Journal of Engineering, Emerging Technologies and Applied Sciences -– Volume 1 Issue 1, April 2023

*Available at **www.ndu.edu.ng/ journalofengineering***

RESEARCH ARTICLE OPEN ACCESS

Synthesis and characterization of Zinc oxide nanoparticles-polyvinyl alcohol-polyethylene glycol nanofluids (ZNO-Nps-PVA-PEG-NF)

Orlando Ketebu
Department of Chemical Engineering, Niger Delta University, Wilberforce Island, Bayelsa State
Email: ketebu.orlando@ndu.edu.ng

-------------------------------------*************************--------------------------------

Abstract

Water and oil are known conventional fluids used in heat transfer processes due to their availability at low cost. The limited heat transfer potentialities of these conventional fluids in the industries for heat and mass transfer equipment such as heat exchangers, air coolers and chemical unit processes, has been a major challenge over the years. This is due to the poor thermal conductivity of these conventional fluids. Nanofluid offers a promising future for such industries because they give better performance than conventional fluids due to the presence of suspended nanoparticle which has high thermal conductivity. Nanofluid is a fluid containing particles in nanometer range called nanoparticles. This research work looks at the synthesis and characterization of Zinc oxide nanoparticles polyvinyl alcohol/polyethylene glycol nanofluids (ZnO-Nps-PVA-PEG-NF). The results from the experiment showed that ZnO Nps with hexagonal wurtzite structure and average size 15 nm was formed using X-ray Diffraction (XRD) analysis to determine the sample crystalline structure and sizes. Scanning electron microscopy (SEM) image used to determine the morphology of the prepared ZnO Nps-PVA-PEG NF showed a well dispersed ZnO Nps in PVA-PEG base fluid. The ZnO Nps-PVA-PEG NF also showed stability for up to two weeks before aggregation and the PVA-PEG composite base fluid also acted as a stabilizing agent for the ZnO Nps in ZnO Nps-PVA-PEG NF. These findings make ZnO Nps-PVA-PEG NF a possible replacement for conventional fluids with its unique properties.

Keywords — Zinc oxide nanopaticles, Polyvinyl alcohol, Polyethylene glycol, Nanofluid, X-ray diffraction, Scanning electron microscopy

-------------------------------------*************************--------------------------------

I. INTRODUCTION

Fluids for heat and mass transfer equipment such as heat exchanger, air coolers, towers and chemical unit processes has been a major challenge over the years. Conventional fluid such as water, oils and ethylene glycol are often used as heat transfer fluids due to their availability at low cost. But these fluids are known to have poor thermal conductivity which limits their heat transfer potentials, and this drawback impedes their effectiveness in heat exchangers and other heat and mass transfer equipment (Czaplicka, et al., 2021, Okonkwo, et al., 2021). This has made researchers to look for alternative fluids to these conventional fluids that are effective, cheap with good thermal conductivities. One of such fluids is nanofluids. Nanofluid offers a promising future for industries making use of heat and mass transfer equipment, because they give better performance than conventional fluid due to the presence of suspended nanoparticle which has high thermal conductivity.

Nanofluids are colloidal suspension of nanometer-sized particles also known as nanoparticles in a base fluid (Samir and Mandal, 2015). Nanoparticles such as metal nanoparticles, carbon base nanoparticles, metal oxide nanoparticles are used in the formation of nanofluid. These nanoparticles have their individual unique properties that contribute effectively to the thermal conductivities of heat and mass transfer operation, fuel cell design, microelectronics and pharmaceutical processes etc. (Das et al., 2007). Nanofluids are known to have enhanced thermal conductivity with effective heat transfer coefficient (convective heat transfer) when compared to their base fluid (Kakac et al., 2009, John et al, 2022). Nanofluids can be a single phase or two phase fluid depending on the components involved in the synthesis. It is a single phase fluid when the physical properties of the nanofluid is due to its constituents and concentrations, or a two phase fluids when two component are involve in its synthesis (Lu et al., 2013). Nanofluids can be synthesized through a one-step method or two step method. The one step method concurrently disperses the nanoparticles in the base fluid and is often used in synthesizing of metal nanoparticles nanofluids. The two step method involves agitating the nanoparticles in the base fluid with an agitator to homogenize the nanoparticles in the base fluid forming nanofluid and is suitable for large scale nanofluid production.

There are different techniques for synthesizing nanofluids such chemical precipitation, direct evaporation, chemical vapour condensation, gas condensation /dispersion, and bio-base methods. This work focuses on the synthesis and characterization of nanofluids using polyvinyl alcohol (PVA), polyethylene glycol (PEG) mixture as base fluid and zinc oxide nanoparticles (ZnO Nps) as nanoparticles source.

PVA is non-hazardous water soluble synthetic polymer made up of vinyl alcohol unit connected together in a repeating pattern (Rigved and Jatin, 2019). PVA can be fully or partially hydrolyzed depending on the amount of vinyl acetate replaced by hydroxyl group in the ester group. PVA is used in the manufacture of adhesives, medical and biomedical applications, food processing, coating industries, films and elastomers, biopolymer etc.

PEG is also a synthetic water soluble polymer synthesized when ethylene oxide interacts with water. PEG has a wide range of applications such as in medical and biomedical processes, industrial and chemical processes and for commercial activities (Hoang Thi et al., 2020).

Zinc Oxide nanoparticle is a metal oxide nanoparticles with unique properties such as its semiconducting and piezo-electric properties, antifungal and antibacterial properties, photochemical and ultraviolet filtering properties (Sirelkhatim, et al., 2015). ZnO Nps can be synthesized using micro-emulsion, sol-gel, thermal evaporation, laser ablation and chemical vapour deposition techniques and these techniques also affects the nanoparticles sizes.

Researchers have synthesized ZnO Nps with polymers such as PEG, PEG-PVA nanocomposites (Irina et al, 2021, Nibiyouni et al., 2011, Liufu et al., 2004, Minea et al., 2022) but were interested in the synthesis route, for drug storage, monitoring the adsorption of PVA/PEG nanocomposites and heat transfer analysis of PEG 400 on ZnO Nps. Non looked at combining PVA-PEG with ZnO Nps to synthesize nanofluid that might be a good alternative for conventional fluids.

II. MATERIALS AND METHOD

The following chemicals and equipment were used to carry out the experiment.

The chemicals are; hydrolyzed PVA (98%), PEG-4000, Zinc acetate dehydrate, distilled water, Methanol, Potassium hydroxide, and the equipment are; Magnetic stirrer, Hot plate, Centrifuge, 100 milliliter Beakers, 100 milliliter volumetric flasks, Ultrasonicator, syringe, weighing balance, X-ray diffractommetry (XRD), and Scanning electron microscopy (SEM).

A. Synthesis of ZnO Nps

ZnO Nps were prepared following similar method adopted by Singh and co researchers (Singh et al, 2012). The procedure involves dissolving 294.1 mg of zinc acetate dihydrate in methanol (100 ml) to form 13.4 millimole of zinc acetate dihydrate mixture followed by drop wise addition of potassium hydroxide solution at 52°C with constant agitation for two hours. The two hours is the time range for precipitation to occur and 52°C is the temperature required for the solvothermal process. Potassium hydroxide solution was prepared by dissolving 162.5 mg of potassium hydroxide in 100 ml methanol to form 28.96 millimole of potassium hydroxide solution (100 ml). Precipitates of ZnO Nps were formed as the agitation continues at 52°C when the solution turns turbid. The heating and agitation process was stopped and the precipitate allowed to cool at room temperature for two hours. The excess liquid was decanted and the precipitated ZnO Nps was washed with 50 milliliters of methanol twice and centrifuged to collect the nanoparticles. The ZnO Nps were dried at room and placed in an airtight container.

B. Synthesis of Polyvinyl alcohol-Polyethylene glycol- base fluid (PVA-PEG)

Three weight percent of PVA-PEG base fluid were synthesized by dissolving 2.55 grams of PEG and PVA in distilled water (80 milliliters) at 60°C. The mixture were stirred continuously for complete dissolution and formation of homogeneous mixture. After complete dissolution, the mixture were left at room temperature to cool.

C. Formation of Polyvinyl alcohol-Polyethylene glycol-Zinc oxide Nanoparticles nanofluid (ZnO Nps PEG-PVA-NF)

Grounded powder of ZnO Nps (5 weight percent) were obtained by crushing the dried ZnO Nps. The ZnO Nps powder were then dispersed in 3 weight percent of PVA-PEG base fluid through ultrasonication. The dispersed solution were allowed to stand for 2 weeks to monitor its stability and aggregation. This in turn affects the size and shape of the nanoparticles as evaporation of the base fluid occurs.

D. Characterization of ZnO Nps -PVA- PEG-NF

The synthesized ZnO Nps PEG-PVA-NF were characterized with SEM to determine the nanoparticles and base fluid surface morphologies and XRD to determine the crystalline nature of ZnO Nps formed and the presence of PEG, PVA and ZnO Nps peaks at desired Bragg's angles.

III. RESULT AND DISCUSSION

Fig. 1a shows the synthesized ZnO Nps which is the whitish particles on the plate. Fig. 1b shows the prepared PVA-PEG base fluid. In Fig. 1b the base fluid is a transparent homogeneous mixture resulting from the combination of water soluble PVA and PEG.

Fig. 1 (a) shows the synthesized ZnO Nps (b) synthesized PVA-PEG base fluid

Fig. 2 Synthesized ZnO Nps-PVA-PEG nanofluid

Fig. 2 shows the synthesized ZnO Nps-PVA-PEG nanofluid. The ZnO Nps are homogenized in the base fluid through ultrasonication process. The ZnO Nps-PVA-PEG nanofluid remained stable for two week without aggregation of the ZnO Nps. This shows that the combination of PVA and PEG to form base fluid also acted as a stabilizing agent for the ZnO Nps preventing the nanoparticles from aggregating.

Fig. 3 shows the XRD image of the synthesized ZnO Nps-PVA-PEG nanofluid. The diffraction peaks (100), (002), (101), (102), (110), (103), and (201) located at 31.84°, 34.52°, 36.33°, 47.63°, 56.71°, 62.96° and 69.18° respectively indicate that the ZnO Nps formed had hexagonal wurtzite phase of Zinc oxide based on JPCDS card number: 36-1451. The average nanoparticles size diameter (D) was approximately 15 nm applying Debye-Scherrer formula in equation 1.

$$D = \frac{0.89\lambda}{\beta \cos \theta} \qquad (1)$$

Where λ is X-ray wavelength, β is the full width at half-maximum (FWHM), 0.89 is Scherrer's constant, and θ is the Bragg diffraction angle.

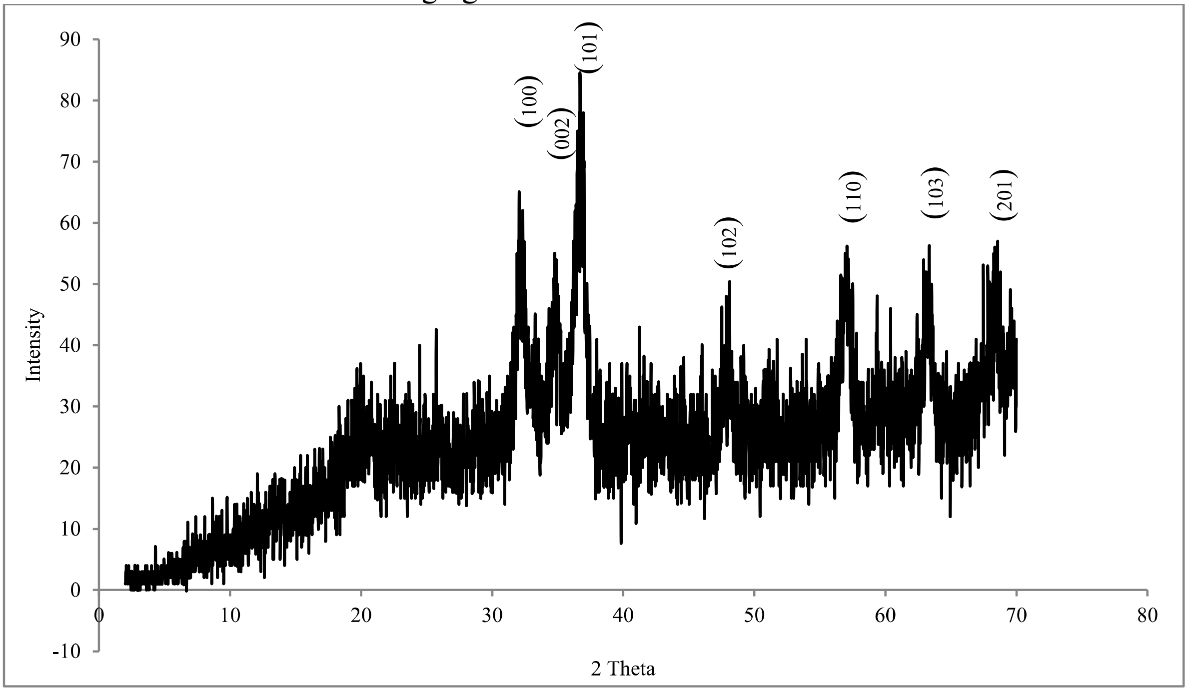

Fig. 3 XRD analysis of ZnO Nps-PVA-PEG-NF

Fig. 4 showed the XRD pattern for the synthesized ZnO Nps powder. The diffraction peaks 002, 102 and 110 indicate ZnO Nps was formed. The presence of diffraction peaks denoted as X, might be due to impurities during synthesis.

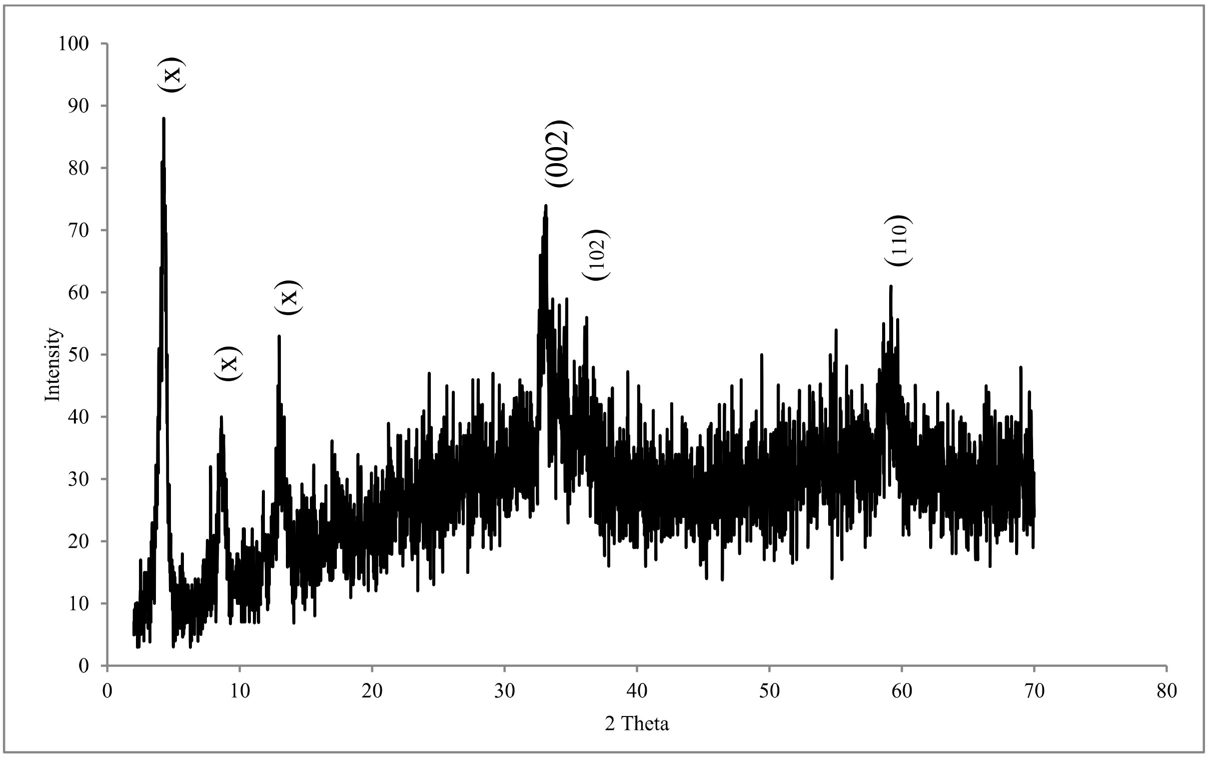

Fig. 4 XRD plot for ZnO Nps

Fig. 5 shows the SEM image of ZnO Nps-PVA-PEG nanocomposite nanofluid synthesized. The figure showed a well dispersed ZnO Nps in the PVA-PEG base fluid forming ZnO Nps-PVA-PEG nanocomposite nanofluid. This also indicates that the PVA-PEG composite base fluid also acts as a stabilizing agent for dispersing the ZnO Nps thus preventing aggregation of the particles.

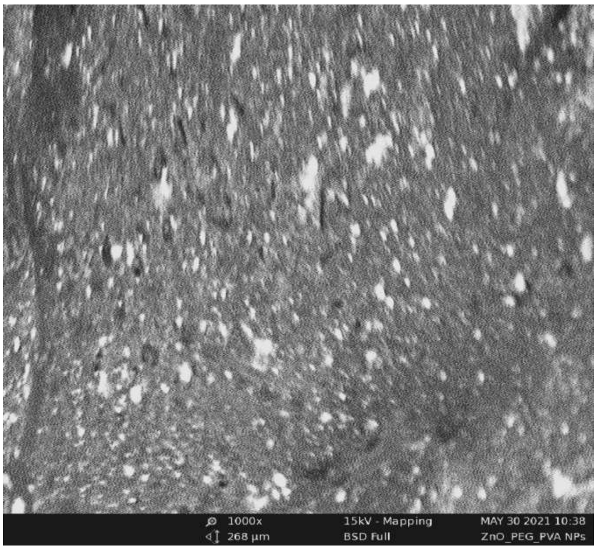

Fig. 5 SEM image of ZnO Nps-PVA-PEG-NF synthesized

Fig. 6 is the SEM image of the synthesized ZnO Nps. The figure shows aggregated ZnO Nps which is normal with nanoparticles as they aggregate over time. But the addition of PVA-PEG composite stabilized the ZnO Nps as shown in Fig. 5.

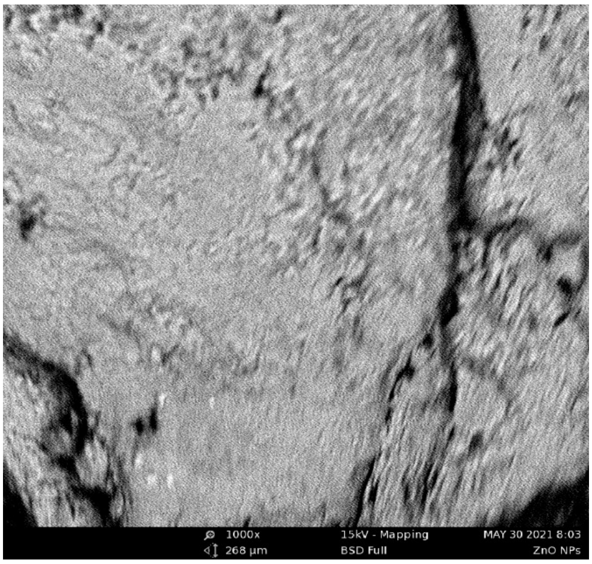

Fig. 6 SEM image of aggregated ZnO Nps without PVA-PEG composite

IV. CONCLUSION

In conclusion the results showed that Zinc oxide nanoparticles were successfully synthesized and ZnO Nps-PVA-PEG nanocomposite nanofluid were prepared with the Zinc oxide nanoparticles. The nanofluid showed stability for up to two weeks before aggregation and the PVA-PEG composite base fluid also acted as stabilizing agent for the ZnO Nps in ZnO Nps-PVA-PEG nanocomposite nanofluid. The average nanoparticles size of the ZnO Nps in ZnO Nps-PVA-PEG nanocomposite nanofluid was calculated to be 15nm using diffraction peaks 002, 100 and 102. The XRD analysis of the diffraction peaks showed that the synthesized ZnO Nps had hexagonal wurtzite phase of ZnO. The hexagonal wurtzite phase of ZnO is known for its unique properties including its thermal conductivity. The SEM image of ZnO Nps-PVA-PEG-NF showed well dispersed ZnO Nps in PVA-PEG base fluid. This also indicates that the unique properties of ZnO Nps including its thermal potentials are well distributed in the base fluid.

REFERENCES

Czaplicka , N., Grzegórska, A., Wajs, J., Sobczak, J., Rogala, A. (2021). Promising Nanoparticle-Based Heat Transfer Fluids-Environmental and Techno-Economic Analysis Compared to Conventional Fluids. *International Journal of Molecular Science,. 22*, (17), 9201.

Okonkwo, E.C., Wole-Osho, I., Almanassra, I.W. *et al.* (2021). An updated review of nanofluids in various heat transfer devices. *Journa of Thermal Analysis and Calorim*etry, *145*, 2817–2872

Samir, K. N., Rajib, K. M. (2015). MHD Stagnation-Point Flow and Heat Transfer of Nanofluid over a Shrinking Surface. *Journal of Nanoscience and Nanoengineering*, *1* (4), 183-192

Das, S.K., Choi, S.U.S., Yu, W., Pradeep, T. (2007). Nanofluids: science and technology. *Wiley-Interscience*, 397.

Kakac, S., Cao, L. (2009). Analysis of convective two-phase flow instabilities in vertical and horizontal in-tube boiling systems. *International Journal of Heat and Mass Transfer*, *52*, 3984–3993

Joshua, B., Michael, P., Kallie ,I., Jake, W., Marcus, C., Ryan, F., Branden ,S., Saeid, V. (2022). Heat Transfer Enhancement in the Microscale: Optimization of Fluid Flow. *nanomaterials,12*, 3628

Lu, G.; Hu, H.; Duan, Y.; Sun, Y. (2013). Wetting kinetic of water nano-droplet containing non-surfactant nanoparticles: A molecular dynamic study. *Applied Phyics Lett*er, *103* (25): 253104

Rigved, N., Jatin, Patel. (2019). Polyvinyl Alcohol: A Comprehensive Study. *Acta Scientific Pharmaceutical Sciences, 3*, (4), 34 - 44

Hoang Thi, T.T., Pilkington, E.H., Nguyen, D.H., Lee, J.S., Park, K.D., Truong, N.P. (2020). The Importance of Poly(ethylene glycol) Alternatives for Overcoming PEG Immunogenicity in Drug Delivery and Bioconjugation. *Polymers (Basel). 12*, (2), 298. doi: 10.3390/polym12020298. PMID: 32024289; PMCID: PMC7077443.

Sirelkhatim, A., Mahmud, S., Seeni, A., Kaus, N.H.M., Ann, L.C., Bakhori, S.K.M., Hasan, H., Mohamad,

D. (2015). Review on Zinc Oxide Nanoparticles: Antibacterial Activity and Toxicity Mechanism. *Nano-micro Letters. 7*, (3), 219-242.

Irina ,M.F., Júlia, M. A., Paulo, H. C., Derval S. R., Bruna A. L., Marcelo B., Emerson, R. D., Juliana, S. S. (2021). ZnO Nanoparticle/Poly(vinyl alcohol) Nanocomposites via Microwave-Assisted Sol–Gel Synthesis for Structural Materials, UV Shielding, and Antimicrobial Activity *ACS Applied Nano Materials* **,** *4* (7), 7371-7383

Nabiyouni, G., Barati, A., Saadat, M. (2011). Surface Adsorption of Polyethylene Glycol and Polyvinyl Alcohol with Variable Molecular Weights on Zinc Oxide Nanoparticles. *Iranian Journal of Chemical Engineering. 8*.

Shengcong, L., Hanning, X.., Yuping, L. (2004). Investigation of PEG adsorption on the surface of zinc oxide nanoparticles, *Powder Technology*, *145*, (1), 20-24

Minea, A.A.; El-Maghlany, W.M.; Massoud, E.Z. (2022) Heat Transfer Analysis of Nanocolloids Based on Zinc Oxide Nanoparticles Dispersed in PEG 400. *Nanomaterials*, *12*, 2344

Singh, D.K., Pandey, D.K., Yadav, R.R. (2012). A study of nanosized zinc oxide and its nanofluid. *Pramana Journal of Physics*, *78*, 759–766, https://doi.org/10.1007/s12043-012-0275-8