Stabilized Magnetic fluids: Synthesis, Structure and Properties

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**Abstract**

 Four Magnetic colloids containing superparamagnetic Fe3O4 nanoparticles coated with citric acid have been prepared by different methods. The samples were characterized using different techniques (XRD, FT-IR, and TEM). XRD showed the formation of nano Fe3O4 with inverse spinel structure. TEM image confirmed the formation of nano Fe3O4 ranged between 8 – 12 nm. The The physical tests have been performed on the prepared samples, in order to reveal their microstructural and rheological features.

**Keywords:** Magnetic nanoparticles; Rheological properties and  Magnetic properties

**1 Introduction**

 Magnetic fluids are stable colloidal dispersions of ultra-fine ferro- or ferri-magnetic particles, in a nonmagnetic liquid carrier.The dispersion of the ferrophase is ensured by coating the nanoparticles with adequate surfactant (able to assure steric or electrostatic stabilization) .The properties of magnetic fluids have been intensively studied due to their multiple applications and .Magnetite nanoparticles with superparamagnetic properties have great potential to achieve convenient properties for biomedical applications due to their biocompatibility. Various synthesis methods, adequate for magnetic nanoparticle preparation have been described in literature [1-6]. Chemical routes have often been found as most convenient methods used for the production of high quality magneticnanoparticles. In the present work, we used coprecipitation method and surfactants to prepare magnetic fluids of nano Fe3O4 stabilized by citric acid.

**2 Methodology**

Under vigorous and continuous stirring aqueous solution of ferrous and ferric chloride (mole ratio of Fe2+: Fe3+ is 1:2) in presence of 10 m mol surfactant was heated at 80-90 0C. Concentrated ammonia solution was added slowly into the mixture presents in the beaker by a pipette. A black precipitate of iron oxides was formed immediately. The ferrophase was decanted and filtrated to separate the supernatant. The iron oxide powder was was stabilized with 5 g of citric acid in 10 ml deionized water at the temperature of 90 °C. The samples were denoted as Ssulph, SCPB, SACA and STX for the samples prepared using sulphonic, CPB, ACA and TX surfactants respectively. The prepared aqueous magnetic fluid samples showed dark-brown colloids

 **3 Main Results**

 An X-ray diffraction pattern of the synthesized Fe3O4 nanoparticles is showed peaks agree well with the corresponding reported JCPDS file (19-629 ) for the magnetite inverse spinel structure. Fig. (1) show the positive magnetic behavior of the prepared ferrofluids in presence of permenant magnet. The results of all TEM images showed diameter values ranged between 8 and 13 nm as presented in Table (1), exhibiting different shapes depending on the type of surfactant. Some large aggregates and particle chains have been also observed. It is well known that the control on the particle size,morphology and size distribution is strongly dependent on the particularities of the preparation method. Polydispersed colloids are obtained as a result of simultaneous formation of new nuclei and growth of the earlier formed particles. Less size dispersed colloids are formed when the rate of nucleation is high and the rate of particles growth is low. This situation corresponding to a rapid addition and a vigorous mixing of reagents. Slow addition of reagents in the co-precipitation reaction leads to the formation of bigger nuclei. An increase in temperature (in the range 20–100 °C) significantly accelerates formation of ferrite particles. Variation of the surfactant of the reacting solution also results into different rate of growth and hence control each of particle size and its morphology.

 IR-analysis showed a slight blue shifts is observed in intense band at ~ 1600 cm−1 which may be assigned to the symmetric stretching of CO from COOH group, revealing the binding of citric acid radicals to the magnetite surface. This indicates that the citric acid binds chemically to the magnetite surface by carboxylate chemisorption and citrate ions are formed. The chemical adsorption is able to assure electrostatic stabilization of the interaction forces preventing the agglomeration tendency of the magnetic nanoparticles.

 Magnetization curves of investigated samples at room temperature are presented in Fig. (2). From which the saturation magnetization values Ms the initial susceptibility values *[χ](http://www.sciencedirect.com/science?_ob=MathURL&_method=retrieve&_udi=B6W7T-4V42J94-1&_mathId=mml15&_user=4265827&_cdi=6635&_pii=S1567173908002836&_rdoc=16&_ArticleListID=1383572335&_issn=15671739&_acct=C000062639&_version=1&_userid=4265827&md5=d819754eab0d61f56ee3939054eedbb4" \o "Click to view the MathML source)*[0](http://www.sciencedirect.com/science?_ob=MathURL&_method=retrieve&_udi=B6W7T-4V42J94-1&_mathId=mml15&_user=4265827&_cdi=6635&_pii=S1567173908002836&_rdoc=16&_ArticleListID=1383572335&_issn=15671739&_acct=C000062639&_version=1&_userid=4265827&md5=d819754eab0d61f56ee3939054eedbb4" \o "Click to view the MathML source) were determined and the average size of magnetic diameter am  ,Table (1).The differences evidenced between *a*TEM values and *a*M values, can be assigned to the size of the surfactant shell of the magnetite core, the surfactant layer being often considered as a magnetically dead coating, which can affect the uniformity or magnitude of magnetization due to quenching of surface moments[1]



Fig.1 Fig. 2

Table (1): The physical properties, volume fraction data and mean physical diameter of magnetic nanoparticles

| Magnetic fluid sample | aTEM(nm**)** | aM (nm**)** | [Φ](http://www.sciencedirect.com/science?_ob=MathURL&_method=retrieve&_udi=B6W7T-4V42J94-1&_mathId=mml1&_user=4265827&_cdi=6635&_pii=S1567173908002836&_rdoc=16&_ArticleListID=1383572335&_issn=15671739&_acct=C000062639&_version=1&_userid=4265827&md5=c6742931d9131fdc40430f7a353582df) (%) | Density (g/cm3) | Surface tension (×10−3 N/m) | Viscosity (×10−3 kg/ms) |
| --- | --- | --- | --- | --- | --- | --- |
| SCPB | 8 | 5.2 | 3.0 | 1.027 | 71.87 | 1.25 |
| SACA | 9 | 5.4 | 3.4 | 1.032 | 72.17 | 1.35 |
| SSulph | 11 | 5.7 | 4.1 | 1.083. | 75.24 | 2.51 |
| STX | 13 | 5.6 | 5.7 | 1.093 | 78.35 | 2.86 |

Table (2): Magnetic data of investigated samples

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Magnetic Fluid sample | aTEM (nm) | aM (nm) | M(%) |  | Ms(kA/m) |
| SCPB | 8 | 5.2 | 3.6 | 0.08325 | 18.5 |
| SACA | 9 | 5.4 | 3.9 | 0.0891 | 19.8 |
| Ssulph | 11 | 5.7 | 4.3 | 0.0972 | 21.6 |
| STX | 13 | 5.6 | 4.6 | 0.099 | 23.1 |