PECULIARITIES OF CONFOCAL, POLYGONAL AND FAN-LIKE TEXTURES IN SMECTIC AND CHOLESTERIC LIQUID CRYSTALS

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Abstract. - Polycrystalline textures of liquid crystals arise as the result of breach of optical continuity in structures of liquid crystalline mesophases. Their importance is connected with their significance for identification and classification of liquid crystalline mesophases and also for investigation of the character of different defect types in liquid crystalline structures.

In the present work, a comparative investigation of the peculiarities of confocal, polygonal and fan-like textures in smectic A, smectic C and cholesteric liquid crystals have been carried out. Morphological and structural peculiarities of these textures are presented. The microphotographs of different types of confocal, polygonal and fan-like textures, observed in the investigated liquid crystals are shown.

1. INTRODUCTION

Deformations and defects in liquid crystals attract, at present, a great interest. First of all, they have important fundamental significance; but what is rather important is their application in obtaining nondefected oriented textures in liquid crystals used in devices of optoelectronics, microelectronics and addressing systems [1]-[4].

Defects are topological elements, that are specifically connected with the symmetries of crystals. They appear and disappear by the prolonged influence of different external effects, depending on the elastic peculiarities of liquid crystals. Availability of defects are necessary to take into account when the results of different physical investigations are interpreted.

Liquid crystals are characterized with different types of optical pictures – the textures, which can be observed by a polarizing microscope [5]-[8]. Typical textures in liquid crystals can be devided into two main groups: the oriented (planar, homeotropic, pseudohomeotropic and twist) textures, which are monocrystalline; and
the nonoriented (confocal, polygonal, fan-like, mosaic, marple-like, schliren, finger-print etc.) textures, which are polycrystalline. Polycrystalline textures gain much interest because they display different defect types in liquid crystals; i.e., these textures arise as the result of breaking in optical continuity of structures of liquid crystalline mesophases.

Defects in liquid crystals are distinguished from defects in solid crystals. The energy necessary for stabilization of defects in liquid crystals is less than the energy necessary for stabilization of defects in solid crystals. Besides that, defects in liquid crystals are kept stable by the surfaces of sandwich-cell, i.e., by mechanical inclusions. These defects may also arise through the influence of mechanical deformations, flows, electrical, magnetic and thermic fields. They can be observed and studied by using the polarizing-optical technique [9]-[11].

In this work, we study the nature and comparative peculiarities of confocal, polygonal and fan-like textures, which take place in smectic and cholesteric mesophases of liquid crystals and obtain their optical and structural properties.

2. METHODS AND SAMPLES

Investigations on peculiarities of textures and dynamics of their temperature dependence are carried out by the method of polythermic polarizing microscopy. In the present work, an "Olympus" BX-P polarizing microscope, a microphotographic system, a special thermostat-heater and λ-plates (λ = 137 nm and λ = 530 nm) have been used. As known, the method of polythermic polarizing microscopy with application of crystallography methods is the most convenient and simplest one for investigation of mesomorphologic, morphologic and orientational properties of liquid crystalline materials [5]-[7], [12]. We study the morphological and optical properties of liquid crystalline textures by means of optical mapping technique, presented in [13], [14].

The investigated samples were of sandwich-cell type glass plane capillary. The thickness of the liquid crystalline layer in the sandwich-cell was determined by using Mylar thin film and was found to be 20 μm.

In our work, we studied smectic A, smectic C and cholesteric mesophases. The names, structure formulae and temperature ranges of these mesophases are shown in Fig. 1.

3. RESULTS AND DISCUSSIONS

The microphotographs of confocal textures of smectics A and C are presented in Fig. 2 (a) and (b). As seen in these microphotographs the observed textures are characterized by different sizes of confocal formations and different density of disposition of these formations.
4'-octyl - 4' -n-cyanobiphenyl (Smectic A: 21.5 - 33.5 °C)

4'-decyl - 4' -n-cyanobiphenyl (Smectic A: 44.0 - 50.5 °C)

4,4'-octyloxyazoxybensol (Smectic C: 107.3 - 125.5 °C)

4,4' - diheptyloxyazoxybensol (Smectic C: 95.4 - 124.2 °C)

4' - (4-methoxybensylidenamino)amilecynammat (Cholesteric: 82.3 - 102.3 °C)

2- methylbuthyl - n - (n' methoxybensylidenamino) cynammat (Cholesteric: 76.0 - 125.0 °C)

Fig. 1. - Names, structure formulae, temperature ranges and types of the investigated smectic and cholesteric liquid crystals.
Fig. 2. - Confocal textures of smectic A (a), smectic C (b) and cholesteric (c) liquid crystals; Magnification $\times$ 200; Crossed polarizers.
As mentioned above, the confocal textures and their varieties, the polygonal and fan-like textures, have polycrystalline structure. The appearance of confocal textures in smectics is connected with the following fact: the layer structure of smectics causes a certain limitation on the permissible deformation types, since for the compression of smectic layers a sufficiently great energy is needed. Therefore, in smectics both the twist and bend deformations are absent [15], [16]. But in smectics the deformations, for which the distance between smectic layers are kept constant, are quite feasible. Hence, in smectics, layers can easily slide on one other. In this case the ideal packing of smectics can easily be deformed to a more complicated arrangement with bent layers. And if the joining center takes place on the reference surfaces of the sandwich-cell, the smectic molecules acquire a radial or fan-like packing; thus, smectic layers form a family of equidistant surfaces which are normal to the direction of molecules [9], [17]. In other words, confocal textures are formed as the result of two-dimensional defects in liquid crystalline layers.

The geometry of each individual confocal formation is very complicated. Confocal formations are three-dimensional figures, of elliptical foundations (Fig. 3a). Through one of the focal points of the ellipse construct an hyperbola, which is formed in the plane perpendicular to the ellipse. When the conical surfaces with foundations on the ellipses and with apexes at the ends of hyperbola are constructed, the confocal formation can be obtained [16], [18].

The investigation of the smectic A and C textures showed that in real confocal textures, the confocal formations are not as exact as the ones presented in Fig. 3 (a). The smectic layers have high mobility and can slide on one other in the diametrical direction, because in smectics wave-like and splay deformations can easily appear. Besides that, since confocal textures are continuous, the confocal formations in these textures must interact among themselves [16], [17]. These interactions lead to the appearance of different configurations observed in real textures (Fig. 2). In Figs. 3 (b), (c) and (d), the scheme of some of these configurations are shown. As seen in these microphotographs, in all of the real configurations, the smectic layers contiously cross from one confocal formation to other. This was observed by polarizing-optical investigations of the textures of smectic A and C.

Confocal textures are not specific textures and were also observed for the cholesteric mesophase. Generally, among characteristic textures of smectics and cholesterics and in particular among their confocal, polygonal and fan-like textures, we observed a certain likeness. The likeness of characteristic textures of investigated liquid crystals is connected with the translational periodicity of smectic and cholesteric structures in an equilibrium state. In cholesterics the period is equal to the half of the spiral step of cholesterics, but in smectics the period is equal to the distance between smectic layers. In Fig. 2 (c), the confocal texture of cholesterics is presented. However, by comparing the microphotographs, presented in Figs. 2 (a), (b) and (c), it can be seen that these textures are essentially different. First of all, it can be noted, that confocal textures of smectics are characterized by larger confocal formations and sharper details. That is why the spiral step in cholesterics can be changed easily, but the distance between smectic layers is practically constant. Therefore, the textures in cholesterics are less
regular than those in smectics. Besides that, the microscopical investigations of the confocal textures of cholesterics, which have spiral structure, showed that the axis of the spiral is oriented inclined to the surfaces of the sandwich-cell. And unlike smectics, in confocal textures of cholesterics the long axes of molecules are perpendicular to straight lines, constructed through the ellipses and the hyperbola [9], [16]. Because of these, and as we observed experimentally, the confocals of cholesterics have a negative optical sign, but the confocals of smectics have a positive optical sign.

Fig. 3. - Types of confocal formations: (a) general look of confocal formation; (b) formation with low conicity; (c) two formations with incomplete ellipses and (d) three formations with incomplete ellipses.

The surfaces of confocals, presented in Fig. 2, were cleared up and darkened when the microscope table was rotated. Besides that, by the rotation of crossed polarizers relative to the immovable sample, the clearing up and darkening of the confocal surfaces was also observed. Fig. 4 presents, as an example, the optical mapping of smectic A confocal texture. As seen from this optical mapping, confocal textures of smectic A have positive optical sign. The investigation of the confocal textures by optical mapping technique shows that the molecules of smectics situated along the conic surfaces. By that the angle between the direction of vector-director and the normal to the sandwich-cell plane changed in sufficiently large range for different confocals. Moreover, the displacement of the surfaces of sandwich-cell with confocal textures, in the case of cholesterics, led to the planar texture formation, but in the
Fig. 4. - Optical mapping of confocal formations for smectic A; Magnification × 200; Crossed polarizers.
case of smectics A this displacement led to the rise of an hemeotropic texture. All of these facts make easier the identification of smectics and cholesterics.

We observed that polygonal textures are also formed in the investigated smectics and cholesterics. A polygonal texture arises due to the bond of smectic layers in different confocal formations (Fig. 5 (a)). The smectic layers of one formation cross continuously in the layers of other formations. Hence, a smectic layer is divided in pyramidal and tetrahedral blocks (Fig. 5 (b)). As it was pointed out in Refs. [15] and [20], in each of the pyramidal blocks there exists a few types of confocal formations, but in tetrahedral blocks the smectic layers bind the confocal formation in pyramids of different types. In polygonal texture of cholesterics, the ellipses of confocal formations

![Diagram](image)

**Fig. 5.** - Scheme of polygonal texture [19]: (a) scheme of smectic layers bond in confocal formations; (b) scheme of blocks in polygonal texture.

... are joined with the upper and lower reference surfaces of the sandwich-cell. This is easily observed with a polarizing microscope. Meanwhile, we observed that these confocal formations fill in completely the sandwich-cell volume.

Fig. 6 (a), (b), (c) shows the polygonal textures of smectics A, C and the cholesterics. As seen in these microphotographs, as in the case with confocal textures of smectics and cholesterics, the polygonal texture of the smectic A are characterized by larger sizes of polygonal formations and sharper texture details, compared to the polygonal textures of cholesterics. A distinctive peculiarity of polygonal texture of smectic A from polygonal texture of smectic C is that in smectic C textures a great number of disclinations connected with the breach of confocal formation orientations in polygonal blocks, which consist in the pyramidal and tetrahedral regions, take place.

In cholesterics we have obtained polygonal textures, in which the strips with periodical change of intensity have been observed (Fig. 6 (d)). The availability of these
Fig. 6. - Polygonal textures of smectic A (a), smectic C (b) and cholesterics (c) and (d). Magnification × 200; crossed polarizers.
Fig. 7. - Fan-like textures of smectic A (a), smectic C (b) and cholesteric (c). Magnification × 200; crossed polarizers.
strips are stipulated with the periodical change of refractive index, which is connected with the turning of molecules, characteristic for cholesterics [21].

The third variety of confocal textures occurring in smectics and cholesterics are the fan-like textures. In Fig. 7, the observed fan-like textures in smectics A and C and cholesterics are presented. As can be seen by comparing the presented microphotographs (Figs. 2, 6 and 7), both likenesses and differences were observed for confocal, polygonal and fan-like textures of the investigated smectics and cholesterics. Optical investigations show that in the obtained fan-like textures of smectics A and C (Fig. 7 (a) and (b)), confocal formations occur in the planes containing the hyperbolas. But in fan-like textures of cholesterics (Fig. 7 (c)), the confocal formations occur in planes perpendicular to the texture. Ellipses of these formations are settled down along divergent fan-like lines. In Fig. 8, a schematic structure of this fan-like textures is shown. The hyperbolas in this figure are the boundaries between different homogeneous regions. These boundaries are, sometimes, named as Grandjean's boundaries. Thus, confocal, polygonal or fan-like textures can be obtained depending on the position of confocal formations in the volume of sandwich-cell.

In conclusion, we would like to note that textures of liquid crystals are very sensitive to different external effects and types of these textures depend on the method of samples preparation. Therefore, as it is noted in [16], [22], earnest physical investigation of liquid crystals must precede an attentive study of optical and morphological properties of textures for each concrete experimental sample.

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REFERENCES


