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Preparation and Diverse Properties of Cobalt Ferrite Ferrofluid

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Abstract

The synthesis of cobalt ferrite ($CoFe_2O_4$) nanoparticles by sol-gel auto-combustion and their characterization by standard techniques like X-ray diffraction (XRD) used to characterize the structure, the size of the nanoparticlesafter successful characterization, these magnetic $CoFe_2O_4$nanoparticles were dispersed in water to obtain ferrite nanofluids i.e. ferrofluids. Poly-vinyl- alcohol was used as surfactant while preparing ferrofluids. In this study, $CoFe_2O_4$nanoparticles were synthesized by sol-gel auto-combustion technique. Stable$CoFe_2O_4$ ferrofluids in various volume fractions (0.0, 0.5 and 1.0) have been prepared using water as base liquid. Poly-vinyl-alcohol was used to increase the inter particle interactions of surface modified $CoFe_2O_4$ nanoparticles. Specific gravity bottlewas used to measure density, Ostwald's viscometer used for viscosity measurements and ultrasonic investigationsare done by ultrasonic interferometer at 2 MHz for the ferrofluids at different temperatures.

Keywords: *Ferrofluid, Cobalt Ferrite, XRD, Ultrasonic*

1. INTRODUCTION

Magnetic nanofluids or ferrofluids colloidal suspensions of nano-magnetic particles in base fluids. They have enormous importance in industrial and biomedical applications due to their tuneable thermophysical properties. They have attracted much attention in the past decades because of their potential applications in automobiles, coolants [1], brake fluids [2], domestic refrigerators [2], solar devices [3,4], cosmetics, drug delivery [5], defect sensors [6], microwave absorber[7],optical filters [8], hyperthermia [9], and sealant [10].

Among the magnetic nanofluids, cobalt ferrite ($CoFe_2O_4$) based magnetic fluids have been widely analysed due to high electromagnetic performance, excellent chemical stability, mechanical hardness, and high cubic magneto-crystalline anisotropy. These properties make it a promising candidate for many applications in commercial electronics such as video, audio tapes, high-density digital recording media [11]. Among the mentioned applications, the hyperthermia treatment has been recognized as very novel and promising, and the efficiency of cobalt ferrite nanoparticles has been clearly established [12]. Also, as concerning biomedical application, the possibility of using radioactive ^{60}Co to produce enriched ferrofluid unlock a new perspective, as for instance in the targeting of cancer cells using antibody-coated nanoparticles [13]. From the literature it is found that there are only few reports available on the ultrasonic properties of nanofluids [14]. Reportson the magnetic nanofluids [15] prove the tuneable optical, rheological and thermal properties and also show the dependence of ultrasonic velocity on the clustering structure of magnetic fluid. A big deviation of the experimental values of velocity and attenuation from the theoretical predictions is also reported [16]. The fundamental understanding of exact mechanisms responsible for the amazing behaviours of magnetic nanofluids still remains unclear because of the lack of molecular level understanding of the ultrafine particles. This fact demands the systematic studies on the molecular interactions of magnetic nanofluids with respect to the variations in concentration, temperature and the external magnetic fields [17].

This paper is intended to the systematic experimental study on the response of cobalt ferrite magnetic nanofluids to the ultrasonic wave propagation for the basic understanding of how the cobalt ferrite nanoparticles behave in water and how they interact with each other and also with water. Preparing the stable and homogeneous suspensions of cobalt ferrite magnetic nanofluids and attaining a deeper understanding of particle-fluid, particle-particle interactions as functions of concentration, temperature and magnetic field, are the main concern[18-19].

2. EXPERIMENTAL

2.1. Preparation of $CoFe_2O_4$ nanofluids.

Nano-crystallinepowder of $CoFe_2O_4$ was prepared by sol–gel auto-Combustion method The Auto-Combustion was completed within a minute, yielding the brown-colour ashes termed as a precursor. It is known that the pure $CoFe_2O_4$obtained by the sol–gel method can be formed at 600°C and thoroughly crystallized at temperatures above 600°C [20]. The as-prepared powders of all the samples were heat treated separately at 600°C for 4 h to get the final product.The mixture of $CoFe_2O_4$nanoparticles and water was vigorously stirred for 10 min by dispersing the nanoparticles in double distilled water (DDW). PVA coated$CoFe_2O_4$nanoparticles were collected. Surface modified $CoFe_2O_4$ are easily disperse in distilled water in present work we prepare $CoFe_2O_4$ – Waternanofluids in 0, 0.5 and 1 volume fraction. Prepared sample is ultrasonicated for two hours [21].

3. RESULTS AND DISCUSSION

3.1 X-Ray Diffraction (XRD)

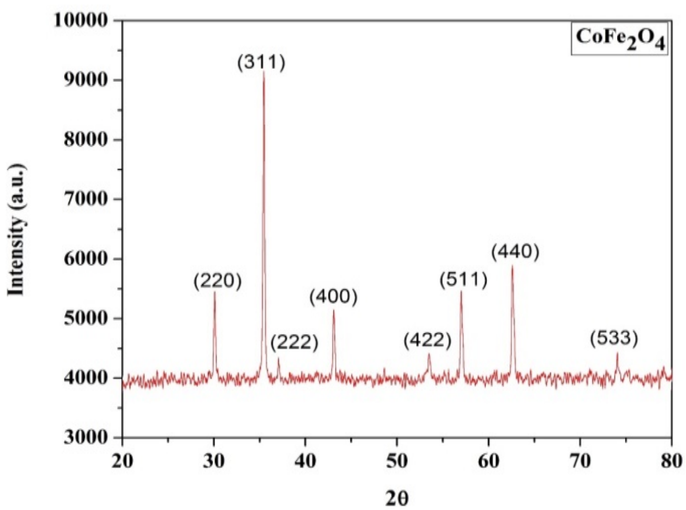

Fig 1:X-ray diffraction pattern of $CoFe_2O_4$ nanoparticles

Fig. 1 represents X-Ray diffraction (XRD) pattern of $CoFe_2O_4$ nanoparticles recorded at room temperature. XRD pattern shows the reflection (220), (311), (222), (400), (422), (511), (440) and (533). All the reflections belong to cubic spinel structure. The analysis of X-Ray pattern was done by Powder-X Software. The results of XRD pattern confirmed formation of cubic structure with nanophase. The structural parameter like lattice constant, X-Ray density, etc. calculated from XRD data.

From the most incense (311) peak the average sizes of the particles were found to be 37 nm.The lattice constant of the present $CoFe_2O_4$ nanoparticles is found to be 8.388 Å ± 0.004 Å which is closely agree with reported literature [21]. To confirm nano-crystalline nature of prepared $CoFe_2O_4$sample, the crystallite size was calculated using Scherrer's formula [21].

3.2 Magnetization

The magnetic properties were studied by pulse field hysteresis loop technique at room temperature. The $CoFe_2O_4$ shows good magnetic properties with saturation magnetization 83 emu/g. viscosities of ferrofluids also changes by changing magnetic field externally.

3.3Density Measurement

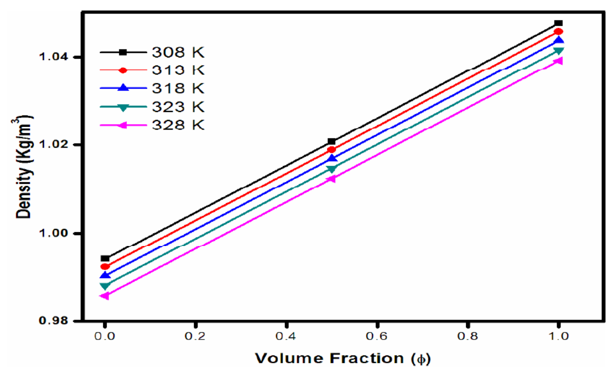

Figure 2. Variation of density (ρ) with volume

3.4.Measurement of Viscosity

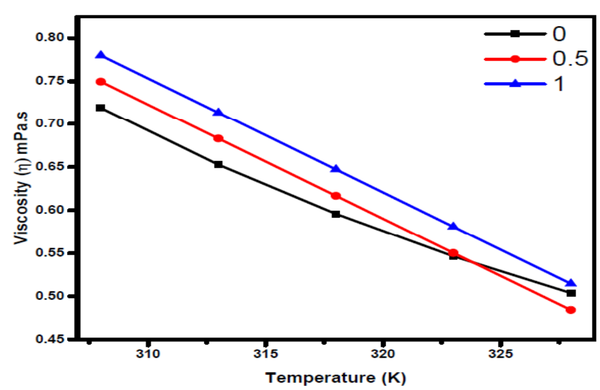

Figure 3: Relation between Viscosity and temperature with volume fraction.

In the present study, an Ostwald's viscometer which is10mlcapacity is used for the viscosity measurement of Water-$CoFe_2O_4$ferrofluids.The viscosity of the Water-

$CoFe_2O_4$ferrofluids can be determined using the relation [24].

3.4 Ultrasonic Velocity

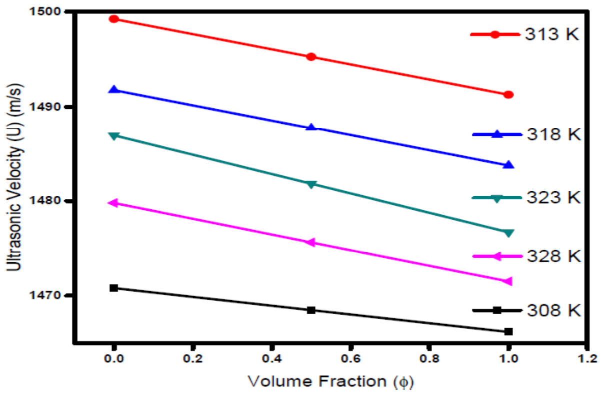

Figure 4: Relation between Ultrasonic Velocity and temperature with volume fraction

In ultrasonic interferometer, a piezoelectric crystal slab (like quartz) with parallel faces develops charges of opposite polarity on their faces when it is strained; such a crystal slab exhibits electrostriction when placed in a region of electric field. The speeds of sound in pure liquids and Water - $CoFe_2O_4$ferrofluid were measured using single-crystal variable path ultrasonic interferometer operating at 2 MHz the uncertainty in speed of sound measurements was within the range of ±0.1ms-1.The obtained values are presented in fig. 4.

4. CONCLUSION

Cobalt Ferrite ferrofluids of (0, 0.5 and 1) concentrations of Cobalt Ferrite have been synthesized and are found to be stable without any phase separation. Ultrasonic parameters have been measured for 0, 0.5 and 1 concentrations and different temperatures. The results clearly point out the enhancement in particle-particle interaction resulting in the formation of chain like clusters at higher concentrations. Experimental results indicated that density of Cobalt Ferrite ferrofluids increases with increasing volume fractions and viscosity of the ferrofluids is increases with increasing volume fraction and decreasing with temperature. As the temperature range chosen for the study is sufficient to make thermal rupture of the open packed structure of water, it can be confirmed that the changes of the acoustical parameters with temperature variation indicate the predominance of the cohesion of water molecules over the thermal expansion

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