Type (J/kg.K) Research
0	1909	1910
0.29	1039.138	1039.438
0.39	934.4656	934.4755
0.49	858.5157	859.5159
0.81	718.4456	718.4467

Based on Table 1 above, it can be concluded that the heat value of nanofluid tends to decrease as the volume concentration of nanofluid increases [27].

Density

The synthesized ferro-lubricant and the density of ferro-lubricant as a function of particle addition variation are shown in Figure 5. The density of 0.84g/cm^3 is obtained at 0.3g of magnetite particles coated using 1.2 ml of TEOS that acts as the silica precursors. Then, the particles (0.1 g) were immersed in 100 ml of lubricant. The TEOS and particle addition in the lubricant was chosen because showing better liquid stability, as analyzed in our previous investigation [26]. Based on the graph, the increase of the silica-coated magnetite particles (0.1 to 0.4 g) used as the additive could enhance the density of ferro-lubricant from 0.84 to 0.88 g/cm^3. A similar trend was also observed by Syam Sundar et al. [27] when the volume concentration was increased in the magnetite-water nanofluid. Viscosity is another critical factor of thermophysical properties, representing the internal resistance of fluid flow [26], and viscosity correlates with temperature [27]. Ferro-lubricant's viscosity analysis and comparison.

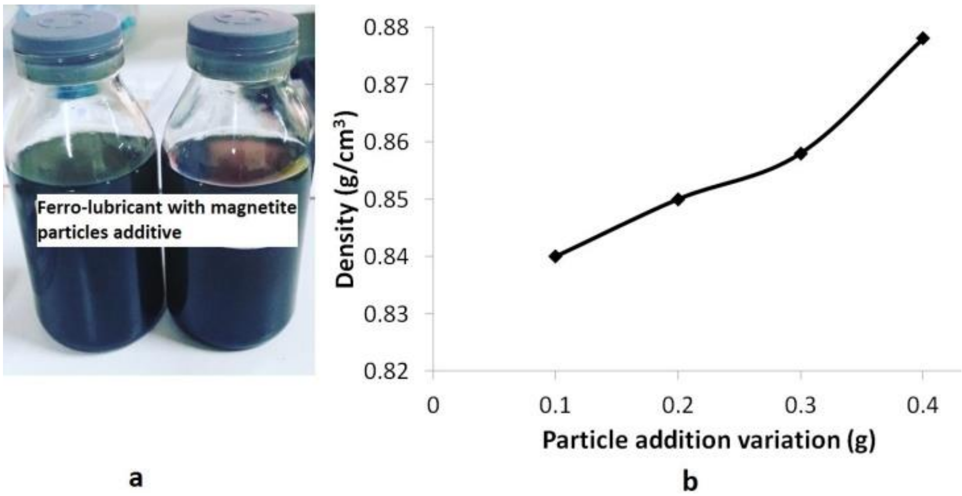

Figure 5. a) Ferro-lubricant that have been synthesized in the laboratory; b) Densityofferro-lubricant as a function of particle addition variation

Transmission Electron Microscopy (TEM)

Transmission Electron Microscopy (TEM, Tecnai G2 S20 twin) was used to analyze the magnetite particle size and distribution. The magnetite particles' thermal behavior at two different conditions: with and without silica (TEOS) coating.

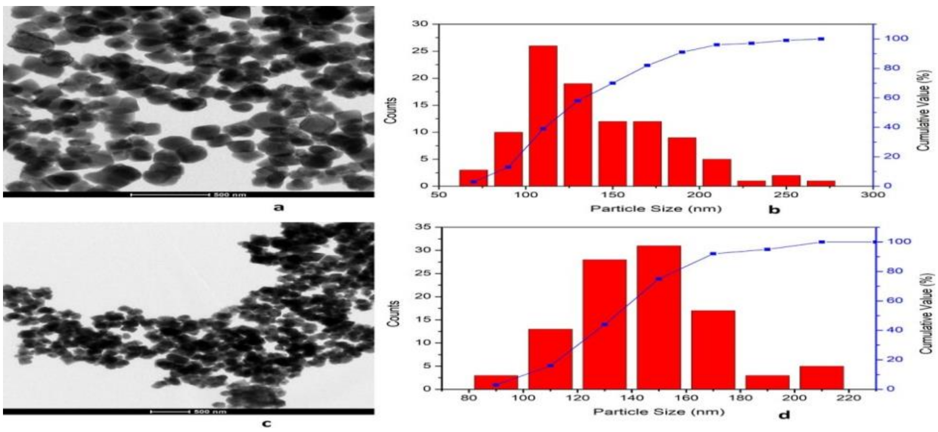

Figure 6. a) TEM image of uncoated magnetite particles; b) Histogram of uncoated magnetite particles size; c) TEM image of silica-coated magnetite particles; d) Histogram of silica-coated magnetite particles size.

Figure 6. The results suggested that the particles coated using silica (TEOS) have a larger average diameter of 150 nm than the uncoated particles with an average size of 120 nm. Thus, silica layers have been successfully coated on the surface of the magnetite particles. The coating layer of silica, which has an oleophilic characteristic, is essential for the particles to be easily dispersed in the lubricant and improve stability [23–27]. This is one of the proofs that the TEOS nanoparticles are coated with Magnetite (Fe_3O_4) and can be clearly seen by TEM measurements of the properties of pure magnetite (Fe_3O_4) and (Fe_3O_4) with TEOS [23–27].

CONCLUSION

Magnetite nanoparticles of pure (Fe_3O_4) and Fe_3O_4 with TEOS were successfully synthesized from natural iron sand using the coprecipitation method. The effect of TEOS addition to Fe_3O_4 indicates that the increase in true density results is 4.95 gr/cm^3. The stability of nano-lubricant on Fe_3O_4 nanoparticles with the addition of TEOS 1.2 ml was dispersed homogeneously. The thermal conductivity value also increases due to the addition of TEOS to Fe_3O_4 nanoparticles in a volume fraction of 0.8% of 1,631 W/m.K and the type of heat produced was 718.44 J/kg. K.

ACKNOWLEDGMENTS

The authors would like to thank the Foundation Internal Fund (DIYA) for financial support with Grant No. 1815/LP2M/03.1.1/VI/2023. We also thank the S.O.S Laboratorium Trakindo BSD for the facilities used in this research and the support from Universitas Medan Area Medan, Universitas Sumatera Utara (USU) for supporting this research.

REFERENCES

1 Hui, C., Shen, C., Tian, J., Bao, L., Ding, H., Li, C., Tian, Y., Shi, X., & Gao, H. J. 2011. Core-shell Fe 3 O 4@ SiO 2 nanoparticles synthesized with well-dispersed hydrophilic Fe 3 O 4 seeds. *Nanoscale, 3*(2), 701-705.

2 Cowley, M. D. 1989. Ferrohydrodynamics. By RE ROSENSWEIG. Cambridge University Press, 1985. 344 pp.£ 45. *Journal of Fluid Mechanics, 200*, 597-599.

3 Tetuko, A. P., Shabani, B., & Andrews, J. 2016. Thermal coupling of PEM fuel cell and metal hydride hydrogen storage using heat pipes. *International Journal Of Hydrogen Energy, 41*(7), 4264-4277.

4 P. Tetuko, A., Shabani, B., & Andrews, J. 2018. Passive fuel cell heat recovery using heat pipes to enhance metal hydride canisters hydrogen discharge rate: An experimental simulation. *Energies*, *11*(4), 915.

5 Xu, J. K., Zhang, F. F., Sun, J. J., Sheng, J., Wang, F., & Sun, M. 2014. Bio and nanomaterials based on Fe3O4. *Molecules*, *19(*12), 21506-21528.

6 Sebayang, P., Kurniawan, C., Aryanto, D., Setiadi, E. A., Tamba, K., & Sudiro, T. 2018. Preparation of Fe3O4/bentonite nanocomposite from natural iron sand by co-precipitation method for adsorbents materials. *In IOP Conference Series: Materials Science and Engineering*, 316(1), 012053.

7 Setiadi, E. A., Amriani, F., & Sebayang, P. 2017. The evaluation of temperature in synthesizing process of natural iron sand based Fe3O4 nanoparticles for Ni ion adsorption. *In AIP Conference Proceedings, 1904*(1).

8 Rianna, M., Sembiring, T., Situmorang, M., Kurniawan, C., Tetuko, A. P., Setiadi, E. A., Priyadi, I., Ginting, M., & Sebayang, P. 2019. Effect of calcination temperature on Microstructures, magnetic properties, and microwave absorption on BaFe11. 6Mg0. 2Al0. 2O19 synthesized from natural iron sand. *Case Studies in Thermal Engineering, 13*, 100393.

9 Setiadi, E. A., Sebayang, P., Ginting, M., Sari, A. Y., Kurniawan, C., Saragih, C. S., & Simamora, P. 2016. The synthesization of Fe3O4 magnetic nanoparticles based on natural

iron sand by co-precipitation method for the used of the adsorption of Cu and Pb ions. *In Journal of Physics: Conference Series, 776*(1), 012020.

10 Setiadi, E. A., Simbolon, S., Yunus, M., Kurniawan, C., Tetuko, A. P., Zelviani, S., & Sebayang, P. 2018. The effect of synthesis temperature on physical and magnetic properties of manganese ferrite (MnFe2O4) based on natural iron sand. *In Journal of Physics: Conference Series, Vol. 979*(1), 012064.

11 Kurniawan, C., Eko, A. S., Ayu, Y. S., Sihite, P. T. A., Ginting, M., Simamora, P., & Sebayang, P. (2017, May). Synthesis and characterization of magnetic elastomer based PEG-coated Fe3O4 from natural iron sand. *In IOP Conference Series: Materials Science and Engineering, 202*(1), 012051.

12 Rianna, M., Sembiring, T., Situmorang, M., Kurniawan, C., Setiadi, E. A., Tetuko, A. P., ... & Sebayang, P. 2018. Characterization of natural iron sand from Kata Beach, West Sumatra with high energy milling (Hem). *Jurnal Natural, 18*(2), 97-100.

13 Zhang, X., Han, D., Hua, Z., & Yang, S. 2016. Porous Fe3O4 and gamma-Fe2O3 foams synthesized in air by sol-gel autocombustion. *Journal of Alloys and Compounds, 684*, 120-124.

14 Hariani, P. L., Faizal, M., & Setiabudidaya, D. 2013. Synthesis and properties of Fe3O4 nanoparticles by co-precipitation method to removal procion dye. *International Journal of Environmental Science and Development, 4(*3), 336.

15 Chen, H. J., Wang, Y. M., Qu, J. M., Hong, R. Y., & Li, H. Z. 2011. Preparation and characterization of silicon oil based ferrofluid. *Applied surface science, 257(*24), 10802-10807.

16 de Mendonça, E. S. D. T., de Faria, A. C. B., Dias, S. C. L., Aragón, F. F., Mantilla, J. C., Coaquira, J. A., & Dias, J. A. 2019. Effects of silica coating on the magnetic properties of magnetite nanoparticles. *Surfaces and Interfaces, 14,* 34-43.

17 Teresa, O. H., & Choi, C. K. 2010. Comparison between SiOC Thin Film by plasma enhance chemical vapor deposition and SiO2 Thin Film by Fourier Transform Infrared Spectroscopy. *J. Korean Phys. Soc., 56*(4), 1150–1155.

18 Jacintho, G. V., Brolo, A. G., Corio, P., Suarez, P. A., & Rubim, J. C. 2009. Structural investigation of MFe2O4 (M=Fe,Co) magnetic fluids. *The journal of physical chemistry C, 113*(18), 7684-7691.

19 Lebed, B. M., & Voronkov, V. D. 1996. State of the art millimeter and sub-millimeter wave ferrite components and devices. *In 1996 26th European Microwave Conference, 2*, 816-822.

20 Wu, S., Zhu, D., Li, X., Li, H., & Lei, J. 2009. Thermal energy storage behavior of Al2O3–H2O nanofluids. *Thermochimica Acta, 483*(1-2), 73-77.

21 Abareshi, M., Goharshadi, E. K., Zebarjad, S. M., Fadafan, H. K., & Youssefi, A. 2010. Fabrication, characterization and measurement of thermal conductivity of Fe3O4 nanofluids. *Journal of Magnetism and Magnetic Materials, 322*(24), 3895-3901.

22 Khan, I., Abro, K. A., Mirbhar, M. N., & Tlili, I. 2018. Thermal analysis in Stokes' second problem of nanofluid: Applications in thermal engineering. *Case studies in thermal engineering*, *12*, 271-275.

23 Masala, O., Hoffman, D., Sundaram, N., Page, K., Proffen, T., Lawes, G., & Seshadri, R. 2006. Preparation of magnetic spinel ferrite core/shell nanoparticles: Soft ferrites on hard ferrites and vice versa. *Solid state sciences, 8*(9), 1015-1022.

24 Das, S. K., Putra, N., Thiesen, P., & Roetzel, W. 2003. Temperature dependence of thermal conductivity enhancement for nanofluids. *J. Heat Transfer*, *125*(4), 567-574.

25 Li, C. H., & Peterson, G. P. 2006. Experimental investigation of temperature and volume fraction variations on the effective thermal conductivity of nanoparticle suspensions (nanofluids). *Journal of Applied physics*, *99*(8).

26 Zhou, L. P., Wang, B. X., Peng, X. F., Du, X. Z., & Yang, Y. P. 2010. On the specific heat capacity of CuO nanofluid. *Advances in mechanical engineering*, *2*, 172085.

27 Rosengarten, G., Tetuko, A., Li, K. K., Wu, A., & Lamb, R. (2011, January). The effect of nano-structured surfaces on droplet impingement heat transfer. *In ASME International Mechanical Engineering Congress and Exposition, 54921*, 1029-1036.