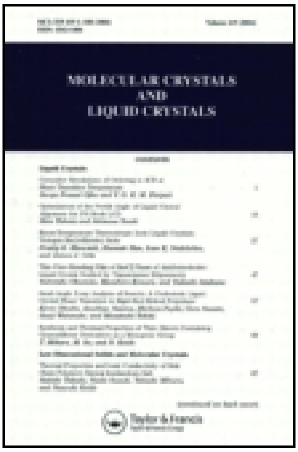

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Director Distribution in Cano-Grandjean Wedge Influenced by Surface Anchoring

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Director Distribution in Cano-Grandjean Wedge Influenced by Surface Anchoring

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Experimental and theoretical studies of the chiral liquid crystal (CLC) director distribution in a wedge shape cell with a weak surface anchoring as well in a planar layer with a gradient of the pitch are performed. The theory predicts that the director distribution in individual Cano-Grandjean zones as well in narrow walls dividing the zones are dependent on the strength and shape of the anchoring potential. The performed calculations for a wedge and a planar layer of variable thickness show that the experimentally distinguishable details of the director distribution in the wedge area between two consequent walls (Cano-Grandjean zone) allow one to obtain information on the shape of the surface anchoring potential and especially favorable for the measurements are several first individual Cano-Grandjean zones. The measurements of the director orientation at the wedge surface with weak surface anchoring versus the coordinate along wedge surface carried out by means of optical polarized transmission spectra were used to reconstruct the director distribution at this surface for the second Cano-Grandjean zone. The relevance of the obtained director distribution to the different model surface anchoring potentials is discussed.

Keywords Cano-Grandjean Wedge; weak surface anchoring; surface anchoring potentials

Introduction

The studies of the shape of actual surface anchoring potential for liquid crystals at various its strength [1–7] are of significant importance, in particular, because the corresponding information may be used for optimization of the numerous LC applications. The reported recently [8] results on observation of very low surface anchoring strength open new options for restoring actual surface anchoring potential [7,9]. The presented below studies at Cano-Grandjean Wedge are targeting at restoration of the actual surface anchoring potential and comparison of the obtained results with those following from the widely used model surface

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anchoring potentials [7,10]. We shall assume that at one wedge surface the anchoring is very strong and at the second one is very weak. It should be noted that the term "weak surface anchoring" really is related to the large values of the dimensionless parameter $S_d = K_{22}/Wd$ (related to $l_p = K_{22}/Wp$), where K_{22} is the elastic twist modulus, p is the CLC pitch, d is the local edge thickness and W is the depth of the surface anchoring potential. So, at any strength of the anchoring a sufficiently thin layer (small d) insures the conditions of "weak surface anchoring". In particular, it will be shown below that the calculations of the local value of pitch in a wedge shape cell with infinitely strong anchoring at one surface and finite anchoring strength at the second one performed for the two sets of model anchoring potentials reveal qualitative difference in the director distributions for the Rapini-Papoular-like [10] and B-like [7] model surface anchoring potentials. So, the calculations results may be useful for an experimental distinguishing of the different shapes of the surface anchoring potential.

General Approach

Let us examine the director distribution in a wedge shape cell with infinitely strong anchoring at one surface and finite anchoring strength at the second one. The director orientation at the limiting sample surface for a wedge shape sample with a finite strength of the surface anchoring at one of its surfaces and infinite anchoring at the other one is determined by the following equation [7]:

$$\partial W_s(\varphi)/\partial\varphi + W(S_d\varphi - 2\pi l_p) = 0, \tag{1}$$

where φ is the angle of the azimuthal director deviation from the alignment (easy) direction at the surfaces with finite anchoring, $W_s(\varphi)$ is the surface anchoring potential, K_{22} is the elastic twist modulus, d is the local wedge thickness.

We performed calculations of the director orientation at the surface with a finite strength of the surface anchoring solving Eq. (1) for the two model anchoring potentials (Rapini-Paupular(R-P) [10] and, so called, B-potential [7]).

The R-P-potential is given by the formula:

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

The B-potential is given by the formula:

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

The period of the B-potential is π i.e. $W_s\ (\varphi + \pi) = W_s(\varphi)$

The Figs 1–4 present the calculated pitch variations in Cano-Grandjean wedge the director orientation at the second Cano-Grandjean zone, respectively. Figures 5, 6 present the calculated director orientation at the surface with finite anchoring for a plane-parallel layer at variations of the layer thickness d. The Fig. 6 demonstrates hysteresis in the director orientation at increasing and decreasing of the layer thickness. As demonstrated by the calculations, at the weak surface anchoring the difference in the director distributions for the Rapini-Papoular-like and B-like model surface anchoring potentials is especially pronounced for a few first Cano-Grandjean zones. It was, in particular, found that for the Rapini-Paupular anchoring potential the several first walls may be absent at all. The first several walls for any shape of the anchoring potentials may be nonsingular, i.e. defectless [7].

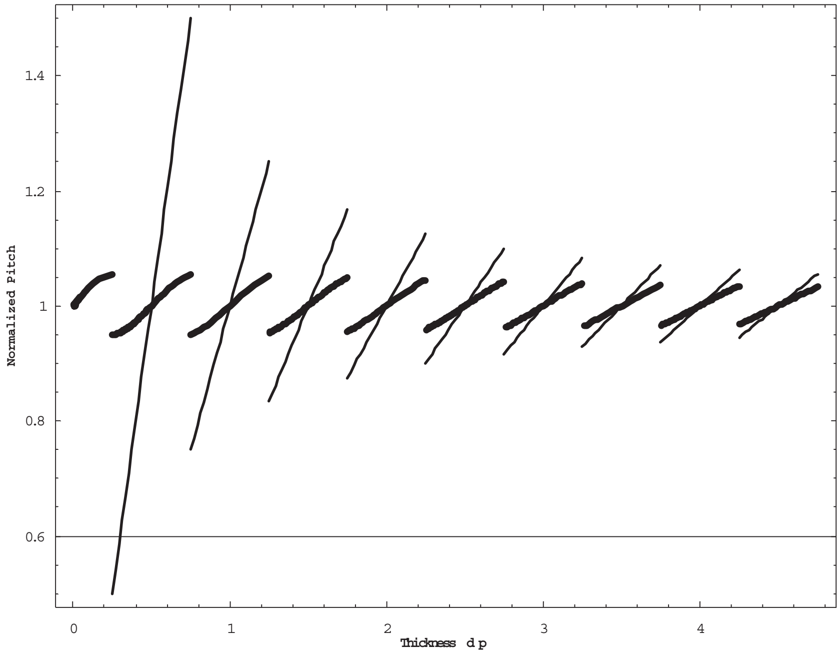


Figure 1. Calculated pitch variations in Cano-Grandjean wedge for model B surface anchoring potential for $l_p = 1.5$ (thin lines relate to infinitely strong surface anchoring; at all figures, except Fig. 8, the dimensionless coordinate (local wedge thickness) and the dimensionless pitch value in the wedge are normalized by the pitch natural value).

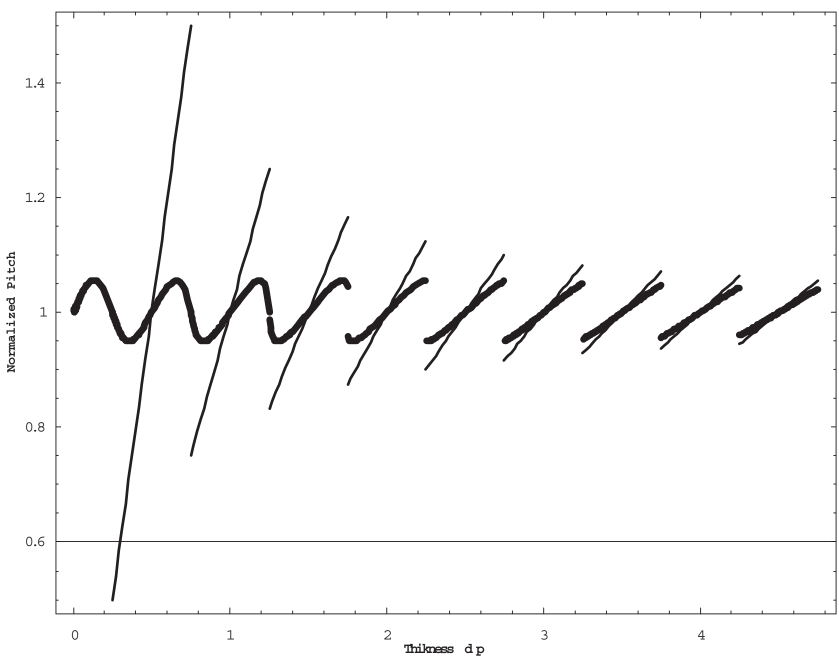


Figure 2. Calculated pitch variations in Cano-Grandjean wedge for model R-P surface anchoring potential for $l_p = 1.5$ (thin lines relate to infinitely strong surface anchoring).

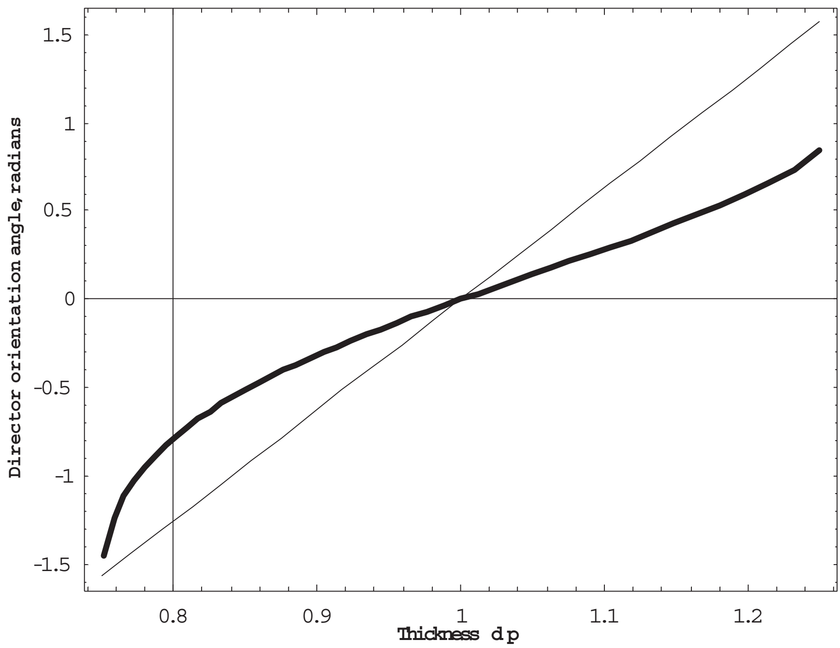


Figure 3. Calculated director orientation in the second Cano-Grandjean zone at the wedge surface for the model R-P surface anchoring potential for $l_p = 0.85$ (thin line relates to infinitely weak surface anchoring).

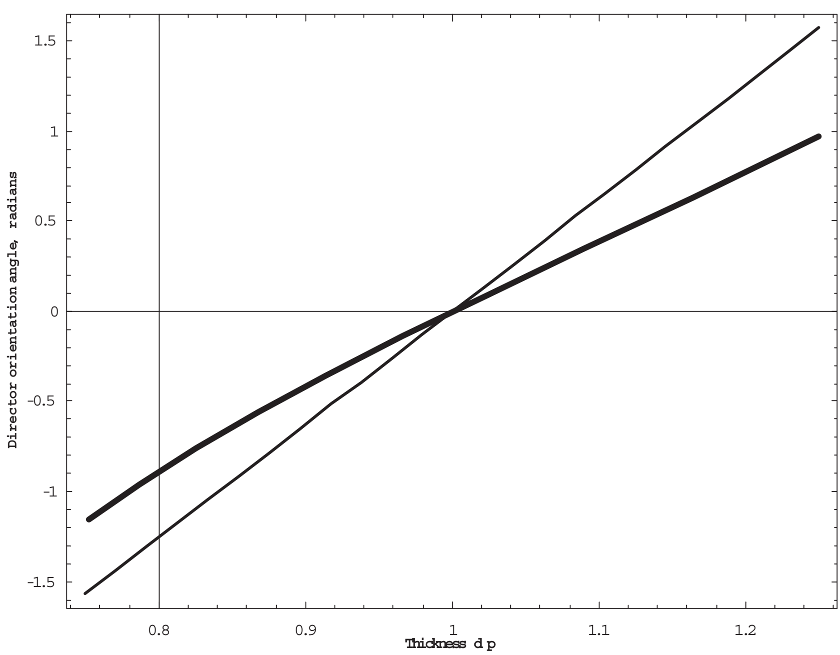


Figure 4. Calculated director orientation in the second Cano-Grandjean zone at the wedge surface for the model B surface anchoring potential for $l_p = 0.85$ (thin line relates to zero surface anchoring).

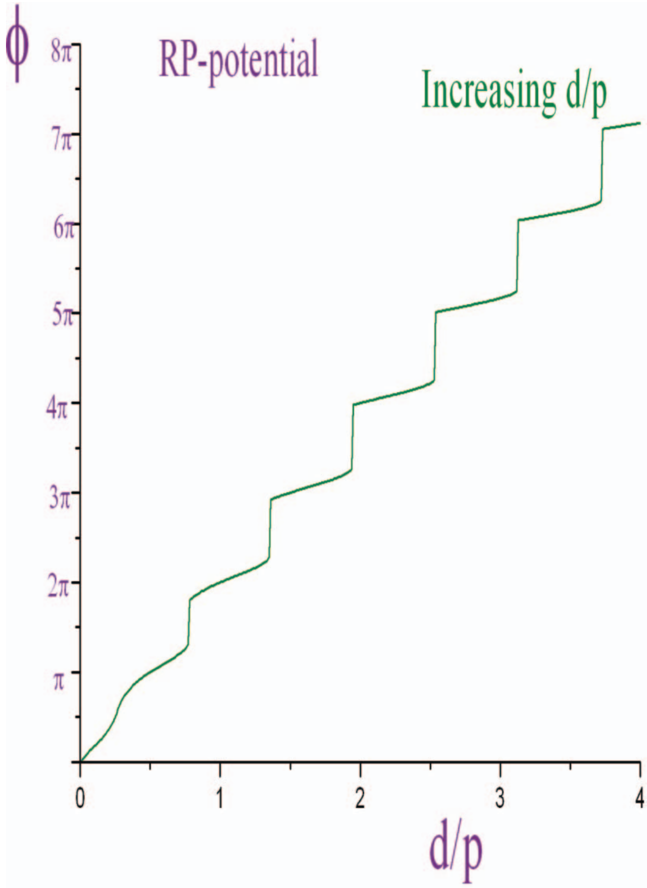


Figure 5. Calculated director orientation at the layer surface with weak anchoring ($l_p = 1$) for R-P model anchoring potential versus the layer thickness increase.

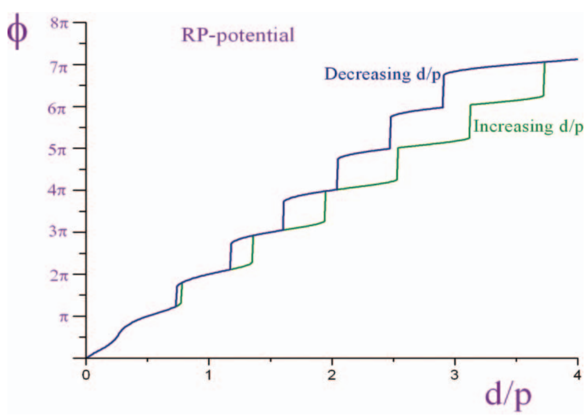


Figure 6. Calculated director orientation at layer surface with weak anchoring ($l_p = 1$) for R-P model anchoring potential versus the layer thickness increase and decrease.

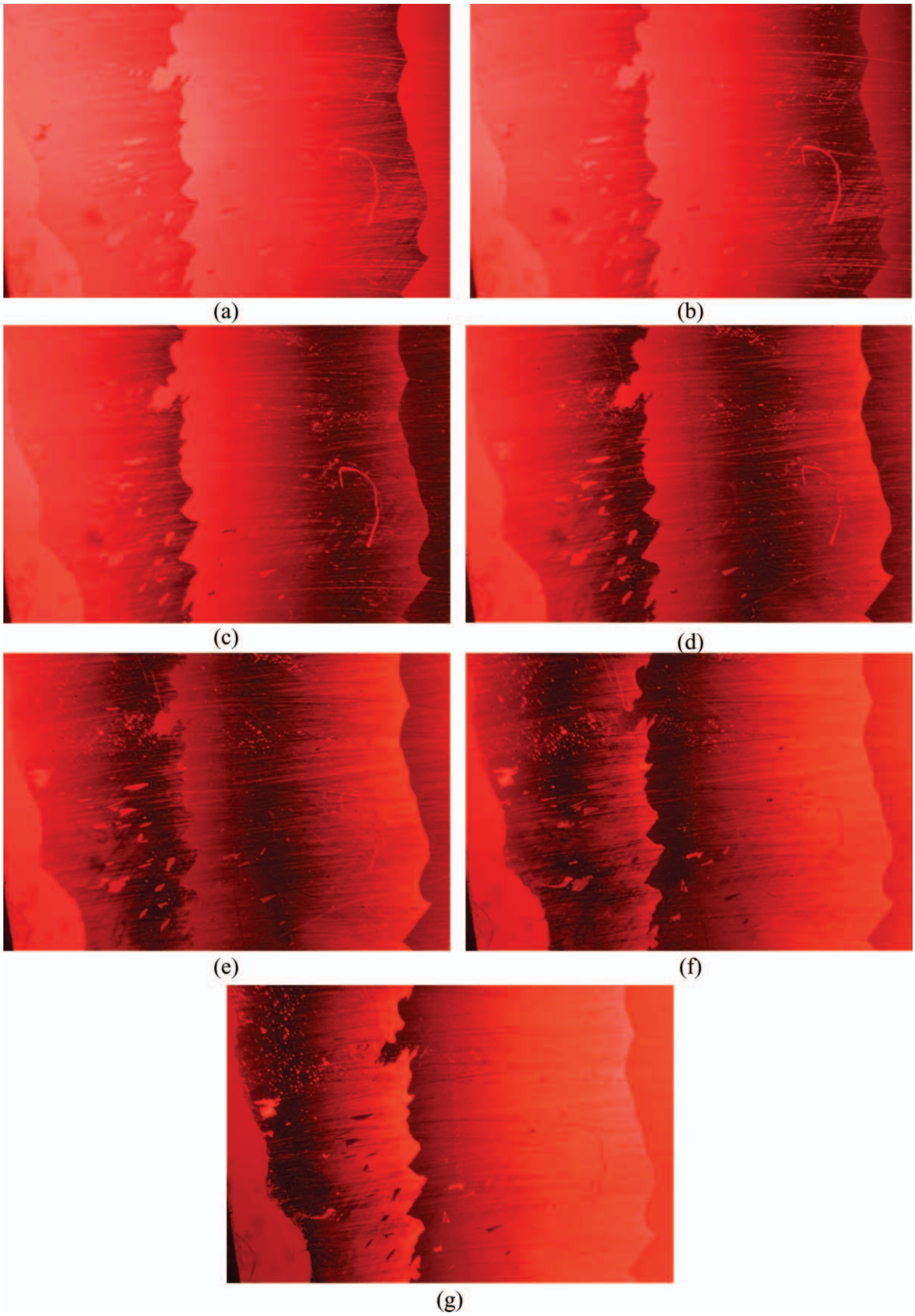
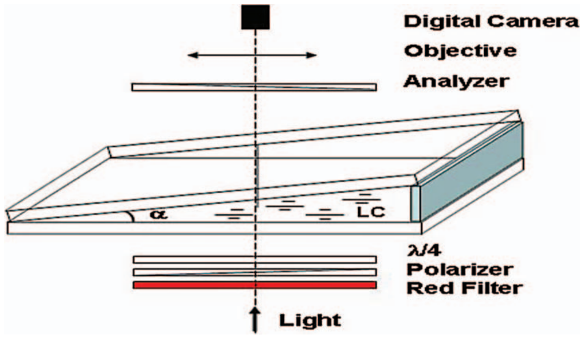


Figure 7. C-G structure at the analyzer orientation relative to the easy axis direction $\varphi_a = 44^\circ$ (a), $\varphi_a = 31^\circ$ (b), $\varphi_a = 14^\circ$ (c), $\varphi_a = 0^\circ$ (d), $\varphi_a = -15^\circ$ (e), $\varphi_a = -30^\circ$ (f), $\varphi_a = -45^\circ$ (g).

Experimental Results

Experimental Setup and Experimental geometry is shown below.



We have investigated experimentally director orientation in individual zones of Cano-Grandjean wedge for different strength of surface anchoring at the opposite wedge surfaces (weak and infinitely strong) by means of the polarization microscopy. Strong and weak anchoring at the wedge surfaces were obtained by the same way as in our previous paper [9] (rubbing and photoalignment). The easy axis direction was the same at the both surfaces being perpendicular to the plane of the shown experimental setup. The angle $\alpha = 0.01$ rad.

As a LC substance was used the Nemoptic chiral mixture with the pitch value 1.5 μm at the temperature 293 K. Rotation of the polarization of linearly polarized light normally incident at the wedge was measured as a function of the local wedge thickness d by means of rotation of the linear polarization analyzer around the normal. The Fig. 7 present some obtained in the experiment pictures of the several first Cano-Grandjean zones at varying orientation of the polarization analyzer. The pictures show variation with the coordinate of the director orientation (variation of the transmitted light intensity) in individual Cano-Grandjean zones and sharp changes of the director orientation at the walls

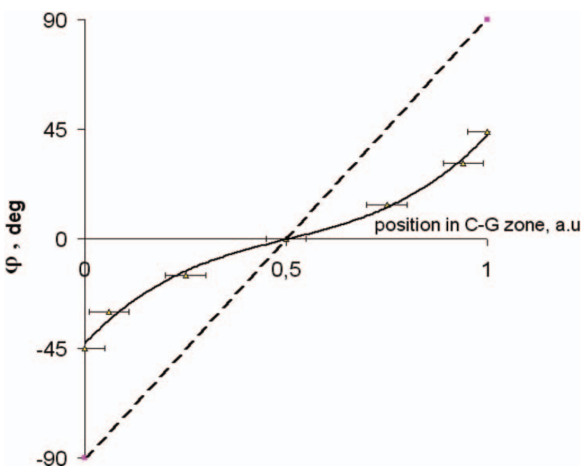


Figure 8. Measured director distribution at the wedge surface in the second C-G zone (dashed line corresponds to zero surface anchoring).

dividing neighbouring zones. Maximal transmitted light intensity at some point in individual Cano-Grandjean zone corresponds to coinciding of the director orientation at this point with the orientation of the polarization analyzer. The Fig. 8 presents obtained from the Fig. 7 angular distribution of the director in the second Cano-Grandjean zone. The obtained distribution may be used to restore the actual surface anchoring potential [7]. As a first step it is interesting to compare the experimentally found distribution with the theoretically calculated distributions for different model surface anchoring potentials.

Conclusion

The performed experimental and theoretical studies of the director structure in the Cano-Grandjean wedge with weak surface anchoring demonstrate a great potential of this approach in studying surface anchoring phenomena. It is worth to note again that the conditions of weak surface anchoring which are favorable for the surface anchoring phenomena studying may be fulfilled for the several first Cano-Grandjean zones if even the anchoring is not too weak in a common sense (the parameter S_d plays the role, not a real strength of anchoring potential). What is concerned of the present results the Figs. 3, 4 demonstrating differing theoretical predictions related to the director orientation distribution at the wedge surface for the second Cano-Grandjean zone for R-P and B- model anchoring potentials show that the accuracy of the performed measurements (Figs 7, 8) occurs to be insufficient to allow distinguish difference between the two theoretical predictions. Nevertheless, the observation of walls beginning from the first Cano-Grandjean zone (compare the Figs 1, 2 and 7) may be regarded as an indication that the actual surface anchoring potential differs from the R-P-potential. However there are options to improve the experimental resolution sufficiently for accurate studying the director orientation distribution at the wedge surface for an individual Cano-Grandjean zone whereas its resolution will remain to be insufficient for studying the director variations inside walls dividing individual Cano-Grandjean zones (the attempt to do this was reported in [9]). In whole, the obtained results demonstrates that in the presented approach some improvement in accuracy of the measurements will be sufficient to reconstruct actual surface anchoring potential and distinguish what kind of model anchoring potential is closer to the actual potential.

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