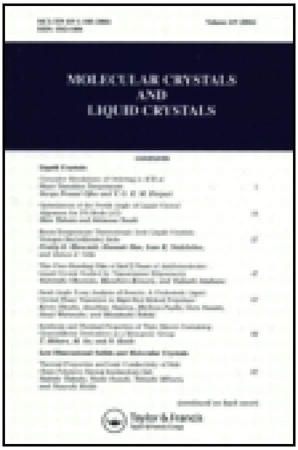

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Orientational Transitions in a Cell with Twisted Nematic Liquid Crystal

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We studied a stability of a twisted nematic liquid crystal with a photosensitive chiral dopant under homeotropic boundary conditions. Transition between the homeotropic and twisted alignment induced by photochanges in twisting agent and anchoring strength show hysteresis. The period of the "fingerprints" texture of twisted nematic changes discontinuously under the continuous changes of the concentration of twisting agent.

Keywords: liquid crystal; cholesteric; chiral agent; orientational transition

INTRODUCTION

Numerous applications of twisted nematic liquid crystals (LCs) stimulated studies of orientation transitions in these systems in cells with different boundary conditions. The twisted structures are often created by a dilution of twisting agent in a nematic LC. The product is a structure with a twisted director configuration which characteristic pitch, p, depends on a concentration of twisting agent C, as $2\pi / p = 4\pi\beta C$ (β is a twisting power of dopant).

The authors of references 1 and 2 studied the stability of the orientation of cholesteric LC in a cell with homeotropic boundary conditions. The homeotropic orientation was shown to be stable if $2L/p < K_3/K_2$, where L is a cell thickness, K_2 and K_3 are the Frank elastic constants. At the higher values of $2L/p$ the systems becomes unstable and the structures beyond the transition could not be described within one dimension approach. The one-dimensional model predicted that a transition between the structures should reveal hysteresis behavior. Despite the one-dimension approach is far from real experimental situation a hysteresis of the structural transition was observed in reference 3 by varying the concentration of the chiral dopant.

In this work we studied a transition between a characteristic fingerprints texture and a homeotropic orientation in a cell with homeotropic boundary conditions under light induced changes of twisting power of a chiral agent.

Preparation and characterization of liquid crystal cells.

We examined two types of cells. The first was a sandwich-like cell and the second one was a wedge cell. The both were filled with a mixture of 5-cyanobiphenyl (5CB, Merck, Germany) and a chiral dopant on a base of arylydenmenthanone (Single Crystal Institute, Ukraine). The actual cell thickness, L = 65; 20 and 15μm were given with Mylar spacers and measured using interference method.

To provide homeotropic boundary conditions the cell substrates were pretreated with poly(dimethylsiloxane) and annealed on the hot plate at 200-250°C. The etching time varied from minutes to hours to get different anchoring strength. The anchoring energy value, W, was estimated by the measurements of the width of surface inversion walls, d, in a cell of non-doped 5CB aligned homeotropically[4]: $W = \frac{\pi^2 L K_2}{2d^2}$

We found that the cells with L=65 microns made with the substrates annealed during 4 hours featured surface inversion walls with d=25 microns that corresponded to the anchoring energy $W \approx 10^{-3}$ erg/cm^2 for $K_2 = 5 \cdot 10^{-7}$ dyn. The annealing of the substrates for more than 4 hours provided the homeotropic alignment without surface inversion walls. We assumed that strong anchoring with the value $W \gg 10^{-3}$ erg/cm^2 in this case.

In the studies of structural transitions we used 5CB doped with 0.025-2% of chiral dopant from the chemical group of arylydenmentanones [5]. The compounds feature E-Z isomerization under UV light (wavelength 280-330 nm) irradiation. The photoreaction increases the density of Z-isomers. The chiral ability of E-isomer in 5CB matrix is thirty times higher than of Z-isomer. These properties allowed decreasing the concentration of chiral component in the mixture and increasing the induced cholesteric pitch under the UV light irradiation. To control the cholesteric pitch we studied the dosage effect of irradiation in wedge cells with planar boundary conditions. Filled with an induced cholesteric mixture this cells reveals characteristic lines of Cano-Grandjean [6]. The pitch length, p, was obtained from the number of

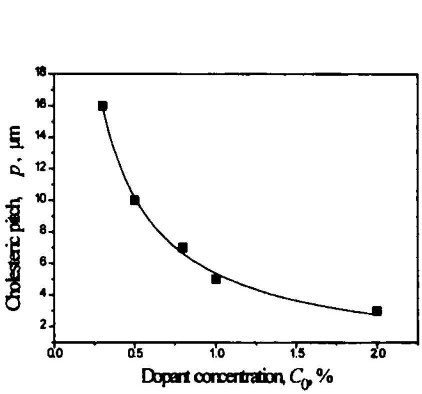

FIGURE 1. Dependence of the length of induced pitch on the concentration of chiral agent.

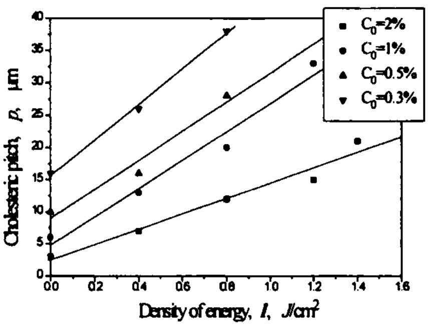

FIGURE 2. Dependence of the induced pitch on the dose of UV irradiation for the different initial concentrations C_0.

disclination lines N: $p=2L/N$. The length of the pitch depends on the dopant concentration as pC_0 =*const* (see Figure 1). Starting from some initial concentration of the dopant C_0 we changed the cholesteric pitch with UV irradiation from high pressure Hg lamp with. Figure 2 shows the pitch length versus the density of energy of UV light irradiation. The length of the pitch increases linearly with the increasing of irradiation dose.

RESULTS AND DISCUSSION

To observe the structural transition we filled the wedge like cells with induced cholesteric mixture C_0=0.6-1%. The characteristic texture at this starting point was fingerprints texture that features λ- and τ- disclinations assembled in χ- disclinations [6]. The irradiation of the cells with UV light induced a structural transition in the thinner part of the cell. Figure 3 shows the coexistence of homeotropic alignment and the fingerprints texture in the wedge-cell. The similar effect occurs in a sandwich like cell. One can see a central spot with homeotropic alignment surrounded by fingerprints textured zones. The homeotropic region is located within the irradiated area. The fingerprints textured zones are out of irradiated region and caused by diffusion of the photo-transformed dopant to this area. Despite a continuous decrease of the dopant concentration along the radius of the irradiated region, the period of the structure changes discontinuously. The step-like change of the fingerprints pitch can be explained taking into account the defects. These defects play the role of boundary walls on which the director is fixed. As a result the cholesteric spiral and the only structure with the integer number of the pitch halves can be shown up in the texture.

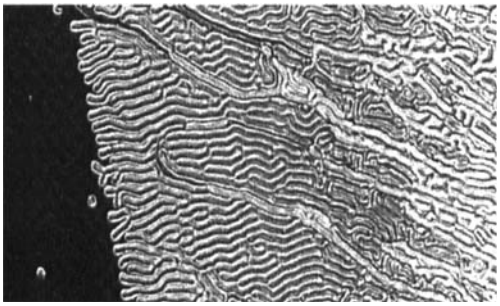

FIGURE 3. Photograph of the wedge cell filled with induced cholesteric mixture after UV irradiation. Cell substrates were treated to provide a homeotropic alignment, magnification x100.

We measured the threshold parameters for the structural transition from the twisted textures to homeotropic alignment performing two types of experiments. The first one was studying the critical parameters of the transition under the changes of dopant concentration C_0 without UV irradiation. We made the cells with different dopant concentrations and observed the textures. The data obtained are summarized in Table 1. The

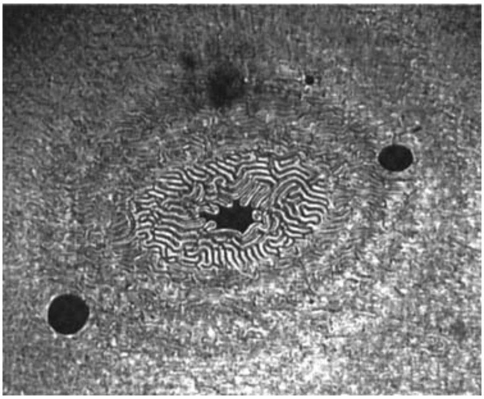

FIGURE 4. Photograph of the sandwich cell filled with induced cholesteric mixture irradiated with UV light through an aluminum mask with a pin hole,

threshold parameter T^{th} was defined as $T^{th} = \frac{2\pi L}{p}$. The sandwich cells with the strong anchoring (W>10^{-3} erg/cm^2) filled with the mixture C_0=0.02-0.1% possesses the homeotropic alignment at T^{th}<4.5. When T^{th}=5 the zones with the fingerprints and homeotropic textures coexist. However, the fingerprint textures are unstable and turn to homeotropic alignment in time. We assigned the critical value T^{th}=5 for the transition from homeotropic to fingerprints texture.

TABLE 1. Parameters of the transition from homeotropic alignment to twisted structure

C_0, %	L, μm	p^{th}, μm	T^{th}
0.22	20	25	5
0.15	30	37	5
0.065	65	86	4.7

The other type of the experiments involved UV irradiation. We prepared the cells with the well-developed fingerprints textures and observed the transition to homeotropic alignment under UV irradiation. The results of this experiment are presented in Table 2. The cells with the strong anchoring feature the threshold parameter T^{th}=3.8-4.2 that is lower than in the case of the transition from homeotropic to fingerprints texture. The experiments confirm that the transition between the fingerprint texture and homeotropic alignment possesses a characteristic threshold. The chiral parameter for the transition from twisted to homeotropic alignment is less than for the homeotropic to the twisted state. This behavior confirms that the orientational transition between chiral and non-chiral structures is the first order with a hysteresis.

TABLE 2. Parameters of the transition from twisted structure to homeotropic alignment under UV irradiation.

C_0, %	L, μm	I, J/cm^2	T^{th}
0.5	30	1.8	3.8
0.8	30	2	3.6
0.8	20	1	4.2
0.3	20	0.6	4.2

CONCLUSIONS

We studied the stability of phases in twisted nematic under the homeotropic boundary conditions and finite anchoring energy. The cholesteric pitch of the induced twisted structure changes discontinuously under the continuous changes of dopant concentration. The transition between homeotropic and twisted configuration of director in the cell with homeotropic boundary conditions is the first order one with the large hysteresis. The chiral parameter for the transition from twisted to homeotropic alignment is less than for the homeotropic to twisted state.

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