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Non-Singular Walls in Cano-Grandjean Wedge

DINA V. SHMELIOVA[1] AND
VLADIMIR A. BELYAKOV[2]

[1]Moscow State University of Instrument Engineering & Computer Science, Moscow, Russia
[2]L.D. Landau Institute for Theoretical Physics, Moscow, Russia

This work is dedicated to experimental investigations of a chiral liquid crystal (CLC) director distribution in a wedge shape cell at weak surface anchoring. For the first time Cano-Grandjean structure for substrates treated by photo alignment technique for different strength of surface anchoring is investigated. The results are compared with theoretical predictions for two models of surface anchoring potential.

Keywords Cano-Grandjean wedge; nonsingular walls; weak anchoring

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I. Introduction

Formation of Cano-Grandjean lines structure in wedge cells filled with cholesteric liquid crystals (CLC) is well studied both experimentally and theoretically [1,2]. It was established that for strong anchoring surfaces these lines represented singular defect π and 2π walls. The latter were observed only for relatively long pitches p (more than some micrometers).

Recently, such structure was considered for a case of weak anchoring surfaces [3–5]. The case of strong anchoring was investigated in [6]. The theory [3] predicts that for a sufficiently short pitch CLC the well known defect lines separating the wedge area differing by the number of director half turns N at the wedge thickness may be replaced by nonsingular walls. The term "weak surface anchoring" really is related to the large values of the dimensionless parameter

$$S_p = \frac{K_{22}}{W \cdot d} \tag{1}$$

where K_{22} is the elastic twist modulus, d is the layer thickness and W is the depth of the surface anchoring potential. So, at any strength of the anchoring a sufficiently thin part of a wedge (small d) insures the conditions of "weak surface anchoring" and one may await appearance of nonsingular walls.

Address correspondence to Vladimir A. Belyakov, L.D. Landau Institute for Theoretical Physics, Kosygin str. 2, Moscow 117334, Russia. Tel.: 7-095-137-32-44; Fax: 7-095-2077; E-mail: bel@landau.ac.ru

The details of director distributions in walls are dependent on the shape and strength of the surface anchoring potential [5].

In particular, for the well known Rapini-Papoular potential:

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

the absence of the first lines is expected.

At the same time for alternative B-potential [5]:

$$W_s(\varphi) = -(W)(\cos^2(\varphi/2) - 1/2), \quad -\pi/2 < \varphi < \pi/2 \tag{3}$$

the first lines should be nonsingular.

The results of calculation for dependences of the pitch on the dimensionless local wedge thickness (d/p) in a wedge gap for two models of surface anchoring potential are presented in Figures 1a and 1b.

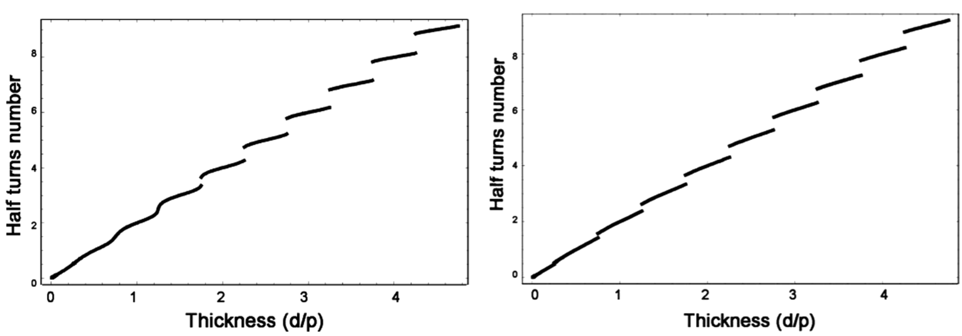
Estimation made in accordance with (1) for typical values of anchoring strength $W = 10^{-6}–10^{-5}\,J/m^2$ and elastic module $K_{22} \approx 5 * 10^{-12}\,N$ showed that the local thickness must be in the range $d = 0{,}5–5\,\mu m$ in order to realize weak anchoring effects.

Due to a small thickness of the walls in a wedge there are problems in the distinguishing of singular and non-singular walls.

To distinguish the images of singular and non-singular walls in a wedge one may take into account the different intensity profile of these walls and its changes under variations of the observation conditions, for example, under the variations of wave length of light used for the wall imaging.

One may expect that under small variations of wave length the image of a singular wall (intensity profile) remains almost unchanged, while for a non-singular wall the profile may be qualitatively changed, especially if the wave length is close to the CLC pitch (see Fig. 2).

If the wave length of light used for the wall imaging is much shorter than the pitch ($p >> \lambda$) the Mauguin limit is applicable for description of light propagation in CLC and the polarization measurement may be useful for identification of singular and non singular walls. In the region of a non-singular wall linearly polarized



(a) (b)

Figure 1. Variation of the half-turn number in the wedge versus the local wedge thickness (d/p) for R-P-potential (a) and B-potential (b) for $K_{22}/(W \cdot p) = 1.5$.

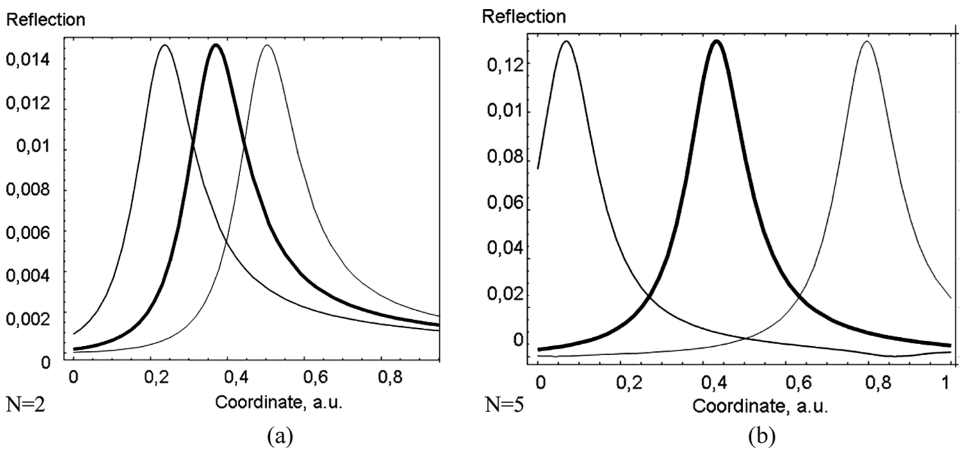


Figure 2. Reflection coefficients of diffracting circular polarized light inside a nonsingular wall versus the coordinate across the wall for several walls numerated by N. The bold line $\lambda = Po$, the thin line $\lambda' = Po/(1+k)$, the line of an intermediate thickness $\lambda'' = Po/(1-k)$, $k = 0.2$) (Dielectric anisotropy $\delta = 0.05$).

light with the polarization direction coinciding with the director (or perpendicular to it) at the entrance surface remains linearly polarized at the exit surface. However the polarization direction rotates continuously following locally to the director at propagation of light through the wall. In particular, it means that the position of a region corresponding to the maximal intensity of the transmitted uncollimated light will move from one edge of the wall to another one at rotation of the analyzer at the exit weakly anchoring surface.

For a singular wall one has to expect nonregular variations of the polarization direction at the exit surface with the wall thickness and some degree of light beam depolarization.

II. Experimental

Method of polarization microscopy was used to investigate experimentally lines in Cano-Grandjean (C–G) wedge for different strength of surface anchoring.

CLC sample with short pitch ($p = 430$ nm for $T = 27°C$) was prepared by adding of 20% Cholesteryl propionate to 80% ZhK mixture 440 (NIOPiK), $K_{22} = 7.2 * 10^{-12}$ N [7]. CLC with short pitch provides realization of weak anchoring effects and correct observation of C-G structure in visible light. We used two technique of photoalignment (PA) treatment. Standard procedure includes *spincoating by Azo-dye solution – heating – illumination*; to decrease the value of anchoring strength another procedure *spincoating by Azo-dye solution – heating – spincoating by pure DMFa – heating – illumination* was used, it provided $W = 5 * 10^{-6} \ldots 1{,}5\ 10^{-5}\ J/m^2$ for exposed time $\tau_{exp} = 1.20$ min as reported in [8]. Work sample was confined between two substrates:

– A top substrate with weak anchoring represents a thin (0.17 mm) glass plate covered by photosensitive film via spincoating of 0.5% Azo-dye in DMFa (NIOPiK), and exposed by polarized UV light ($\lambda = 365$ nm, $\tau_{exp} = 3.50$ min, UV power $= 10\ W/m^2$). Formula of azo-dye can be found in [8].

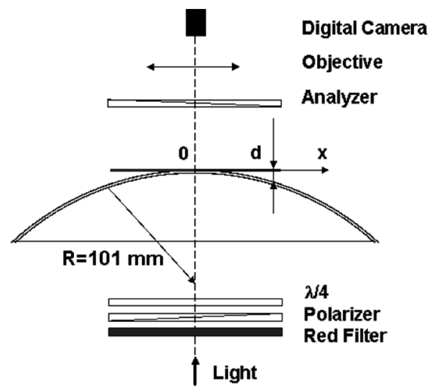


Figure 3. Scheme of the experiment and geometry.

– A bottom substrate with strong anchoring represents a glass spherical lens (Corning®, USA) covered by bakelite solution in ethanol and rubbed.

In finale, orientation of CLC on both substrates was planar. For comparison of results with the case of strong anchoring the cell with two rubbed surfaces was made.

The general scheme of experiment and geometry are shown in Figure 3.

A phase quarter-wave plate was used for creation of left/right circular polarization of light. It was assumed that nonsingular lines would be almost invisible for circular polarization opposite to director rotation whereas a structure of singular lines will be insensitive to sign of light polarization (because the core of singular line scatters light of either polarization).

III. Results and Discussion

The example of C–G structure at weak anchoring (standard procedure) is shown in Figure 4. The most contrast images were obtained in crossed polarizers. The lines are also visible (with a worthier contrast) in the absence of polarizers. The pronounced difference in images was observed at different circular polarizations. At the left polarization corresponding to the sign of a director rotation the image is analogous to that at usage of crossed polarizers. Contrary to it the contrast of images was very poor for the Sectors II and IV of the Figure 4. It is of importance that the first lines are hardly seen in all cases and become practically invisible at right circular polarization of light. It can be explained by very small width of the lines which is comparable with a local thickness and out of optical microscopic resolution. In a thick part of the wedge the lines are distinct – it can be explained as singular character of lines. However a sharp transition of singular line to nonsingular one was not detected by the used method.

The photometry results (Fig. 4 right) demonstrate dependence of the wall image on the observation conditions what agrees with the theoretical calculations (Fig. 2). However, the experimental space resolution does not allow to show the details of intensity variations inside the wall so the walls at (Fig. 4 left) are presented simple by jumps of the intensity.

Alternative procedure for PA treatment described above brings down a surface anchoring strength. It leads to appearance a lot of distortion in the first C-G lines (see Fig. 5a). Lines of higher order hold the circular shape.

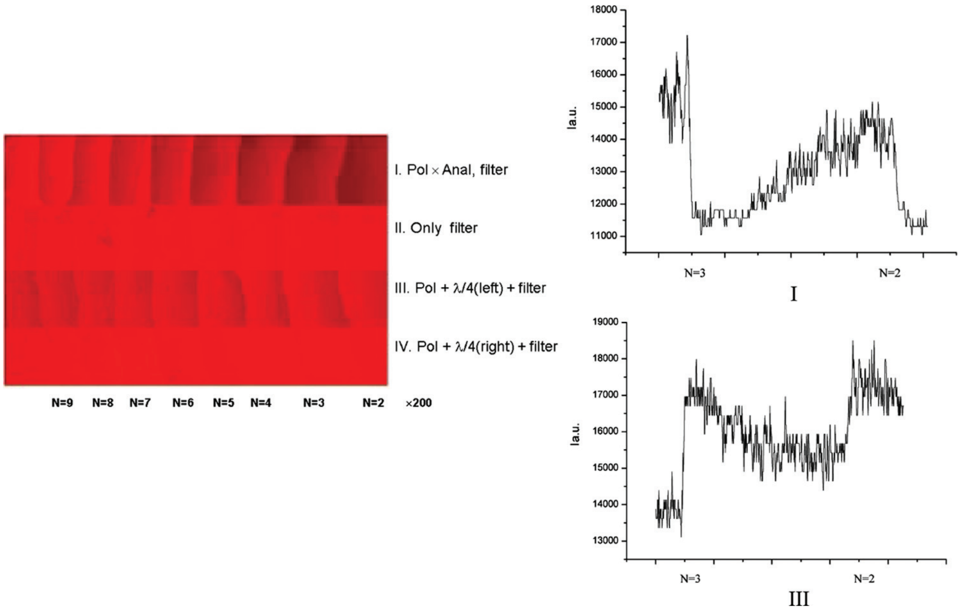
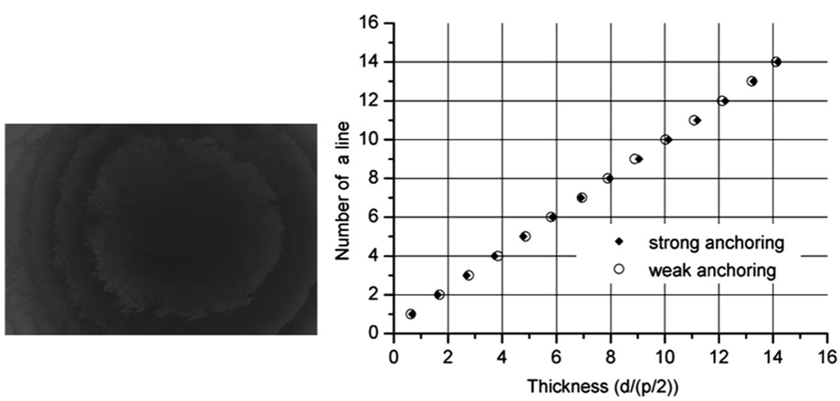


Figure 4. Microscopic images (left) and photometry (right) of Cano-Grandjean lines for planar sample with photoalignment (nonmonolayer of azo-dye – standard technology) by different optical schemes.

It is interesting, that the positions of lines are identical for the samples with different strength of the anchoring and correspond to the case of the strong anchoring (see Fig. 5b).

The availability of the N = 1 – line within the framework [3–5] can be considered as indication on the deviating of the actual surface anchoring potential from the R-P potential.



(a) (b)

Figure 5. Microscopic image of Cano-Grandjean lines for planar sample with photoalignment (monolayer of azo-dye [8], Pol × Anal, filter), ×100 (a) (right part-$\tau_{exp} = 45$ min, left part-$\tau_{exp} = 5$ min). Typical dependence of lines positions for the samples with different strength of the anchoring (b).

IV. Conclusion

1. The first experimental results on Cano-Grandjean structure at weak anchoring are presented.
2. A strong polarization dependence of Cano-Grandjean structure image is demonstrated.
3. The existence of lines for small N numbers ($N = 1, 2, 3$) show that the actual surface anchoring potential differs from Rapini-Papoular surface anchoring potential.
4. The applied technique did not allow distinguish non-singular walls from the singular ones.
5. The further investigations are needed to clarify the structure of Cano-Gradjan lines at weak anchoring. This work is under consideration now.

Acknowledgments

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