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Self-Organization of Liquid Crystals Induced by Aligning of Human Erythrocytes

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The current article presents experimental observations of erythrocytes aligning in nematic liquid crystal (NLC) medium as well as following study of the rearrangement of the NLC matrix induced by aligned bodies. The results of this study showed that a pronounced rearrangement of a pristine NLC mesophase could be induced not only by the insertion of fullerenes or fullerene-based charge-transfer complexes, but by adding non-electrically-neutral biological components such as human blood erythrocytes.

Keywords: erythrocytes; fullerenes; liquid crystal; nanostructures; self-arrangement

1. INTRODUCTION

Unique electrical, magnetic, mechanical, thermooptical, and nonlinear optical features of liquid crystal (LC) mesophase [1,2] predict its application in optical information processing schemes [3,4], laser physics [5], display technique [6], and medicine [7]. The physical-chemical phenomena in liquid crystals under external fields connect with the weak intermolecular interaction of the structural elements of liquid-crystal media [8] with objectives added. One of the more important property of liquid crystals is their orienting ability, which is used to

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develop new composite materials [9,10]. The interaction between the LC matrix and the particles suspended in it provokes the sensitivity of new composite to the external field. As results, the orientation or order parameter of the LC matrix could be also changed. To take advantage of such factors as the presence of weak dispersion forces between the molecules of liquid crystals and the high orienting ability, a nonlinear liquid-crystal medium has been proposed for visualizing, fixing, and orienting human red blood cells [11]. As an additional, the aligning effect has been repeated in fullerene-doped liquid crystals [12]. It permits to study the erythrocytes configuration with good advantage.

It should be mentioned that blood reacts to the extremely multifarious processes that are triggered in an organism by various external factors or by a change in the number or activity of the cells circulating in the blood, by the state of the liquid phase, and by the reactivity of these components in relations to the physical factors of the medium. At the present time the configuration of the red blood cells (erythrocytes) is an important indicator of the health of a person, along with the color and hemoglobin concentration of the blood. A healthy human red cell is disk-shaped. A different transformation of the erythrocytes can result from energy and immunological imbalances. An elevation of the count of transformed cells is a deleterious factor that can lead to a number of pathological processes in the human organism to be revealed. A judicious choice of the medium into which the erythrocytes are placed will make it possible to determine rather simply both the number and shape of the cells. Moreover, the possibility of limiting the number of degrees of freedom of the cells (without loss of important vital functions) and to line up a group of test cells along a single direction will substantially simplify the data processing, which presents many difficulties for medical personnel in the usual biochemical studies.

In the present article the self-arrangement effect in LC induced by the erythrocytes adding is studied and discussed. It has been considered as feedback effect connected with former observation of erythrocytes aligning phenomenain liquid crystals.

2. EXPERIMENTAL CONDITIONS

The experiments were performed using quartz or glass cells assembled in *S*-configuration with a gap width of 10–12 micrometers. The immersion of the NLC mesophase was represented by cyanobiphenyl-group of liquid crystals. To align the LC mesophase the different methods

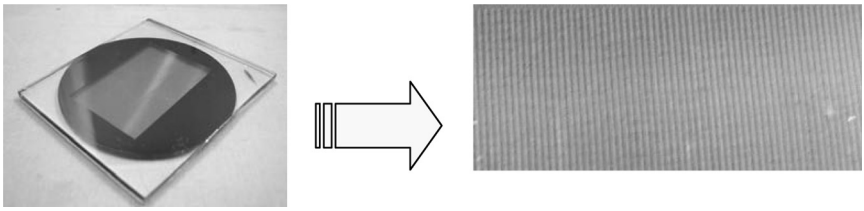

FIGURE 1 The view of the grating formed with holographic method.

have been used, such as holographic grating formation, rubbing technique, and surface electromagnetic wave treatment of the aligning layers. Some type of the obtained relief is shown in Figure 1. As can be seen in this figure the relief with grating of 10 micrometers (20 or 40 micrometers can be made too) can be developed using holographic recording method. It should be noticed that in our experiments the cells have been made with an orienting coating based on a fluoroplastic solution in a mixture of acetone and amyl acetate. When the experiments have been done with an orienting coating based on admixture of toluene, it provoked a greater number of deformed erythrocytes while having no effect on the change in the angle of suspension of the liquid-crystal molecules and the related alignment direction of the erythrocytes. Initially the choice of the organic orienting substance was motivated by the fact that, as had been shown in Refs. [13,14], the properties of the orienting film have a substantial influence on the dynamical characteristics of a liquid crystal and largely determine the value of the pre-tilt angle of the liquid-crystal molecules to the substrate surface. Since the highest contrast, better orienting features, and fastest response have been obtained when polymer-orienting coatings have been applied; the compound indicated above has assuredly been used more often than oxide orienting substances.

The samples containing human blood erythrocytes were prepared as follows. The blood sample taken from a peripheral vein of a patient was centrifuged for 3 min at 1500 rpm, after which blood serum was separated by a syringe. Another syringe was used to take 0.1 ml of a liquid crystal solution, after which the same syringe was used to take 0.01 ml (from the surface) of the centrifuged residue containing predominantly erythrocytes. Then, the syringe was slowly rotated about the horizontal axis in order to mix the components. Finally, a thin layer of this mixture was introduced into the quartz or glass cell until its complete filling with the aid of capillary forces.

The process of NLC structurization was studied using a Polam P-312 microscope (LOMO, St.-Petersburg, Russia). The observations were performed in a polarized light at a magnification of $\times 400$ or $\times 800$.

3. RESULTS AND DISCUSSION

The study of the complicated systems based on erythrocytes and a liquid crystal reveals self-arrangement effect in liquid crystal matrix. The basic results are shown in Figures 2–5.

An analysis of the micrographs presented in Figures 2–5 leads to the following evidences. The appearance of a biaxial structure and its separation into domains are apparently related to the interaction of two charged systems: liquid crystal dipoles and blood cells. Indeed, the electro-neutrality of a LC is violated under the action of a polarization relief of the surface, while the effect of a charged shell of the blood cell is determined by the transformations of proteins inside the cell. Apparently, the dipole moment of stretching vibrations of the C≡N bond (oriented parallel to the long axis of a rigid nucleus of the liquid crystal molecule) remains uncompensated, which leads to the attraction of blood cells and their orientation along inhomogeneities of the NLC mesophase. As a result, the blood cells repeat the arrangement of liquid crystal molecules and, at the same time, induce the more complicated processes involving a change in the order parameter of the new liquid crystal composite. Thus, new self-arrangement effect can be observed due to erythrocytes introduction.

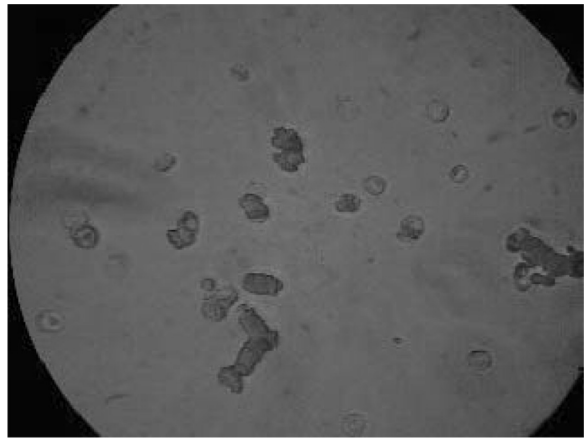

FIGURE 2 The typical packing of erythrocytes in an isotropic nonoriented liquid crystal medium.

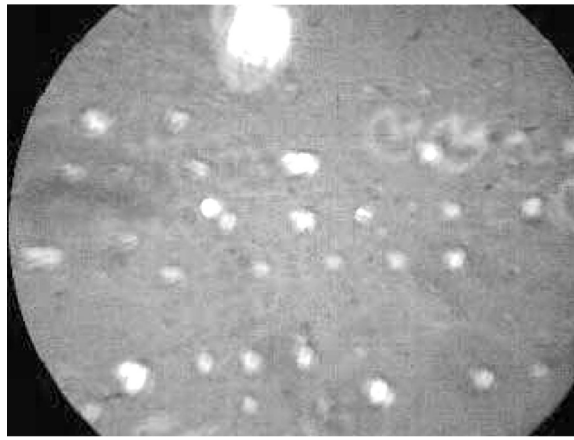

FIGURE 3 The alignment of erythrocytes along the NLC director oriented in the horizontal direction (this micrograph was made with intentional partial underfocusing).

It should be noticed that the same effect has been observed after the introduction of a charge-transfer organic donor-fullerene complex with an additional dipole moment into the nematic liquid crystal mesophase (see the results of the articles [16–18]). The local polarizability (proportional to third-order non-linear sensitivity and the unit of volume) and general polarization of the sensitized system have been

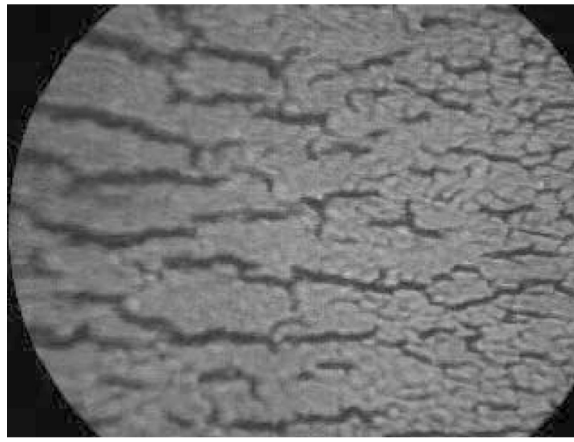

FIGURE 4 The initial stage of the NLC structurization upon the introduction of erythrocytes.

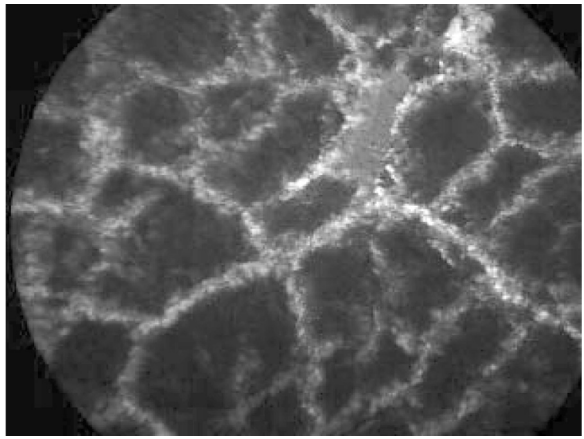

FIGURE 5 Final structurization of the NLC mesophase with introduced erythrocytes after a few-day observation of the establishment of a thermodynamic equilibrium in the system.

increased. It has been shown that the third-order non-linear sensitivity $\chi^{(3)}$ of a nanoobjects-sensitized liquid crystal system is much more pronounced than can be experimentally observed and calculated from the analysis of a photo-induced change in the refractive of a non-sensitized structure. As the result this process may provoke the liquid crystal molecular self-arrangement with good advantage. Thus, the increased polarizability can be responsible for this phenomenon as the general effect.

4. CONCLUSION

Summarizing the results, one can say that this investigation showed that the structurization of an NLC mesophase could be induced by the introduction of not only dyes and fullerene- or nanotubes-containing complexes with charge transfer, but also of non-electrically-neutral biological components such as human blood erythrocytes. Some new studies can be opened in this direction using the methods of dynamic holography for the observation of diffraction on the ordered biaxial structures. It should be mentioned that the NMR experiments could be useful to check and control the changes in the NLC order parameter in the presence of erythrocytes.

These investigations can be also useful for medicine by providing a means of monitoring changes in the shape of human blood cells using pure NLC mesophases, a fullerene- or nanotubes-containing LC

compositions. These structures and method permit to orient human blood cells and to identify the change in matrix under condition of non-electrically-neutral biological components introduction.

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