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Dynamic stability of iron oxide-ethylene glycol nanofluids

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Abstract
Nanopowders/Nanostructures have attracted the attention of engineers and scientists for their tunable properties and extended applications. One of the extended application of nanopowders is nanofluids. Nanofluids are assumed as the most preferred next generation coolants and their stability is essential for their successful implementation. Iron oxide nanoparticles were prepared by the sol-gel method using Ferrous sulphate as precursors. The prepared nanoparticles were characterized by XRD and photo luminescence. Iron oxide nanofluids (0.1 & 0.3 vol%) with ethylene glycol as base fluid were prepared by a two-step method. The nanofluids were tested for dynamic stability (at 1, 3, 6, 12 and 24-hour intervals). The variation in zeta potential with time is analyzed to predict their stability transformations. We observe that 0.3 vol% nanofluid exhibits better dynamic stability characteristics than the less stable 0.1 vol% nanofluid.

Keywords: Dynamic stability, Ethylene glycol, Iron oxide, Nanofluid

1. Introduction

Nanofluids are two phase materials consisting of a base fluid with a combination of dispersed nanoparticles. The conventional base fluids are the most common heat transfer fluids like water and ethylene glycol. The usual used nanoparticles are metal oxide nanoparticles like ZnO, TiO_2, Al_2O_3, CuO, Fe_2O_3 etc [1]. Several research findings indicate the efficient heat transfer capability of nanofluids in comparison to the base fluids [2]. Iron oxide finds potential applications in biosensing, magnetic recording, magnetic resonance imaging, and targeted drug delivery [3]. They also posses super paramagnetic nature, are biocompatible, and less toxic. They can be put into applications in the form of nanopowders, nanocoatings and nanofluids. Ethylene glycol (EG) is a fluid which is primarily used for convective heat transfer in automobiles and electronics heating/cooling applications. EG has a specific heat capacity of 50% of water but when mixed with water, it offers the advantage of broadening the temperature limits on both ends for heat transfer applications. Nanofluids can be prepared by one or two step methods. Two step methods have their own advantages, like preparing nanofluid at a large scale and also obtaining any required composition as reported by Herman and Schulz [4]. Iron oxide nanofluids are used to manifest the thermal conductivity of existing coolants. They have proven to be less toxic and also enhance engine efficiency [5]. In the present work, iron oxide nanofluids have been prepared by a two step method. The iron oxide nanopowders are prepared by sol gel method and dispersed in ethylene glycol base fluid by ultrasonication technique.

A major challenge in the application of nanofluids is the stability of the nanofluids [6]. The stability of nanofluid is governed by several factors including size of nanoparticle, volume fraction of nanoparticle, shape of nanoparticle, nature of nanoparticle and base fluid [7]. Cylindrical shaped nanoparticles have a higher probability of forming chain like structure and could give a stability of nearly 1000 hrs [8]. The stability of nanofluid can be enhanced by the presence of surfactant. Anionic surfactants like sodium dodecyl sulphide were effective for nano ZnO dispersions [9]. However, the incorporation of surfactants was found to have a decrement effect on the thermal conductivity of naosuspensions.

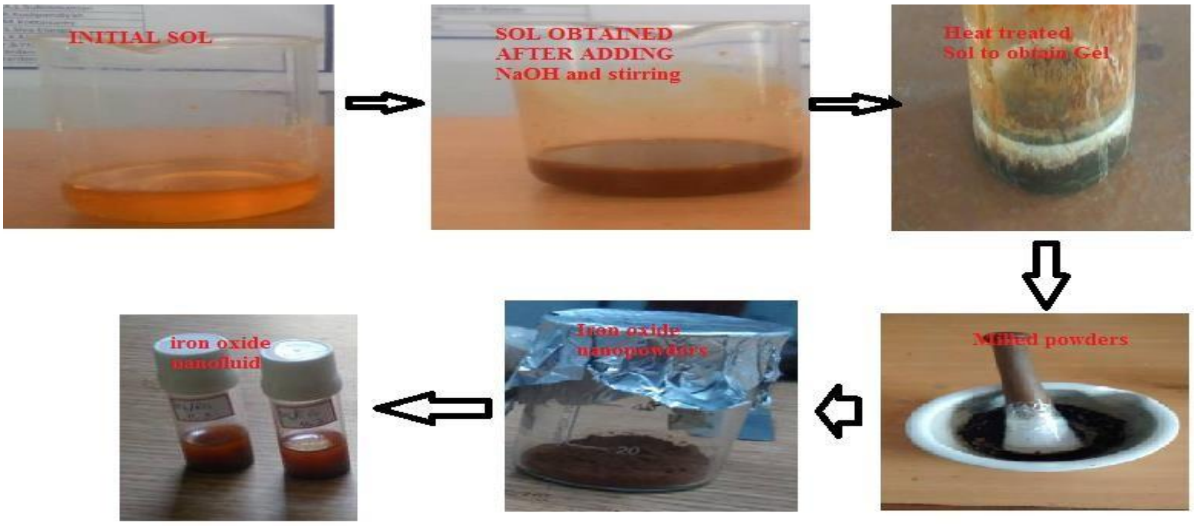

Figure 1. Synthesis of iron oxide – Ethylene Glycol nanofluid by our two step method.

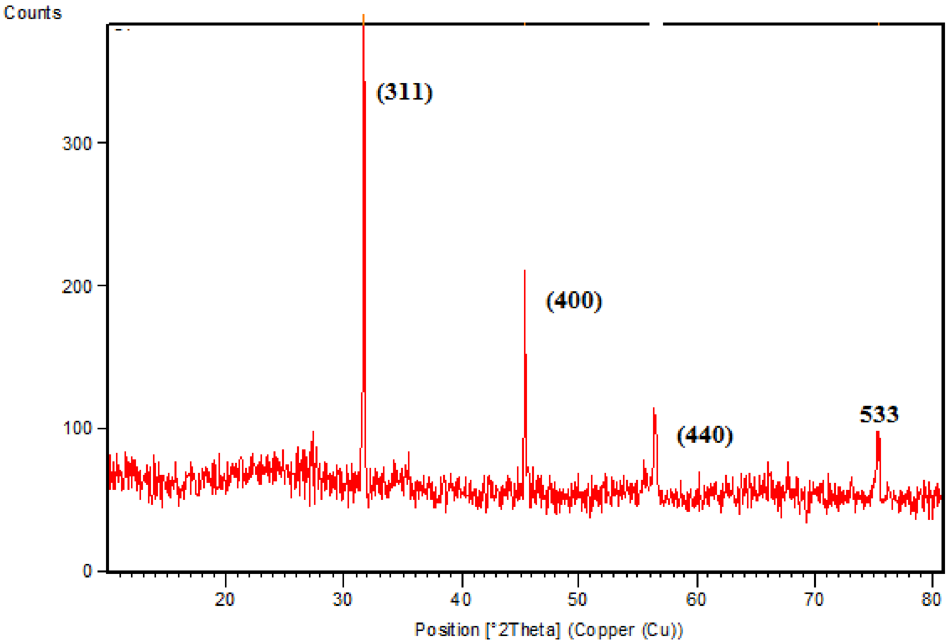

Figure 2. XRD pattern of the prepared iron oxide nanopowders.

Hence there is a need for evolving surfactant free nanosuspensions. The stability of nanofluid can be identified by zeta potential measurements or sedimentation tests. A zeta potential above -30 mV to +30 mV is an indication of very good stability [7]. The variation of zeta potential with time for a given nanosuspension is yet to be explored and investigated. In the present work, an attempt has been made to investigate the change in zeta potential of the iron oxide-ethylene glycol nanofluids within twenty four hours to identify the variation in zeta potential.

2. Materials and methods

Iron oxide nanopowders were prepared by sol-gel method with Ferrous Sulphate Heptahydrate as precursor. The sol is prepared by mixing 2.78 g of Ferrous Sulphate Heptahydrate with 100 ml of distilled water by a magnetis stirrer. A light red colloidal sol is obtained. Sodium hydroxide is used to control the pH of the sol in the range of 10.5 to 11. In the present work 5 g of sodium hydroxide is mixed and the solution is subjected to further magnetic stirring for 3 hours. A chemical reaction proceeds between Ferrous Sulphate Heptahydrate, Sodium hydroxide, and water and a dark red sol is obtained. This is followed by ageing for 2 days. The solution is heated at 130 ºC for 3 hours to obatin iron oxide powders. The hand milling technique is used to crush the product further to reduce the size of powders. The nanopowders are then mixed in ethylene glycol with a volume fraction of 0.1 and 0.3% by ultrasonication at a frequency of 42 KHz for 20 minutes to obtain the nanofluids. The entire process is indicated in figure 1.

3. Results and discussions

The prepared nanopowders were characterized by XRD and PL Spectra. (figures 2&3). XRD studies was done with an incident radiation of 1.54 Å and scanning for

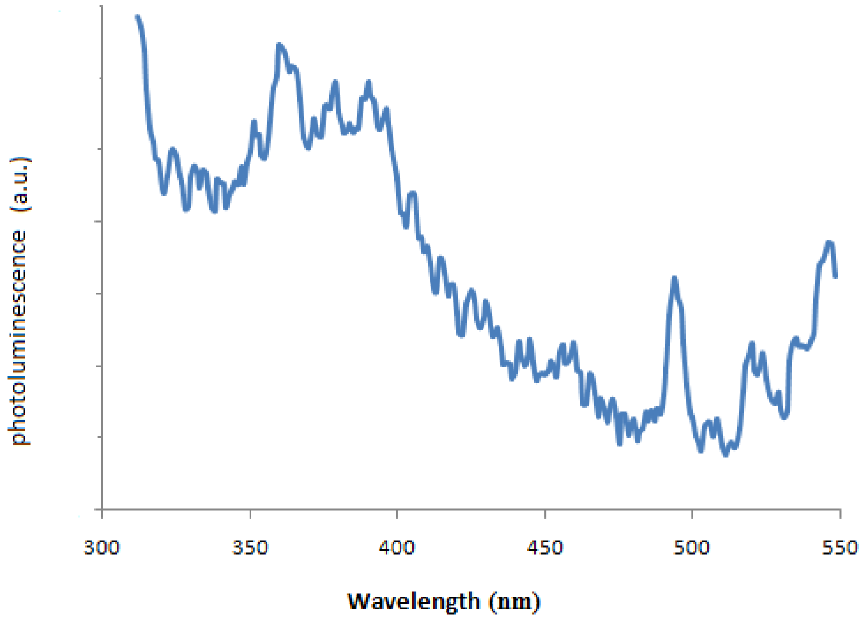

Figure 3. PL Spectra of the prepared Iron oxide powders.

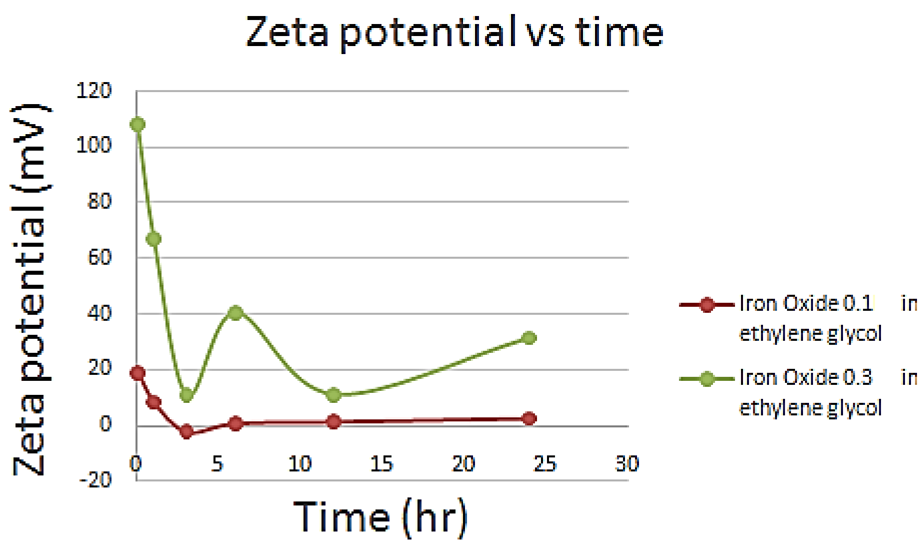

Figure 4. Dynamic stability of nanofluids.

diffraction peaks from 20 to 80. The maximum peak in the XRD pattern (2θ) is observed as 31.67° and peaks are at 45.42°, 56.5° and 75.47°. This result shows the spinal state structure of iron oxide nano particles as reported by Sardar Siddique Ur Rahman and co workers [10]. The average crystallite size of the nano particle is calculated using Debye Scherrer approximation and is found to be about 90 nm.

Photoluminescence is a phenomenon of light emission observed in bulk materials and nanoparticle. Photoluminescence involves light emissions from visible to near infrared and the operating excitation mechanisms can range from bound exciton to surface plasmon. Photoluminescence measurements of the iron oxide nanoparticles show peaks at 360 nm, 420 nm, and 490 nm when illuminated with laser light. Thus, iron oxide exhibits three different distinct wavelengths and electron mobility. The photoluminescence spectra of iron oxide was reported to show Peaks at 310 nm, 514 nm and 610 nm by Yong Zhan and co workers [11]. The peak shift may be due to variation in nanosize of the iron oxide.

The dynamic stability of the nanoparticles in the nanofluid was identified with DLS measurement techniques at 1, 3, 6, 12, and 24-hour intervals for both 0.1 and 0.3% volume fractions (figure 4). Highly Stable nanofluids have zeta potential above -30 mV to +30 mV. The nanofluids prepared with 0.1 vol% are less stable than 0.3 vol% over a period of 24 hrs. A stable zeta potential is observed from 6 to 24 hrs for 0.1 vol% nanofluid, but below 30 mV for the entire period which indicates poor stability. There is a decrease in zeta potential for first three hours from 20 to 2 mV which indicates rapid fall of stability.

For 0.3 vol% nanofluid, there is a huge change in zeta potential from 110 to 30 mV for a period of 24 hrs. Further, we report that the zeta potential of 0.3 vol% nanofluid is highly stable within any time period. Hence, 0.3 vol% nanofluid is characterized by better dynamic stability features, compared wuth the less stable 0.1

vol% nanofluid. We observe that a greater vol% of iron nanoparticles in ethylene glycol base fluid may lead to enhanced dynamic stability characteristics.

4. Conclusions

Iron oxide nanoparticles were prepared by the sol-gel method using Ferrous sulphate as precursors. The prepared nanoparticles were characterized by XRD and photo luminescence. The average grain size by Debye Scherrer approximation was 90 nm. Photoluminescence measurements of iron oxide nanoparticles show peaks at 360, 420, and 490 nm when illuminated with laser light. Thus iron oxide exhibits three different distinct wavelengths and electron mobility. A stable zeta potential is observed from 6 hrs to 24 hrs for 0.1 vol% nanofluid by DLS technique, but this indicates the complete sedimentation phase. We suggest using 0.3 vol% of iron oxide nanoparticles in ethylene glycol suspensions for better dynamic stability and efficient nanofluid based applications.

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