A NEW METHOD FOR THE SYNTHESIS OF NANOPARTICLESFOR BIOMEDICAL APPLICATIONS

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Abstract: Research into novel chemical synthesis techniques for solution-based nanoparticle fabrication of biocompatible polymer-coated iron oxides and other nanoparticle sizes has been undertaken. Using the electrohydraulic technology for nanohomoganization, a novel particle processing system has been designed for the production of high performance nanomaterials and their potential medical uses. Superparamagnetic iron oxide nanoparticles (SPIONs) are stable and dispersible in water at physiological pH or salinity, making them ideal for use in biomedical applications. Biocompatible SPIONs were created by synthesising particles with a size of 10-15 nm and coating them with ascorbic acid. In order to investigate how phase transitions impacted the nanoparticles' magnetic characteristics, experiments were conducted using vibrating sample magnetometers (VSM). The saturation magnetization was determined by using VSM on the samples at room temperature. Due to their hydrophilic outer surface that contains hydroxyl and amine groups, the iron oxide nanoparticles coated with ascorbic acid were discovered to be effectively distributed in water. Their bioactivity is anticipated to be enhanced by this hydrophilic outer surface. As a result, they have great potential as a biological medication carrier.

Keywords: nanoparticles, iron oxides, electrohydraulic technique, ascorbic acid, biomedical applications. ascorbic acid, electrohydraulic method, nanoparticles, iron oxides, biomedical uses

Introduction

Nanoferrofluids, also known as magnetic nanofluids, are composed of a carrier liquid and stable colloidal suspensions of magnetic nanoparticles (MNPs). The core-shell structure is typical of MNPs; organic or inorganic materials make up the shells, while magnetic crystallites form the core. The size of the magnetic core, which contains simply a simple magnetic domain, ranges from few nanometers to tens of nanometers for the majority of nanoferrofluids. The hyper paramagnetic behaviour of the MNPs is a result of their very tiny size. This indicates that MNPs are sensitive to magnetic fields but do not become magnetic when no field is present. A nanoferrofluid may be easily made by dispersing colloidal MNPs in a liquid.

Important biological applications of MNPs include targeted drug delivery, biological labels, magnetic bioseparation, detection of biological entities (cells, proteins, nucleic acids, enzymes, bacteria, viruses, etc.), diagnostic and therapeutic uses (e.g., magnetic resonance imaging), and magnetic fluid hyperthermia (MFH). The building of nanostructure materials and devices with tunable physical and chemical characteristics often requires careful material selection. This is why iron oxide MNPs are ideal for these kinds of devices; in fact, they have been used for over fifty years for in vitro diagnostic purposes.1 Magnetite is one of numerous iron oxides that have been the subject of MNP research in the last ten years.

Managing the dimensions, form, stability, and dispersibility of MNPs in certain solvents poses a significant technical hurdle. Due to their high surface energy and huge surface-to-volume ratio, iron oxide MNPs are an attractive material. Because of this, they band together to reduce surface energy as much as possible. Naked iron oxide NPs are very reactive chemically and readily oxidised in air, particularly by magnetite, which often causes them to lose their magnetic properties and become dispersible. Thus, the purpose of this study was to stabilise iron oxide MNPs by applying an appropriate surface coating and by creating some efficient protective techniques. The particles are often coated with an inorganic layer, such as silica, or organic molecules, such as surfactants, biomolecules, polymers, or tiny organic molecules. Alternatively, inorganic layers, such as oxides or sulphides, or metals, may be used as grafts. Not only can the protective shells stabilise the NPs, but they may also be used for further functionalization in many instances.3 Obtaining Fe_3O_4 or γ-Fe_2O_3 is often done by co-precipitation.4 Ionic strength of the medium, reaction temperature, pH value, ferric and ferrous ion ratio, salt type (chlorides, sulphates, nitrates, perchlorates, etc.), stirring rate, and rate of basic solution addition are some of the other reaction parameters that determine the size and shape of the iron oxide NPs. However, there is need for improvement in this technology to achieve mono dispersity, a requirement for biological applications. Our groundbreaking application of the electrohydraulic treatment, often known as the Yutkin treatment, in a popular nanoparticle production scheme allowed us to do this by drastically lowering the particles' radius scatter.5,6

Preliminary investigations have shown that the suggested technique greatly enhances the dispersion of the solution. Resonant treatment of chemically synthesised particles is also produced by the strong oscillations associated with the electrohydraulic approach. An electrical discharge (electro spark) in a liquid is used to trigger a sequence of controlled explosions in this procedure. Discharges produce enormous pressure impulses and shock waves, which operate as a homogenizer on nanoparticles. Particles' solubility in water is enhanced and their radii are almost identical as a consequence.

Therefore, we have primarily concentrated on developing methods for preparing, determining the structure of, and studying the magnetic characteristics of surface functionalized iron oxide MNPs and their applications in this work. A comparison was made between the electrohydraulic approach and the chemical method for synthesising functionalized iron oxide nanoparticles, and their characteristics.

We have prepared the magnetic colloid using an electrohydraulic treatment and a modified co-precipitation approach, and we have further stabilised the magnetite. The saturation magnetization of iron oxide NPs coated with ascorbic acid is determined by analysing the samples at room temperature using VSM.

Experimentals

Synthesis of Magnetic Nanoparticles

Chemical precipitation of a mixture of iron(II) chloride tetrahydrate (FeCl2•4H2O) and mixed iron(III) chloride hexahydrate (FeCl3•6H2O) or iron(II) sulphate heptahydrate (FeSO4•7H2O) with iron ions in a 2:1 molar ratio in a NaOH or NH4OH solution at room temperature or relatively high temperature (80ºC) in air or under a nitrogen flow was used to create magnetite nanoparticles. Nucleation, or the establishment of crystallisation centres, and particle development are the two main steps in chemical co-precipitation.

To conduct the co-precipitation process, we used Massart's4 method, which entails adding NaOH solution dropwise to a mixture of aqueous solutions of iron salts while stirring vigorously at ambient temperature or 80°C. The responses are shown below.

(1) FeCl2•4H2O + 2FeCl.6H2O + 8NaOH = Fe3O4 + 8NaCl + 20H2O. **

(2) Fe3O4 + Na2SO4 + 6NaCl + 17H2O is the result of reacting 7H2O with 2FeCl, 6H2O, and 8NaOH.

The production of magnetite (Fe3O4) was indicated by the solution's transformation from brown to black. To make sure that magnetite particles nucleated and grew, the mixture was stirred magnetically for 60 minutes. After the precipitation process was finished, a solid and a liquid supernatant were seen to have separated. The dark

After carefully removing the supernatant, the solid phase was magnetically decanted and washed with deionized water many times to eliminate any remaining salts. After additional washing with ethanol to remove any remaining water, the precipitate was heated for a few minutes to allow the ethanol to evaporate. To get the final product, a highly dispersed magnetic nanofluid, the prepared nanofluid was electrohydraulic treated for about 1 hour. Deionized water was used to wash the black precipitates once again after electrohydraulic treatment. Finally, the Fe3O4 magnetic nanoparticles were modified by adding 10% ascorbic acid by weight to the mixture, which was then heated to 80°C while being stirred magnetically. The solution was magnetically separated to remove the Fe3O4 magnetic nanoparticles (black precipitate) that had formed after 1 hour of modification. The particles were then washed many times with ethanol and deionized water. To create an atmosphere that would be suitable for living things, the pH was set to 8. The nanoparticles were successfully dispersed after two hours of sonication. This was followed by allowing the nanoparticle solutions to cool to ambient temperature.

Nanoparticle size must be carefully considered during the manufacture of nanofluids. There shouldn't be much variation in the dimensions from the average. In this regard, the current synthesis procedures fall short of expectations. Using the electrohydraulic technology allowed us to guarantee top-notch quality. We developed a tool—now used as stationary pilot equipment—to do this. One step in the production of magnetic nanofluid was the use of the electrohydraulic technology. Our gadget can homogenise nanofluids, allowing for the production of highly distributed magnetic nanofluids. Figure 1 shows the schematic of the electrohydraulic apparatus.

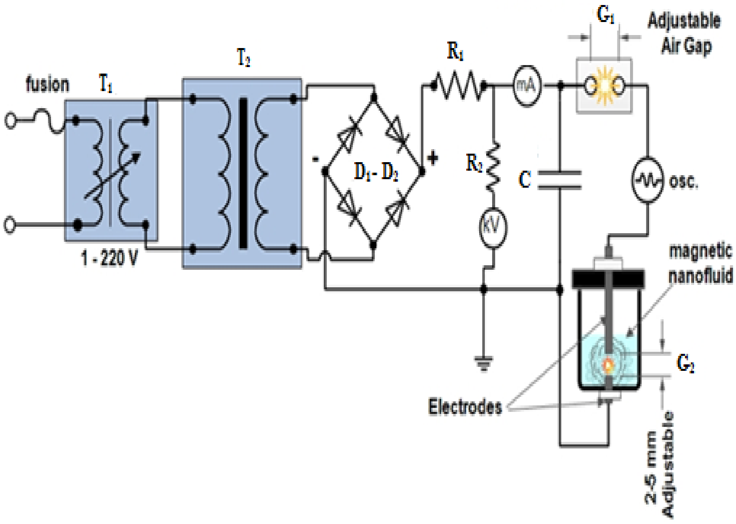
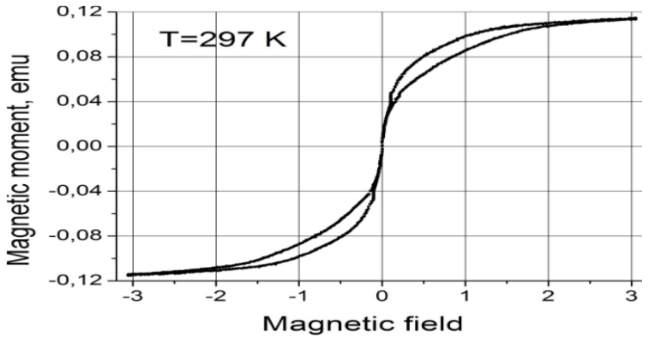


Figure 1 shows a schematic of the electrohydraulic apparatus. The apparatus consists of a power source, transformers (T1, T2), charger resistances (R1, R2), a storage capacitor (C), as well as surface electrodes (G1) and submerged electrodes (G2) that may be adjusted for the air gap that generates a spark.

At room temperature, a Standard 7300 Series Lake Shore Cryotronics vibrating sample magnetometer (Criogenic Ltd, UK) was used to test the magnetic characteristics of the polymer-coated magnetite nanoparticles in a water solution condition. With a precision of 10-4 emu, the hysteresis loop of every sample was measured throughout an applied field range of -3 to +3 T.

Results and Discussion

To test the MNPs' magnetization in response to an external magnetic field (H) between -3 and 3 Tesla, VSM was used. The magnetic behaviours of the MNPs may be studied using the VSM curve that was acquired at room temperature. For instance, the hysteretic loop property and zero magnetic remanence (when H is zero) at ambient temperature suggest that the MNPs are super paramagnetic. Another way to find saturation magnetization is by looking at the plateau portion of the VSM curve. Figures 2–5 show the magnetic momentum of MNPs as a function of magnetic field.



In Figure 2, we can see the relationship between the applied external magnetic field and the magnetic moments of magnetic nanofluid for bare magnetic nanoparticles made using the chemical co-precipitation method. In Figure 3, we can see the same relationship, but with the addition of an electrohydraulic treatment to the nanoparticles.

The dependency of the magnetic moment of bare MNPs on the magnetic field is seen in Figure 2.

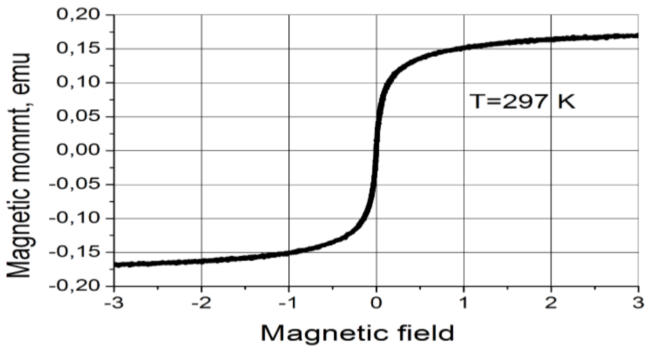


Figure 3: The response of electrohydraulically treated bare MNPs' magnetic moments to varying magnetic fields

The generated nanomaterials are super paramagnetic, as seen in the figures. These graphs also show that the electrohydraulic treatment greatly enhances the nanomaterials' magnetic characteristics and increases the dispersion of the magnetic particles.

As demonstrated in Figure 4, the moments of magnetic nanoparticles coated with ascorbic acid rely on an external magnetic field; Figure 5 shows the similar dependency for magnetic nanoparticles treated with an electrohydraulic device prior to coating. The medicinal applications of magnetic nanoparticle formulations coated with ascorbic acid are very new. Antioxidants, excipients in food and medicine, and stabilisers are just a few of the many uses for hydrophilic ascorbic acid derivatives such ascorbyl glycoside.

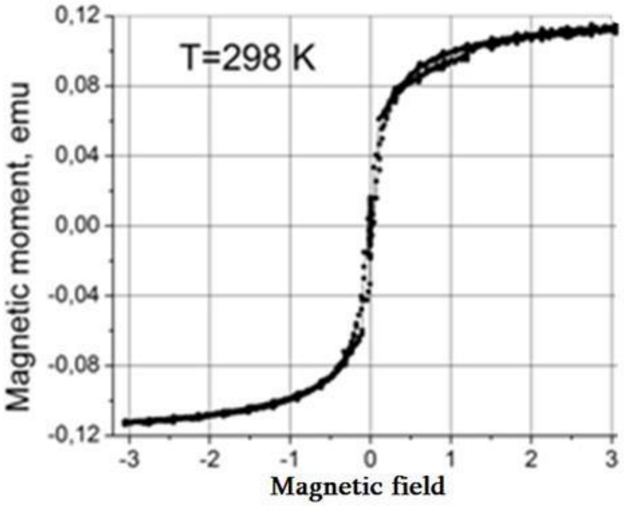


Figure 4. The dependence of the magnetic moment of ascorbic acid coated MNPs on magnetic field.

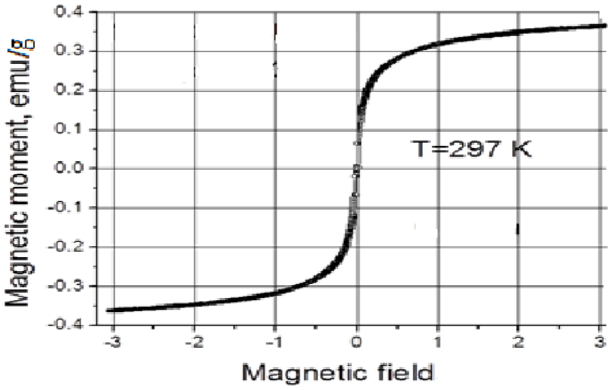


Figure 5. The dependence of the magnetic moment of ascorbic acid coated and electrohydraulic treated MNPs on magnetic field.

Nanoparticle technology is being incorporated into many areas of molecular science and biomedicine. Because nanoparticles are small enough to enter almost all areas of the human body, including the cells and circulatory system, they have been and are being used for diagnostic and therapeutic purposes in clinical settings, in addition to fundamental biomedical research. Working with particles that are consistent in size and shape is quite beneficial for studying the coating process.

One major benefit of the precipitation technique is the ability to synthesise a huge volume of nanoparticles. But because only kinetic parameters are influencing the crystal's development, regulating the particle size distribution is something of a challenge. Utilising the electrohydraulic phenomena allows us to circumvent this disadvantage.

Developing nanomaterial processing methods is crucial for optimising nanoparticle utilisation and addressing their application-related challenges. This paper announces new technique for solution-phase synthesis of biocompatible nano-composite particles and oxides with nano-sized particles. We also touch on the topic of electrohydraulic treatment methods (such as homogenization) briefly.

The goal of this study is to develop a nanoparticle that is safe, effective, and inexpensive; this will be essential in the fight against cancer. Additionally, organic systems are less affected by magnetite ($Fe3O4$). Nanoparticles treated electrohydraulically have a much higher magnetic moment than their untreated counterparts, as shown in the loop. $Fe3O4$, a powerful magnetic vector, may be used to penetrate tumours via synthetic magnetite. Biocompatibility, a big enough moment for targeting, and super paramagnetic behaviour are three requirements for nanoparticles used in biomedical applications including hyperthermia, medication administration, and magnetic resonance imaging (MRI).

Both the uncoated and coated nanoparticles' magnetization curves, plotted against magnetic field intensity, are shown in the images. The super paramagnetic behaviour of the nanoparticles is shown by the absence of a hysteresis curve in the images. Depending on whether the MNPs were treated with or without electrohydraulics, their magnetic moment values ranged from 0.120 to 0.175% emu.

Furthermore, upon removal of the magnetic field, the magnetization drops below the plateau value and eventually approaches zero. These nanoparticles of iron oxide are structurally similar to magnetite and behave as a single-crystal domain with a single magnetic moment orientation.

Because they are both tiny enough to display super paramagnetic behaviour and do not maintain any magnetism when a magnetic field is removed, magnetic nanoparticles are of great relevance for drug targeting devices, according to VSM investigations.

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