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STUDY OF MAGNETIC FREDERICKSZ TRANSITION IN FERRONEMATICS

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The magnetic Fredericksz transition in ferronematics (thermotropic nematic liquid crystals 7CB and MBBA combined with fine magnetic particles of a size 10 nm) as a function of concentration of magnetic particles was studied by using simple dielectric measurements. The increase of the threshold magnetic field is observed in 7CB based ferronematic while the decrease of threshold field in MBBA based ferronematic is observed when the concentration of magnetic particles is increased. Experimental results are discussed in the framework of Brochard, de Gennes and Burylov, Raikher theories.

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1. Introduction

The combination of a liquid crystal and a magnetic fluid give an interesting material; the so-called ferronematic or ferrocholesteric. Brochard and de Gennes constructed a continuum theory of magnetic suspension in liquid crystal in their fundamental paper [1] prior chemical synthesis of these materials. The first experimental paper was of Rault et al. [2], where the basic magnetic properties of suspension of rod like $\gamma-Fe_2O_3$ particles in MBBA liquid crystal were studied. Later, on the basis of estimates given in work [1] at first lyotropic [3, 4] and then thermotropic [5, 6] ferronematics were prepared and studied. In theoretical papers [7, 8] Burylov and Raikher analysed the Brochard and de Gennes theory and the limitations of its applicability to real thermotropic systems were given. The main difference between above-mentioned theories is the fundamental fact that in thermotropic ferronematics with finite anchoring on particles the equilibrium orientational state is $n(r) \perp m(r)$ (where $n(r)$ is the director of nematic molecule and $m(r)$ is the local magnetization) not $n(r) \parallel m(r)$ (the co-alignment postulate). Burylov and Raikher [8] studied the magnetic Fredericksz transition (the instability of a uniform texture) and derived the increase of the threshold magnetic field of thermotropic ferronematics in comparison with threshold field of pure liquid crystals. The aim of this work was to prepare 7CB and MBBA based ferronematics and to study the magnetic Fredericksz transition by means of simple dielectric measurements.

2. Experimental results and discussions

The magnetic particles were magnetite particles (particles traditionally used in magnetic fluid technology) with a mean diameter $D_v = 10$ nm and a standard deviation $\sigma = 0.325$. The ferronematics were prepared by simply adding the magnetic powder to liquid crystal and then sonicating 10 minutes. Two samples of 7CB based ferronematics with reproducible measurements of Fredericksz transition were obtained only. The volume concentrations of magnetic particles were $f_1 = 2.5 \times 10^{-4}$ and $f_2 = 5 \times 10^{-4}$, respectively. The initial planar (7CB based ferronematic) and homeotropic (MBBA based ferronematic) alignment of nematic liquid crystal molecules was obtained by coating the capacitor electrodes with HTAB (hexadecyl tri methyl ammonium bromide). To orientate the samples 0.3 T magnetic field was used. The magnetic Fredericksz transition was indicated from dielectric measurements. The measured capacitor cell was constructed from two flat thin SnO_2 layer coated non-magnetic glass electrodes connected to regulated thermostating system. The distance between electrodes was $D = 60$ μm. The measurement of capacitance were carried out using standard RLC-bridge with an accuracy 0.1% in voltage 50 mV at frequency 20 kHz. The temperature was stabilized with an accuracy $\pm$ 0.01°C.

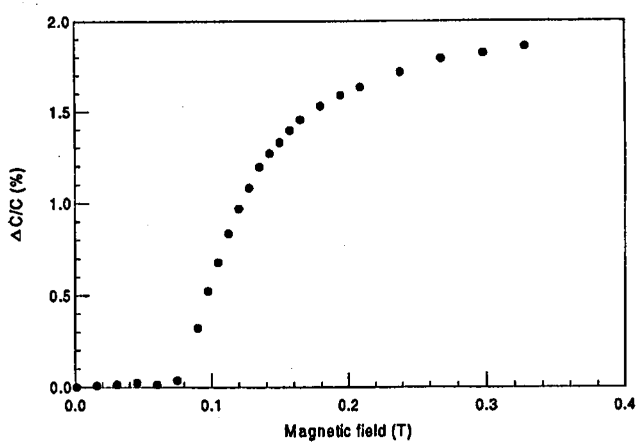

Fig. 1. Typical Fredericksz transition in MBBA doped with volume concentration $f = 10^{-3}$ of magnetic particles.

As an example the typical Fredericksz transition for MBBA based ferronematic with volume concentration $f = 10^{-3}$ of magnetite is given in Fig. 1. The influence of the concentration of 7CB based ferronematics doped magnetic particles on the threshold field is summarized in Table.The influence of the concentration

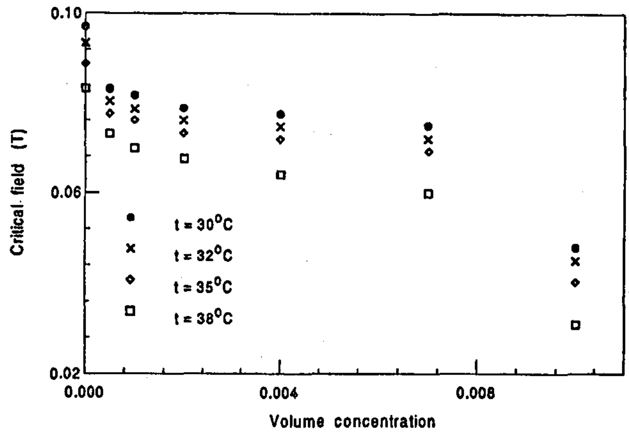

Fig. 2. The critical magnetic field of Fredericksz transition vs. volume concentration of magnetic particles for MBBA based ferronematics.

TABLE

The threshold field for 7CB based ferronematics.

t	$\mu_0 H_C$ [T]		
[°C]	7CB	f_1	f_2
30	0.116	0.135	0.155
35	0.105	0.124	0.146
40	0.094	0.114	0.135

of doped magnetic particles on the threshold field for MBBA based ferronematics is given in Fig. 2. The increase in critical magnetic field in 7CB liquid crystal case while the decrease in critical magnetic field vs. volume concentration of magnetic particles in MBBA case is observed. It is difficult to use the existing theories [1, 7, 8] to our system because they are concerning of ferronematics with rod-like magnetite particles. In our system we have particles of nearly spherical shape. But qualitatively we can say that in 7CB system probably the initial condition $n(r) \perp m(r)$ required from Burylov and Raikher condition [7, 8] is fulfilled while in case of MBBA is not fulfilled. The co-alignment arrangement can take place in Burylov and Raikher theory too, when W (surface density of anisotropic part of interfacial energy on the particle nematic boundary) is negative as discussed in the paper [7]. After performing the analogous calculations scheme in the co-alignment situation and using the same approximations we obtain for critical magnetic field of Fredericksz transition the following relation:

$$H_c^2(f) - H_c^2(0) = 2Wf/\chi_a d, \tag{1}$$

where χ_a is the anisotropy part of the nematic liquid carrier diamagnetic susceptibility, d is the size of magnetic particles and $H_c(0) = (\pi/D)(K/\chi_a)^{1/2}$, where K is the elastic constant. Equation (1) is the same as in the situation when $n(r) \parallel m$ [8]. By means of this relation it is easy to explain the increase and decrease in the threshold magnetic field by changing the sign of the coupling energy W between magnetic particles and molecules of nematic liquid carrier.

In conclusion we can say that MBBA-based ferronematic is probably a candidate with negative surface energy coupling between magnetic particles and the nematic liquid crystal.

Acknowledgment

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