

PREPARATION AND PROPERTIES OF A FERROMAGNETIC NEMATIC SUSPENSION

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A stable ferromagnetic suspension based on a nematic liquid crystal (LC) doped with nano-particles of ferric oxide is obtained for the first time. In the outward appearance, the suspension does not differ from a pure LC. Using AFM spectroscopy, the size of nano-particles is determined, and their concentration in the matrix is estimated. The basic characteristics of the suspension such as the phase transition temperature (nematic-isotrope), LC director pretilt angle on the orienting surface, and azimuthal anchoring energy are determined. A high sensitivity of the suspension to a magnetic field makes it promising for applications in the devices for information storage and display.

in a liquid crystal matrix. The use of low-concentrated nano-scale particles allowed strongly decreasing the orientational elastic interaction and the magnetic dipole-dipole interaction between particles that led to the particles' aggregation. Due to a small size of nano-particles, they do not disturb the director field, and such a system looks like pure LC. At the same time, the doping of nano-scale particles results in the enhancement of the LC sensitivity to magnetic fields.

Introduction

Composite liquid crystals (LCs) attract a great attention due to their unique electro- and magneto-optical properties. Typical composite LC systems are aerosol suspensions, suspensions of ferroelectric nano-particles in a nematic matrix, and nematic suspensions of magnetic particles [1–8]. In the 1970s, ferromagnetic liquid crystal suspensions were suggested by Brochard and de Gennes for increasing the LC sensitivity to magnetic fields [4]. In 1983, Chen and Amer produced the first ferromagnetic suspension based on ferro-particles of ferric oxide in a LC matrix MBBA. It was demonstrated that this system was sensitive even to the magnetic field of the Earth [5]. Unfortunately, the strong aggregation of ferro-particles in magnetic fields $H > 10$ G was an essential drawback of this system.

The problem of ferro-nematic LC suspension instability was partially solved for lyotropic LCs only in the 1990s [9]. A stable ferromagnetic suspension based on thermotropic nematics never was developed. The aim of our work was producing and investigating a stable optically homogeneous ferromagnetic suspension based on nematic LC. Unlike other works, where a high volume concentration ($f \approx 10^{-2} \div 10^{-3}$) of micro-particles [4] or a small volume concentration ($f < 10^{-4}$) of submicron ($\approx 0.5 \mu\text{m}$) particles [5–6] was applied, we used the low-concentrated ($f < 10^{-5}$) dispersion of nano-particles

1. Materials and Experiment

The ferro-nematic suspension consisted of the dispersion of ferromagnetic particles Fe_3O_4 covered with a surfactant in liquid crystal 5CB (Merk). Ferromagnetic material Fe_3O_4 is an oxide of ferrous iron and ferric iron that forms crystals with the spinel structure. Under normal conditions, the Fe_3O_4 magnetization is 450–500 G, and the magnetic moment $\mu \approx 4.1 \mu_B$. 5CB is a classic nematic LC, whose phase transition temperature to the isotropic phase $T_c = 35.5^\circ\text{C}$. 5CB possesses small diamagnetic anisotropy $\Delta\chi = 10^{-7}$ esu. As a surfactant, we used oxyethyl-propylene glycol which consists of polymer chains (a molecular weight of 1000–3000) with central hydrophilic fragments and side hydrophobic fragments.

Ferric oxide particles having size $\approx 1 \mu\text{m}$ were mechanically milled with the surfactant in ratio 1:2. The milling time was hundreds hours, at least 120 h. During the milling, the particles were covered with a thin layer of the surfactant that decreased their coagulation. To separate the particles by size, the mixture was placed after the milling in a segregation column. After keeping in the column during 3 days, the upper part of the mixture was taken out for the suspension preparation and added to LC at $T = 50^\circ\text{C} > T_c$. Then the suspension was additionally segregated in a centrifuge with a rotation speed of 1500 rpm. The final suspension did not differ from pure LC by site.