Optical Properties of Ionic Ferrofluid of MnFez04

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The optical birefringence of the ionic aqueous ferrofluid of MnFea04 is measured as a function of temperature, without the application of a magnetic field. The experimental results indicate the existence of an anisotropic magnetic fluid

I. Introduction

Ionic ferrofluids[1-4] are colloidal suspensions of small magnetic grains, electrically charged, dispersed in a liquid carrier. It is well known that these fluids become optically anisotropic[5-9] when they are submitted to a magnetic field. More recently[9,10], experimental evidences concerning the existence of a small birefringence ($\sim 10^{-5}$) in ionic ferrofluids without the presence of magnetic fields were obtained.

More evidences on the birefringence at zero fielcl, as a function of temperature and concentration of magnetic grains are presented in this paper.

II. Experimental results and discussions

The magnetic fluid used is a water base ionic ferrofluid composed of grains of $MnFe_2O_4$. The $MnFe_2O_4$ oxides have a spinel-type structure. The elementary cell is composed of 32 oxygen atoms (cpc lattice) with 64 tetrahedral sites of which 8 are occiipiecl by Mn^{2+} cations and 32 octahedral sites of which 16 are occupiecl by Fe^{3+} cations. The ferrofluid was synthesized by one of us (F.A.T.) at the Université Pierre et Marie Curie-Paris (France). Tlie mean diameter of the particles, obtained by means of X-ray powder diffraction technique is 60Å.

The sample is put, by flux, inside microslides (thickness 0.2 mm, width 2.5 mm, length 20 mm) from Vitrodynamics Corp. The microslide with both ends sealed[4], is placed in a temperature controlled device (stability of 0.1 °C). The device is coupled to a microslide plate of a non-magnetic material, in order to avoid spurious external fields. The observations are made using an orthoplan-pol Leitz microscope with a tilting compensator to measure the optical birefringence.

Two different concentrations of magnetic grains are used in this work: c1 = 0.5 $\times 10^{16}$ grains/cm^3 ($\phi 1 \equiv$ volume fraction E 0.06%) e c2 = 2.7 $\times 10^{16}$ grains/cm^3 ($\phi 2 = 0.31\%$).

Fig. 1 shows the hirefringence (An) as a function of temperature for both concentrations c1 and c2, without application of a magnetic field. For both cases, the optical axis of the sample ($\vec{n}$) orients parallel to the longest axis of the microslide, i.e., along the filling flux direction. It is important to remark that the inner walls of the microslide, examined under interferential microscope, present small channels parallei to its longest axis. $\Delta n (= n_e -$ no, where n_e and n_0 are the extraordinary and ordinary refractive indices, respectively) is negative. The birefringence of the empty microslide is about

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10 times smaller than tlie maximum value of the measured An [5]. In Fig. 1, this effect has already been removed. The experimental error in An evaluated is about 6%. The experimental values showed [Fig. 1] are obtained for increasing temperatures.

The existence of non zero An at any given temperature clearly identifies an anisotropic fluid. The effect is very small at room temperature and becomes more pronounced upon the increase of T. For both cases, for increasing temperatures, An increased, up to a maximum value ($\Delta n^{(m)}$) and after that it decreases. $\Delta n^{(m)}$ at concentration c1 is $\Delta n_1^{(m)} = -3.6 \times 10^{-5}$ (at $T_1 = 36°C$) and at c2 is $\Delta n_2^{(m)} = -5.4 \times 10^{-5}$ (at $T_2 = 46°C$). It is interesting to note that $\Delta n^{(m)}$ is not proportional to the concentration. This fact has already been detected[10] in the study on the birefringence at saturation (in presence of a saturation magnetic fielcl) as a function of the grain concentration in $MnFe_2O_4$.

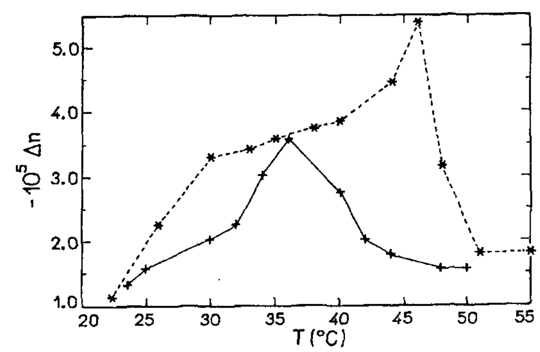

Figure 1: Optical birefringence An of $MnFe_2O_4$ as a function of the temperature T. (+) c1 = 0.5 x 10^{16} grains/cm^3; (*) c2 = 2.7 x 10^{16} grains/cm^3. Tlie solid and dashed lines are only eye guides.

The origin of the birefringence at the zero magnetic field is not a solved problem yet. Both the filling flux process and the presence of channels in microslides could explain the hreak in the symmetry along the long axis of the sample holder. However, only these effects are not enough to explain the existence of An.

As the grains in ionic ferrofluids are not exactly spherical, an anisotropic charge distribution could induce an anisotropic interaction between the grains and induce a long range orientational ordering of them.

Tlie dependence of An on temperature is also an intrigating matter. As the grains are charged by means of a chemical equilibrium between tlie grain's surface and tlie volume solution, the temperature could act to displace this equilibrium and promotes a small scale agglomeration of the grains. More results will be necessary in order to come up with a definite conclusion for the basic process which originates An at the zero field and its temperature dependence.

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