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Surface Anchoring and Twisting of Thin Nematic Layers Influenced by Thermal Fluctuations

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Twisting of planar nematic layers is investigated for a finite strength of the surface anchoring by rotating the cell plate. The measurements of the director twisting are performed by measuring the rotation of polarization plane of light. Smooth and jump-wise changes of twisting variations were observed. The calculations similar to those in [1,2] performed for two different model anchoring potentials reveal that for thick samples the both potentials give almost the same results. For thin samples the calculation results for these potentials differ significantly. It is shown that the measurements allow the determination of the anchoring strength and may be used for the reconstruction of the shape of the actual surface anchoring potential.

Keywords: hysteresis; nematics twisting; surface anchoring

INTRODUCTION

The recent investigations of the temperature pitch variations in planar cholesteric layers and of the influence of finite surface anchoring and thermodynamical fluctuations on these variations [1,2] have

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revealed some effects interesting for the physics of liquid crystals (LC) and for the practical LC applications. As it was known quite long ago, the temperature evolution of the cholesteric LC (CLC) structure [3,4] in samples with finite surface anchoring energy may be continuous at some ranges of the temperature with jump-wise changes at the definite temperature points, with a strong hysteresis when changing the temperature in opposite directions [4]. Similar problems arise in the case of nematics if they are twisted due to the action of external forces. Examination of the corresponding problem for nematics is important as for the physics of surface anchoring so for the numerous applications of the nematics because just twisted nematic cells are widely used in LC devices.

Below twisting of thin planar nematic layers is investigated for a finite strength of the surface anchoring forces: (a) for pure nematics by rotating the cell glass plate and (b) for cholesterics close to the helix inversion point by changing the temperature. The measurements of the director twisting are performed by measuring the polarization plane rotation of light transmitted by the sample. The experimental results are interpreted in the framework of the approach developed in Reference [1,2]. The corresponding calculations are performed for two different model anchoring potentials. Some peculiarities of the studied phenomena for the mechanical twist are revealed.

GENERAL EQUATIONS

Examine the behavior of the director distribution in a planar nematic layer of finite thickness and finite strength of anchoring at one of its surfaces and infinite at another (see Fig. 1) under rotation of the cell glass plate. At the process under consideration smooth and jump-wise changes of the director field in the layer are possible. At the beginning we restrict below the analysis of the corresponding variations of the director configuration in the layer by the assumptions that the mechanism of possible jump-wise changes of the director configuration is

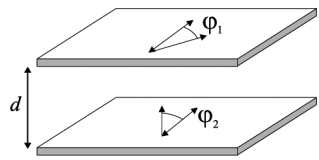

FIGURE 1 Schematic drawing of the layer in the case of unidentical anchoring at the layer surfaces.

connected with overcoming by the director of the anchoring barrier at the layer surface.

Following [1–3] we write the free energy of the layer in the form

$$F(\varphi_0) = W_s(\varphi) + (K_{22}/2d)(\varphi_0 + \varphi)^2, \quad (1)$$

where $W_s(\varphi)$ is the surface anchoring potential, φ is the angle of deviation of the director orientation at the surface of the layer with finite anchoring from the rotating alignment direction (i.e., the easy direction which is rotated together with the plate), φ_0 is the rotation angle of the cell glass plate (so $\varphi_0 + \varphi$ is the resulting angle of the director twisting over the layer thickness), K_{22} is the twist Frank modulus and d is the sample thickness. We assume for the definiteness that the initial undistorted state of the nematic cell corresponds to $\varphi = \varphi_0 = 0$.

Under rotation of the cell glass plate, i.e. increasing of φ_0, the modulus of angle φ (at the beginning of the plate rotation the angle φ is negative) is also smoothly increasing. However for $\varphi_0 > \pi/2$ an abrupt changing of φ may occur. There is even the statement [3] that $\varphi + \varphi_0$, i.e., the director rotation angle, cannot be larger than $\pi/2$. We shall not accept the mentioned limitation on $\varphi + \varphi_0$ and consequently on φ_0 keeping in mind that if even the limitation holds for an unstabilized layer, the layer may be stabilized by the external field (for example, in the case of negative dielectric anisotropy by the field applied perpendicular to the layer surface).

The angle φ may be found from the conditions of minimum of the free energy (1) what gives the following equations for φ:

$$\ldots \partial W_s(\varphi)/\partial\varphi + (K_{22}/d)(\varphi + \varphi_0) = 0 \quad (2)$$

The analysis of the Eq. (2) shows that a smooth changing of the director deviation angle φ is possible while the modulus φ is less than some critical angle φ_c. Upon achieving by φ of the critical value φ_c a jump-like change of the pitch occurs and the transition to a new configuration of the director in the layer differing by one in the number of the director half-turns N in the layer occurs. For example, at infinitely strong anchoring at the both surfaces, in our assumption on stability of the planar texture of the cell under rotation of glass plate, the director twist angle (or the number of half-turns N) is just the same as the angle φ_0 and formally may be arbitrary large. At finite strength of anchoring the maximum director twist angle (and consequently, N) is limited by the strength of anchoring. In reality, of course, even at infinitely strong anchoring the maximum director twist angle is also limited because the corresponding states of the layer with the large

twist angle and consequently with large energy are metastable and there are processes, which result in transitions of the system to the ground state with $N \leq 1$.

In our case of a stabilized layer and a finite strength of anchoring at one of the surfaces said above means that it is possible to reach only some finite value of N_c (angle of director twist in the layer) by rotating the cell glass. Further rotation of the plate does not allow increasing this limiting value N_c and will result only in a sequence of jump-wise (decreasing) and smooth (increasing) variations of N around N_c.

The critical angle φ_c is determined by the solution of Eq. (2), which also satisfies the following relation

$$\partial^2 W_s(\varphi)/\partial^2\varphi + K_{22}/d = 0. \tag{3}$$

As it is known [1,2] the value of critical angle in the general case is dependent on the shape of anchoring potential and the anchoring strength at both surfaces. So the explicit expressions for φ_c shall be given below for each model potential used in calculations.

The value of the cell glass plate rotation angle at the jump point φ_{0c} is determined by the expression

$$\ldots \varphi_{0c} = [\partial W_s(\varphi)/\partial\varphi]_{\varphi=\varphi c}/(K_{22}/d) - \varphi_c. \tag{4}$$

The angle between alignment direction and director just after the jump φ_j is determined by the solution of the following equation

$$\partial W_s(\varphi)/\partial\varphi + (K_{22}/d)[\varphi + \varphi_{0c} - \pi] = 0. \tag{5}$$

As it was shown [1,2] the variations of the director twist (pitch) in the layer and, in particular, the hysteresis are determined by the dimensionless parameter $S_d = K_{22}/Wd$, where W is the depth of the anchoring potential. This behavior is rather universal because it is not directly dependent on the sample thickness. It means that for every specific form of the anchoring potential expressions (1–5) may be transformed to the form, which includes the parameters of the problem d, K_{22}, W only in the combination, which reduces to the dimensionless parameter S_d.

At the next section the given above general expressions will be applied to the specific model anchoring potentials.

MODEL ANCHORING POTENTIALS

To obtain some qualitative predictions one has to assume a specific form of the anchoring potential. We shall use below very popular

Rapini-Papoular (R-P) anchoring model potential [3,5]

$$W_s(\varphi) = -(W/2)\cos^2\varphi, \tag{6}$$

for which the critical angle $\varphi_c = \pi/4$ for an identical anchoring at the both surfaces of the layer.

The performed analysis [1,2] shows that essential features of the director temperature variations are directly dependent on the shape of anchoring potential. It is quite naturally for our problem to perform similar calculations for a potential differing from the Rapini-Papoular model anchoring potential.

The second used here model potential (called below B-potential) is given by the expression (see Fig. 2)

$$W_s(\varphi) = -W\cos^2\varphi/2 + W/2, \quad \text{if } -\pi/2 < \varphi < \pi/2, \tag{7}$$

and continued periodically to $|\varphi| > \pi/2$, according to the relation $W_s(\varphi) = W_s(\varphi - \pi)$. The behavior of the potential (7) is similar to the case of the R-P potential for small φ, however, it differs essentially from R-P close to $\varphi = \pi/2$. In particular, for the case of an identical anchoring at the both surfaces the critical angle φ_c for this potential does not depend on the strength of anchoring (parameter S_d) and is equal to $\pi/2$.

Because there are too many parameters in the general case of the anchoring differing at the two surfaces we shall present below in

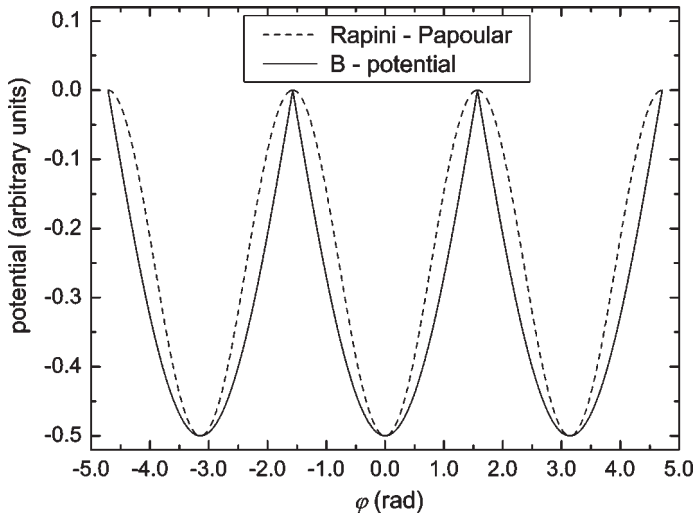

FIGURE 2 Rapini-Papoular (R-P) and B-anchoring potentials.

details a specific case, namely, infinitely strong anchoring at one surface and finite anchoring at the second surface of a layer.

Infinitely Strong Anchoring at One Surface

Let us apply the given above general expressions to the specific case of infinitely strong anchoring at one of the layer surface and finite anchoring at other surface described by the potential $W_s(\varphi)$. The expressions for the free energy given by Eqs. (1,2) and others reduce to the following expressions for R-P-potential.

For the free energy one gets from (2):

$$F(T)/W = [-\cos^2 \varphi + S_d(\varphi + \varphi_0)^2]/2, \tag{8}$$

where the dimensionless parameter $S_d = K_{22}/Wd$ was already mentioned above.

The angle of director deviation φ from the rotating alignment direction is determined by the following expression

$$\sin 2\varphi + 2\ S_d(\varphi + \varphi_0) = 0 \tag{9}$$

and the critical angle φ_c is determined by the relationship

$$\cos 2\varphi_c + S_d = 0, \tag{10}$$

i.e.,

$$\varphi_c = [\arccos(-S_d)]/2.$$

The Eq. (10) and calculations show that the critical angle φ_c is dependent on the parameter S_d contrary to the case of identical anchoring at the both surfaces [1,2].

The value of the cell glass plate rotation angle φ_{0c} corresponding to the jump point is determined from (10) by the following formula

$$\varphi_{0c} = \varphi_c + (\sin 2\varphi_c)/2S_d \tag{11}$$

Solution of Eq. (10) exists only for $S_d < 1$. It means that for weak anchoring (or thin layers) jump-wise changes of director configuration in the layer may be absent. However it should be mentioned that because the Eq. (10) for critical angle was obtained for Rapini-Papoular anchoring model potential the last statement is model dependent. So, experimental investigations of the jump-wise changes of director configuration in the layer may be used for determination of the real shape of the anchoring potential and its deviations from Rapini-Papoular anchoring model potential.

The value of φ_j, i.e., the angle between alignment direction and director just after the jump, is determined by the solution of the following equation:

$$\ldots \sin 2\varphi_j + 2S_d[\varphi_j - [\text{arc cos}(-S_d)]/2 + (\sin 2\varphi_c)/2S_d - \pi] = 0, \quad (12)$$

The expressions for the free energy given by Eqs. (1,2) and following from them formulas reduce to the following expressions for B-potential.

For the free energy one gets from (2):

$$F(T)/W = [-2\cos^2(\varphi/2) + 1 + S_d(\varphi + \varphi_0)^2]/2. \quad (13)$$

The angle of director deviation φ is determined by the following expressions

$$\sin\varphi + 2S_d(\varphi + \varphi_0) = 0 \quad (14)$$

The critical angle φ_c for B-potential remains to be $\pi/2$ as in the case of identical anchoring at both surfaces.

The value of the cell glass plate rotation angle at the jump point φ_{0c} is determined from (14) by the following formula

$$\varphi_0(T_c) = \pi/2 + 1\ (2S_d) \quad (15)$$

The value of φ_j, i.e., the angle between alignment direction and director just after the jump, is determined by the solution of the following equation:

$$\ldots \sin\varphi_j + 2S_d[\varphi_j + 1/(2S_d) - \pi/2] = 0, \quad (16)$$

The given above values of the angles of the director deviation from the rotating alignment direction just before and after the jump and the corresponding value of the cell glass plate rotation angle may be used for the solution of the dynamical problem related to the pitch jump because these values completely determine the initial and final state in the problem to be solved (see [7]).

CALCULATION RESULTS

Below are given the calculation results for the case of infinitely strong anchoring at one of the layer surface and finite anchoring at other surface described by the potential $W_s(\varphi)$ of two shapes, R-P and B-potential.

At Figures 3, 4 the director twist angle versus plate rotation angle is presented. The Figures 3, 4 reveal qualitative difference for these two

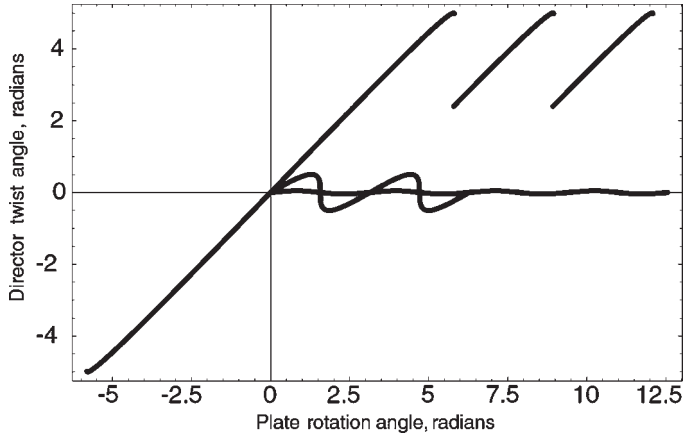

FIGURE 3 Director twist angle versus the plate rotation angle for R-P-potential ($S_d = 0.1, 1, 10$).

potentials in the distribution of twisting of the director in the layer caused by a plate rotation. For a strong anchoring (small S_d) the director twist angle versus plate rotation angle are almost the same for both the R-P and B-potentials. However for a weak anchoring (large S_d) there is a difference between R-P and B-potentials (compare Figs. 3, 4). For the R-P-potential the changes of the director twist

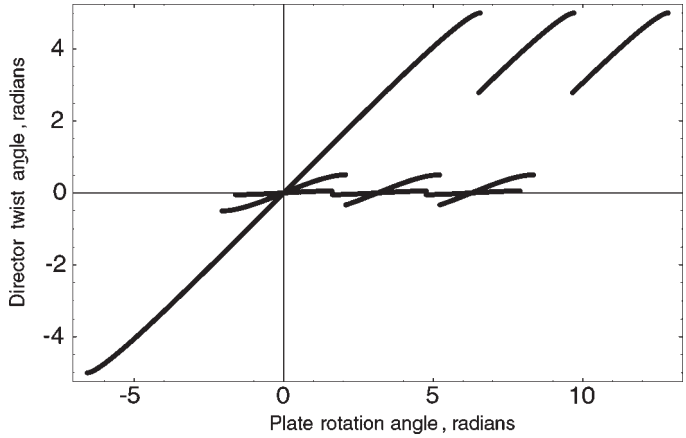

FIGURE 4 Director twist angle versus the plate rotation angle for B-potential ($S_d = 0.1, 1, 10$).

angle under the plate rotation at any angle may be completely smooth for a weak anchoring (large S_d) and include jump-wise changes for strong anchoring (small S_d) similar to those ones for B-potential. In the case of B-potential the jump-wise changes of the director twist angle are present at any strength of anchoring while for the R-P-potential at the large $S_d > 1$ the changes of the director twist angle under the plate rotation at any angle are smooth. It means that for B-potential a bistability reveals itself at any strength of anchoring while for the R-P-potential it appears only for a sufficiently strong anchoring.

The Figures 3, 4 show also that for the B-potential for any strength of the anchoring and for R-P-potential for sufficiently strong anchoring ($S_d < 1$) hysteresis of the jump point for opposite direction of the plate rotation exists. If one denotes by φ_{0j}^{+} and φ_{0j}^{-} the plate rotation angle corresponding to the director twist jump for the plate rotation in the initial and the opposite direction, respectively, the corresponding hysteresis in the value of φ_0 is equal to $\varphi_{0j}^{+} - \varphi_{0j}^{-} = 1/S_d$ for B-potential and $\varphi_{0j}^{+} - \varphi_{0j}^{-} = 2\varphi_c + (\sin 2\varphi_c)/S_d - \pi$ for R-P-potentiaĩ. Because for R-P-potential $\pi/4 < \varphi_c < \pi/2$ the hysteresis for it is less than the hysteresis for B-potential at the same S_d and reduces to zero for $S_d = 1$. The absence of the hysteresis for R-P-potential at weak anchoring ($S_d > 1$) constitutes a qualitative difference between R-P and B-potentials.

Note, that presented above discussion relates to the cases when the thermal fluctuations may be neglected, i.e., for sufficiently thin samples [2]. How the thermal fluctuations influence the presented above picture will be discussed in the next section.

DIRECTOR TWISTING INFLUENCED BY FLUCTUATIONS

The expressions given in the previous section connect thermodynamic equilibrium values of the parameters. However, close to the points of the director twist angle jumps the thermodynamic fluctuations in the bulk of layer may be essential. It means that the fluctuations can change the position of the transition points. For example, the hysteresis can decrease and even completely disappear because of the fluctuations. In terms of the height of the surface anchoring potential between two configurations related to the transition, it means that, if in the previous section we assume that at the jump point the height of the barrier B has to be equal to zero for occurring the transition, in a model taking into account fluctuations [2] the transition may occur at $B \neq 0$, but differing from 0 by qk_BT, where T is the temperature, k_B the Boltzman constant, and q some phenomenological coefficient to be

determined experimentally. That means that the thermodynamic fluctuations of the energy of the LC make possible for the system to overcome the barrier, even if the equilibrium energy of the system is below the barrier. The calculated in the previous section transition (jump) points were determined by the shape of anchoring potential and by the value of dimensionless parameter S_d and were not directly dependent on the layer thickness. On the other hand, the thermal fluctuations result in a direct dependence of the jump points on the sample thickness in direct analogy with the temperature variations of the pitch in planar layers of chiral LC [2].

This dependence of the jump points on the sample thickness is connected with the fact that the anchoring energy is proportional to the area of the layer surface and does not depend on the thickness of the layer. In contrast, the bulk fluctuations of the energy E_f, are proportional to the square root of the volume [6], i.e., the ratio of E_f to the surface anchoring energy for a fixed cell area is proportional to the square root of the cell thickness d. It is why for some thickness of the layer the fluctuations of energy may exceed the surface anchoring barrier and just beginning from this thickness the hysteresis disappears. At smaller thickness the hysteresis remains, however, it decreases due to the fluctuations.

To estimate the thickness which corresponds to the disappearance of the hysteresis we performed calculations of the surface anchoring barrier for the plate rotation angle $\varphi_0 = \pi/2$ at which the free energies of the two director configurations under consideration are equal. To perform these calculations one needs to know the director twist angle at the plate rotation angle $\varphi_0 = \pi/2$. So, at Figures 5, 6 calculated depending on the S_d of value the mentioned angle. Whereas for B-potential the equilibrium value of the director twist angle at the plate rotation angle $\varphi_0 = \pi/2$ is dependent on S_d for all values of this parameter, a similar dependence for RP potential holds only for $S_d < 1$ and the director twist angle is identically zero for $S_d > 1$ at the plate rotation angle $\varphi_0 = \pi/2$. It means that for R-P-potential the hysteresis is absent independently of the fluctuations if $S_d > 1$. This independence of the director twist angle on the value of S_d at $S_d > 1$ (or on the layer thickness at small thicknesses) and correspondingly absence of the hysteresis looks as a some artifact of the specific shape of R-P-potential at φ close to $\pi/2$ and consequently seems to be not very convincing from the physical point of view. For B-potential the hysteresis is present for all values of S_d if it is not suppressed by the fluctuations. So, experimental studies of the hysteresis in the pitch jumps may be used for distinguishing of the anchoring potential shapes.

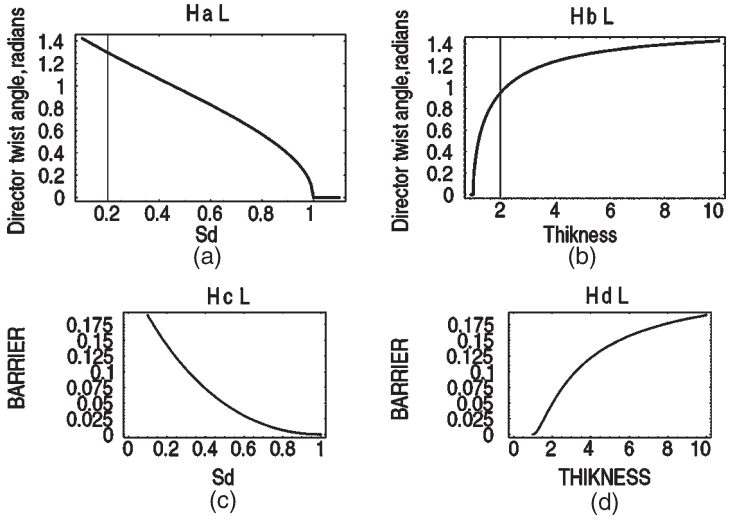

FIGURE 5 Director twist angle at the plate rotation angle $\pi/2$ versus S_d (a), the layer thickness (b), and barrier between two possible ground state director configurations versus S_d (c), the layer thickness (d) for R-P-potential.

EXPERIMENTAL

Sample Preparation

To check the theory presented above we prepared the measuring cell consisted of two glass plates. The plates, after careful cleaning, were unidirectional rubbed on a filter paper or velvet patch. This procedure secured a homogeneous, planar orientation of the nematic layer. The anchoring energy depended on the rubbing intensity and on the kind of material used for rubbing. When strong anchoring was needed, the plate was rubbed strongly or covered with a thin layer of polyvinyl alcohol (PVA) before rubbing. Gentle rubbing gave rather weak anchoring. The experiments were performed with the liquid crystal 1-(trans-4-hexyloxycyclohexyl)-4-isothiocyanatobenzene (abbreviated 6CHBT here). The nematic phase in this material has a large temperature range, including room temperature (from 12°C up to 42°C). After introducing the nematic liquid crystal 6CHBT between the plates, one of them has been rotated by an angle φ_o. This rotation caused the twisting of the nematic director within the sample by an angle θ.

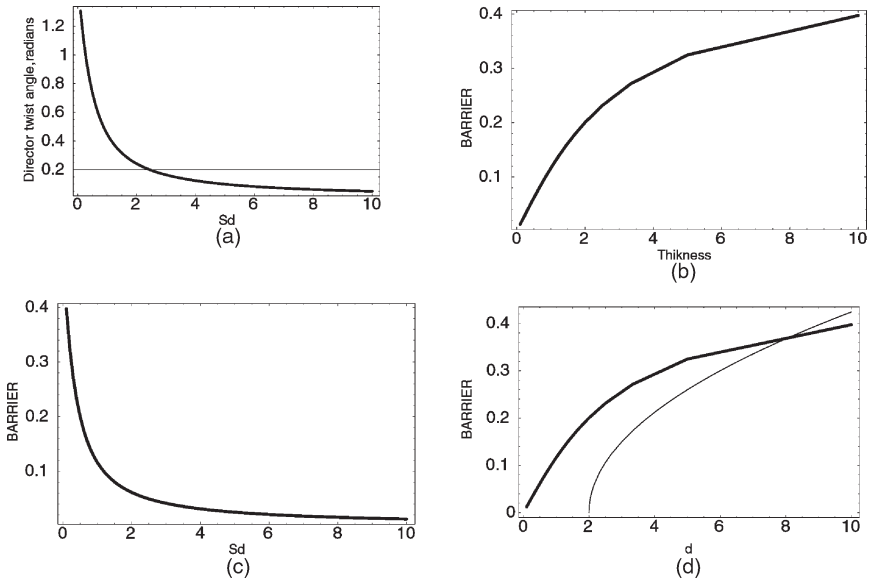

FIGURE 6 Director twist angle at the plate rotation angle $\pi/2$ versus S_d (a) and the barrier between two possible ground state director configurations versus the layer thickness (b), S_d (c) and determination of the layer thickness above which the hysteresis disappears (d), for B-potential. The thin line at Figure 6d presents the fluctuation energy versus thickness (calculated with the same phenomenological constants as in [2]). The intersection point of this curve with the bold curve for the barrier determines the critical thickness above which the hysteresis is absent.

Method of Measurement

As was mentioned above the twisting at the surface exists in a very thin layer, few molecular dimensions thick, i.e., much less than the wavelength of the visible light. Thus, the measurement of this twisting using optical method is hardly possible. On the other hand, such a thin layer does not influence the propagation of light. However, the optical methods may be effective for measurement of the twisting in the bulk θ, and consequently, the angle of director deviation from the alignment direction at the surface φ can be determined as $\varphi = \theta - \varphi_o$ if one assumes that the strength of anchoring is infinite at one of the layer surfaces. Note, that because the plate rotation angle φ_0 always exceeds the director twist angle θ the angles φ and φ_o are always of an opposite sign.

As the measurements show the twist in the bulk is not large – it does not exceed 180° in a sample several μm thick. Therefore we can

assume that the polarization plane of light propagating perpendicularly to the nematic director adiabatically follows the local optic axis (director), similarly as in the twisted stack of thin crystalline plates or in the Schadt-Helfrich cell. In general, the light after passing such a stack of plates or twisted nematic cell is elliptically polarized. Its polarization is linear in two cases only: when the polarization plane on entering the sample is either parallel or perpendicular to the local optic axis of the first layer. Only in these two cases the light ray does not split into two rays and propagates as either the extraordinary or ordinary ray, respectively. Thus, only in the two cases mentioned above it is possible to obtain extinction of the light using a linear polarizer placed behind the sample. The polarization direction of the polarizer determines the direction of the local optic axis in the first layer of the nematic liquid crystal, and the polarization direction of the analyzer – in the last layer. If the anchoring is finite and identical at the layer surfaces the both polarization directions are different from the rubbing direction by the director deviation angle from the alignment direction at the surface φ.

The described method allows for determination of φ with an uncertainity of a constant value equal to π. The twisting of director by the angle θ and $\theta \pm \pi$, $\theta \pm 2\pi$ etc. are undistinguishable. However, when the measurement starts at $\varphi = \varphi_o = 0$, the angle φ can be determined as function of φ_o univocally, as long the φ-changes are continuous. The jump in φ, when exists, appears as a disinclination line separating areas, where the director twist differs by π. The disinclination line presents a kind of director kink or Néel wall. A typical example of the disinclination line, as observed under polarizing microscope, is shown in Figure 7.

The measuring procedure is as follows:

1) The sample is placed on the rotating table of the polarizing microscope between crossed polarizers. The rubbing directions on both glass plates are parallel to the polarizer direction. There is no twist within the sample and the field of view is black. The bottom glass plate, prepared for rather weak anchoring, is fixed to the table. The upper plate prepared to get strong anchoring is fixed to the microscope objective.
2) The lower glass plate is turned by an angle φ_o. The field of view gets bright. The extinction can be, in general, achieved after several adjustments of the position of both the polarizer and analyzer. The final change in the position of the polarizer determines the bottom φ angle (or via the relation $\varphi = \theta - \varphi_o$ the director twist angle at the layer thickness θ if the anchoring at the second surface is

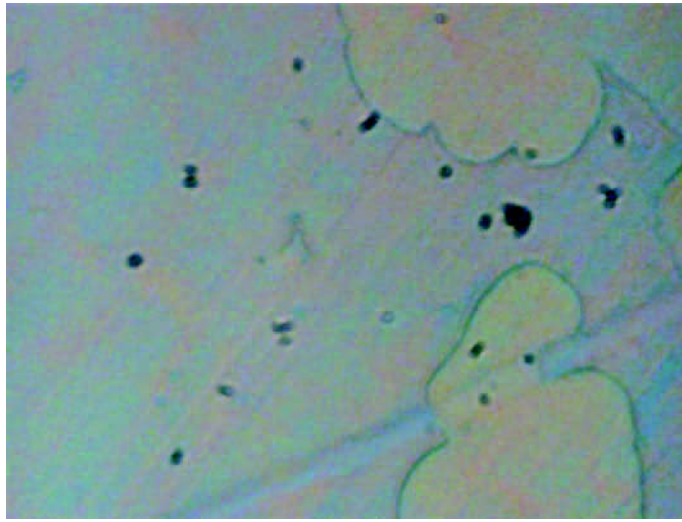

FIGURE 7 Disinclination lines separating areas with director twist differing by 180°. Magnification 90×, crossed polars, walls twist 180°.

infinitely strong). The position of analyzer, respectively, reveals the director orientation close to the upper surface and, by comparison with the rubbing direction allows determining the φ angle at the upper glass plate. In the case of strong anchoring at the upper plate, the analyzer direction is exactly perpendicular to the rubbing direction and the adjustment of analyzer is not necessary.

RESULTS OF EXPERIMENTS

To check the measuring method described above, we prepared a cell, which both walls gave strong anchoring. In this case one can expect that the polarizer rotation is the same as the walls twist. Figure 8 demonstrates that it is really the case. The rotation of polarizer is identical with the glass plate rotation in the whole range of measured angles.

Figure 8 demonstrates also that a sudden jump of director position occurs when the walls rotation φ_o approaches 180°. For some rotation angles two areas may simultaneously exist, where director twist differs by 180°. These areas are separated by a disinclination wall (see Fig. 7). On turning the plate back a large hysteresis of the director twist is observed. For rotation in this direction the jump by 180° takes place close to 0 deg.

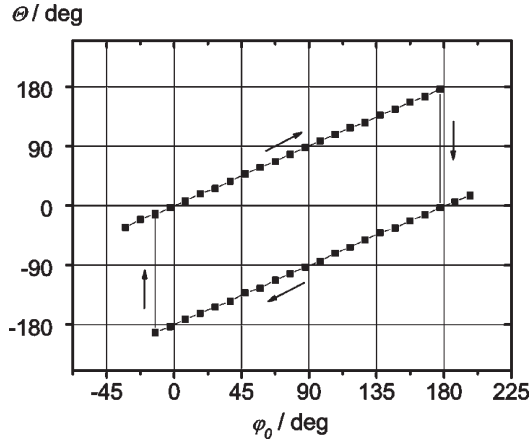

FIGURE 8 Director twist as function of the wall twist in the case of strong anchoring on both walls. Sample thickness 20.5 μm.

In the case of weak anchoring on one surface, the wall rotation angle φ_o differs from the director twist in the layer θ. A typical result of measurement is shown in Figure 9. In this case, as well, a linear dependence θ on φ_o is obtained, however the slope of the straight line is less than 1. It means, the φ angle is nonzero. This result agrees with

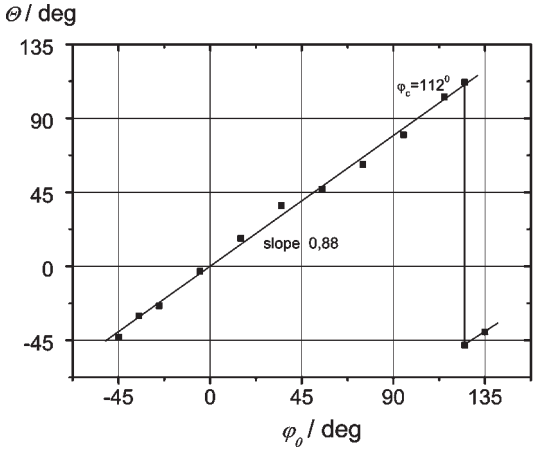

FIGURE 9 Director twist as function of the wall rotation in the case of weak anchoring on one wall and strong anchoring on the other. Sample thickness is 6 μm.

Eqs. (9) and (14), which predict almost linear $\varphi(\varphi_o)$ dependence. The hysteresis of the twist angle occurs as well as in the case of strong anchoring. However, both the jump angle and hysteresis are now smaller (see Fig. 10).

The slope of lines in Figures 9 and 10 can be used for determination of S_d – parameter for each discussed in former chapter model potentials: Rapini - Papoular (RP) and B – potential. The S_d-values calculated for each model are different and these values alone do not allow to decide, which model matches better the experimental results. If, however one takes into account the values of the jump angle the values of φ_{oc} corresponding to jumps suggest that the B-potential can better describe the real situation than the RP potential.

It is evident from Figure 9 that for wall twist angles about 110° and 40° director jumps occur. The jumps are symmetric with respect to the line $\varphi_0 = 90^\circ$, similarly as in the case of strong anchoring (Fig. 8). The Eqs. (9) and (14) demonstrate that S_d is the most important parameter describing the relative contribution of the surface and bulk interactions to the phenomenon of director twisting caused by the walls rotation. The simplest way to adjust this parameter is changing the sample thickness d (the anchoring energy W_s and elastic constant K_{22} are not easy to control).

The role of S_d – parameter was tested in samples of varying thickness. The experiment was performed in conditions of constant other parameters (W_s and K_{22}) which were secured by constant temperature

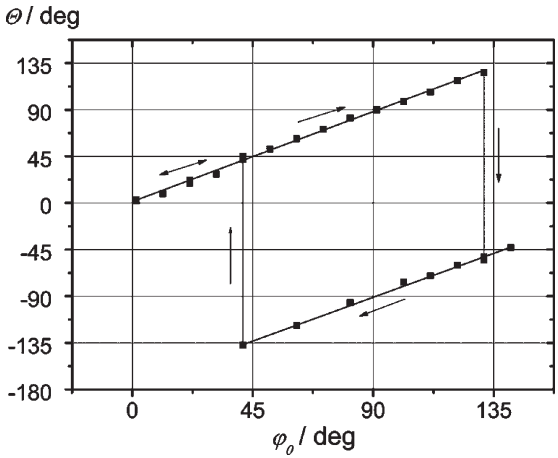

FIGURE 10 Hysteresis of the director twist θ in the case of weak anchoring at one of the walls. Sample thickness is 6 μm.

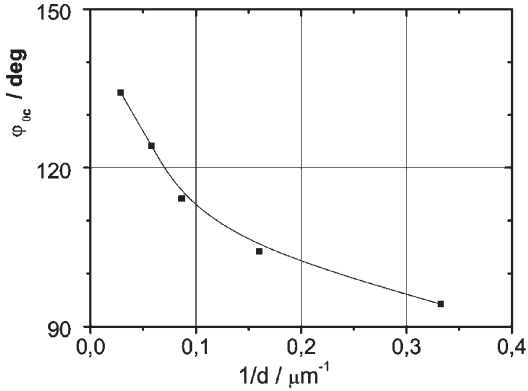

FIGURE 11 Jump angle φ_{oc} as function of the reciprocal of the sample thickness.

and homogeneous surface treatment. The cell of varying thickness was constructed using a flat glass plate and convex lens. The surfaces of both the lens and the plate, after careful cleaning in detergent solution and organic solvents, were dried and unidirectional rubbed on a filtering paper. The lens was fixed to the microscope objective, and the plate to the rotary stage. The rotation of stage caused the rotation of plate with respect to the lens. The director twist was measured using the optical method described above.

The experiment showed that in conditions of strong anchoring the director twist θ is the same as the plate rotation φ_o. This observation is valid in the whole range of the sample thickness (in our experiment varying from 0 to about 100 μm). On the other hand, the critical angle for of the plate rotation for the director jump φ_{oc} depends strongly on the thickness d, thus on the S_d – parameter. This dependence is shown in Figure 11. For small S_d- values (large thickness) the critical angle φ_{oc} tends to 180° and for large S_d (small thickness) φ_{oc} is close to 90°. This behavior agrees with theoretical predictions (Figs. 3 and 4) for both model potentials. The results of the last described experiment confirm the presented theory, however they do not allow concluding which model better describes the real situation.

CONCLUSION

The presented above results show that the variations of the twisted configuration under rotation of the easy direction in a plane nematic layers with a finite strength of surface anchoring as well as the

temperature variations of the pitch configuration in a plane cholestericlayers with a finite strength of surface anchoring [1,2] are directly dependent on the shape and the strength (dimensionless parameter S_d) of anchoring potential. The corresponding variations are dependent also on the director thermal fluctuations. For example, the narrowing of the hysteresis loop observed for a weak anchoring (Fig. 10), which is definitely connected with the increasing of S_d, may be, also partially due to the director thermal fluctuations. It is why the studies of these phenomena allow in the simplest case to determine anchoring strength and in general case not only to determine the anchoring strength but also to reconstruct the shape of anchoring potential. The obtained above results are the first steps in studying of the hysteresis phenomena accompanying the mentioned jumps of the pitch and the bistability, which are of the great application value. In particular, these results may be considered also as a starting point for studying of the dynamics of the director configuration transformation at finite surface anchoring.

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