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The role of solution parameters and ions on superparamagnetic magnetite nanoparticles and magnetic fluids

S.Beyaz[1], *T.Tanrisever*[1] *and H.Kockar*[2]

[1]Department of Chemistry, Science&Literature Faculty, University of Balikesir, Balikesir, Turkey.
[2]Department of Physics, Science&Literature Faculty, University of Balikesir, Balikesir, Turkey.

The nanoparticles are intensively studied and find versatile application in diverse areas, which cannot be achieved by their bulk counterparts. Especially, magnetite (Fe_3O_4) nanoparticles attract a great deal of interest in biomedical application due to showing rather low toxicity. Among reported synthesis methods, the coprecipitation first introduced by Khalafalla[1] only showed that magnetite nanoparticles can be produced allowing some air oxidation. The method has the advantages of simplicity and productivity. The dependence of solution parameters (the type of salts used, Fe^{2+} and Fe^{3+} ratio, temperature, pH and ionic strength of the media) on the control of size and composition of nanoparticles is still unclear. Massart [2] also synthesized magnetite nanoparticles under nitrogen and emphasized the stable acidic magnetic fluids can be prepared in low polarizing anions of, Cl^-, NO_3^- and especially ClO_4^-. The role of the ions on magnetic properties of fluids has not also been fully investigated. In this work, the influence of solution parameters and the ions on the magnetic nanoparticles were studied. The same effect on magnetic fluids was also discussed.

The structural characterization of the magnetic powders was made by Fourier transform infrared spectroscopy (FT-IR) and x-ray powder diffraction (XRD). FT-IR measurements showed that the synthesized magnetic powders presented characteristic peaks at 568 cm^{-1} (tetrahedral metal stretching, Fe-O) and 402 cm^{-1} (octahedral metal stretching, Fe-O). XRD patterns indicated that the nanomagnetic powders have a face-centered cubic spinel structure having the characteristic (311), (400), (220) and (440) peaks. Scherrer equation was used to calculate the size of magnetite nanoparticles, which was in the range of 22 nm to 36 nm from the highest peak intensities of each XRD pattern. It is thought that the variation in the particle sizes is due to the effect of the production parameters.

The hysteresis loops obtained by vibrating sample magnetometer (VSM) confirmed that magnetite powders and fluids are superparamagnetic. Particle sizes of superparamagnetic magnetite powder were also calculated to be in the range 20 nm to 25 nm by fitting the data of the loops using the Langevin function. The particle sizes are in good agreement with the ones calculated from XRD dates. Results also indicated that the superparamagnetic fluids using $HClO_4$ have a slightly higher magnetic saturation, M_{fluid} (67,15 emu/g) and susceptibilities, χ_{fluid} (0,203) than the powders of M_{powder} (60,44 emu/g) and χ_{powder} (0,1104). The magnetic susceptibilities of fluids were also affected depending on the type of the acid used. The susceptibity of the fluid in HNO_3 is 0.1454. The findings of magnetic fluids, the average size, size distributions and surface charges of nanoparticles were confirmed by Nano-Zeta Sizer and discussed in full paper.

References

[1] Khalafalla ES, Reimers GW. IEEE Trans Magn 1980;16:178.
[2] Massart R., Ieee Transactions On Magnetics, Vol. Mag-17, No. 2, March 1981