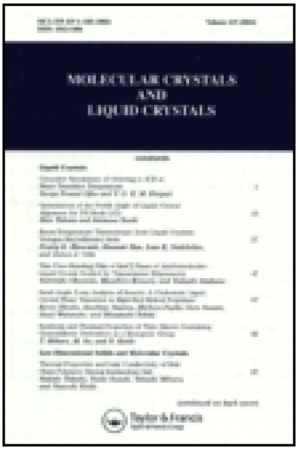

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Defects Connected to the Chevron Texture of a Chiral Smectic C, in a Wedge-Shaped Confined Geometry

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Defects Connected to the Chevron Texture of a Chiral Smectic C, in a Wedge-Shaped Confined Geometry

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Chiral smectics C have given rise to a very large literature, partly because Surface Stabilized Ferroelectric Liquid Crystal (S.S.F.L.C) makes possible displays with very interesting features, and also because the physical properties of this phase are of endless variety. Especially the textures in confined geometry, observed by microscopy, connected to the effect of the interaction with the polarized light, have been largely described and interpreted. However, these studies have been made very often in thin cells, sometimes in thick ones, but never in a cell with variable thickness. In this paper we describe and try to interpret the textures and defects created by a planar anchoring in a wedge-shaped sample, which go with the well known chevron texture.

1. INTRODUCTION

Defects and textures, observed with a polarizing microscope, are a privilaged mean to understand the structure of a mesophase and the organisation of the liquid crystal director in confined geometry. The technique is easy to use, the only difficulty is to prepare the cell suitable to obtain the information desired. The interpretation of the observed « landscape » is more critical. However observations and interpretations of defects and textures are a powerful method to raise hypothesis about the effect on the bulk of the molecular anchoring induced by the aligning layer deposited on the substrates of the cell. These hypothesis can be checked by other physical methods, such as, × rays diffraction or Modulation Polarisation Fourier Transform Spectroscopy.

Defects in the nematic phase are disclinations, that is discontinuities in the orientational order. The smectic phases show defects due to the orientational order, as does the nematic phase, but also to the positional order characteristic of this

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phase. The smectic phases built with chiral molecules display a much wider variety of defects due to the orientational order, to the positional order and to the chirality, specially in confined geometry when the helical structure is disturbed by the anchoring on the substrates.

The chiral smectic C mesophase (S_C^*) has been studied especially from the seventies[1], for the development of the Surface Stabilized Ferroelectric Liquid Crystal (S.S.F.L.C.)[2] which has been proved to be a new way to make displays with a short response time, a large viewing angle, bistability in some conditions and recently a good gray scale in the V-shaped configuration[3,4]. With a planar or almost planar anchoring on the substrates, it is well known that a S_C^*, obtained when cooling the cell from a smectic A (S_A^*) phase, gives rise to a chevron texture of the smectic layers. This organization of the layers has been deduced by N.A. Clark et al[5] and by A. Fukuda et al[6], from the interpretation of defects called « zigzags » which had been misunderstood from some years.

The chevron texture is not only characterized by these famous zigzags, but is also connected to other typical defects which depend on the thickness of the cell. In this paper we will do a systematic study of the defects and textures observed in a wedge-shaped sample, with a planar uniform anchoring, in the S_C^* phase. We will use this study to propose an interpretation leading to a description of the organisation of the director and of the smectic layers as a function of the cell thickness.

2. OBSERVATIONS

2.1. Experimental conditions

The orientation layer is SiO deposited by evaporation under an incidence angle of 60°. The thickness of the layer is 500Å and the pretilt angle of the director induced by the anchoring, is 0±0.3°, measured by the rotating crystal method[7], in the case of a simple nematic

The liquid crystal used to do experiments is ZLI 3774 from Merck. The phase sequence and the temperature transitions are:

$$K \leftarrow< -30°C \rightarrow S_C^* \leftarrow 62°C \rightarrow S_A \leftarrow 76°C \rightarrow N^* \leftarrow 86°C \rightarrow I$$

At 20°C, the tilt angle is 25.5°and the spontaneous pitch is 4 μ m.

The wedge-shaped geometry is obtained by a mylar spacer of 75 μm located at 22 mm from the edge of the upper glass plate. The aligning direction or « easy axis » is normal to the edge of the prism.

The cell is filled with the compound in the isotropic phase and then slowly cooled down to room temperature in the $S_C{}^*$ phase. The thickness of the gap filled with the liquid crystal ranges from less than 1 μm to 50 μm over a distance of 16 mm.

Several cells have been made with the same geometry but with different thickness gradients, using ZLI 3774 and also ZLI 3654 which display the same sequence of phases. In all cases, the main features are very similar. In the following we will present the observations made on the sample described above.

2.2. Preliminary observations

Several features show that the anchoring is efficient enough to induce the formation of a monocrystal in the whole sample. Some of the characteristics described below are present whatever the thickness, while others depend on the thickness.

Informations can be deduced from the observation of:

- the colors of the field and conditions of extinction,
- the topological defects, lines or walls and their association.

2.3. Texture and defects in relation with the local thickness

2.3.1. From 0 to 6 μm: Non adiabatic propagation of a linear vibration

Photo 1 shows an overall view of the wedge-shaped cell in the domain of thickness going from about 0 to 3 μm. The edge is on the left, the polarization vibration and the aligning direction are horizontal on the picture, while the analyzer is vertical. Almost everywhere colors are visible, varying when the thickness increases. Only the part close to the edge is whitish, with small domains defined by different shades separated by grain boundaries. Zigzags, characteristic of the chevron texture, are the most visible defects in this colored field, and are elongated along the normal to the smectic layers.

PHOTO 1 Overall view of the wedge-shaped cell in the region where the thickness varies from about 0 to 3 μ m. The edge is on the left, the polarization vibration and the aligning direction are horizontal, the analyzer is vertical (See Color Plate IX at the back of this issue)

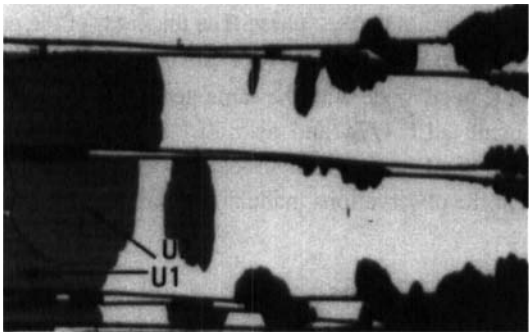


PHOTO 2 0 to 1.5 μm region. Same relative directions as in photo 1 for the polarizers and the aligning direction. Uniform domains U1 and U2, separated by a defect, are visible (See Color Plate X at the back of this issue)

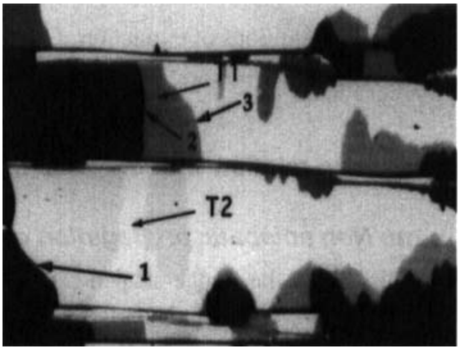


PHOTO 3 The same region after an anticlockwise rotation of 15° of the two polarizers, starting from the situation of photo 2. U1 domains are black and U2 are yellow. A boundary is visible between bluish and pale yellow domains (T1 and T2) (See Color Plate XI at the back of this issue)

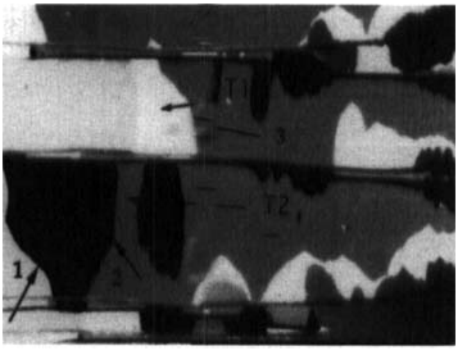


PHOTO 4 The same region after a clockwise rotation of 15° of the two polarizers, starting from the situation of photo 2. U1 domains are yellow and U2 are black. The same boundary as in photo 3 is visible, but the colors of T1 and T2 are reversed (See Color Plate XII at the back of this issue)

2.3.1.1. From 0 to about 1.5 μm

Photo 2, a higher magnification of the left part of photo 1, corresponds to this range of thickness. The texture is constituted by domains (arrows) pinned to small zigzags. They display the same yellow-brown color if the normal to the smectic layers, identified by the zigzag elongation, is parallel to the polarizer P_0 and normal to the analyzer A_0 (Fig. 1). They can be extinguished, between crossed polarizers, by rotating the stage by an angle of ±15°, or by rotating both polarizers in the same way, by an angle of 15° (Fig 2). Domains U1 become dark (Photo 3) starting from the position indicated in Fig. 1, by an anticlockwise rotation and domains U2 by a clockwise rotation (Photo 4). U1 and U2 domains – we will call them uniform domains – are separated by a defect, seen as a line (arrow 1), but which could be either a line or a wall crossing the bulk. This situation, in which U1 and U2 are side by side, exists only in this very thin part of the cell. Some other pale yellow or pale blue domains in photo 2 cannot be extinguished neither rotating the stage, nor rotating independently polarizer and analyzer; we will call them twisted domains. When U1 is black some of these domains, T1, are bluish and the other ones, T2, are yellow (Photo 3). When U2 is black, T1 domains are yellow and T2 domains are bluish (Photo 4). These domains, are separated from the uniform domains, U1 or U2, by lines or walls (arrow 2). It can be noted that U1 is never near T2 and U2 never near T1. T1 can be close to T2, bounded also by a line or a wall (arrow 3). We will discuss further about the nature of these various defects.

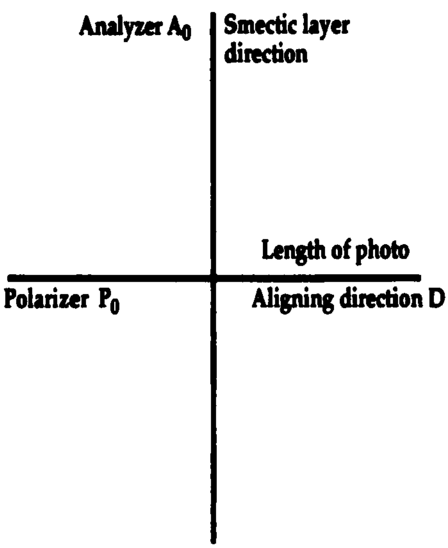


FIGURE 1 Relative positions of the polarizers, P_0 and A_0, of the smectic layers and of the aligning direction corresponding to photo 1

2.3.1.2. From about 1.5 to 3 μm

In this region the whole field is colored (Photo 1) when the aligning direction is parallel to the polarizer, as are the T1 and T2 domains, mentioned in the previous paragraph, and cannot be extinguished neither by a rotation of the stage nor by an independent rotation of the polarizer and the analyzer. There are few zigzags in this region, and T1 is predominating.

2.3.1.3. From about 3 to 6 μm

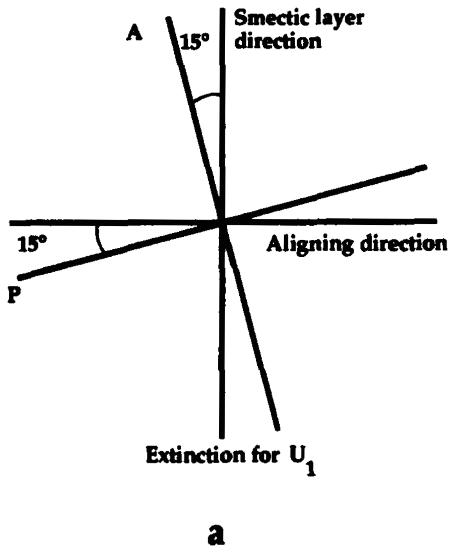
The field is decorated by regular zigzags. It cannot be extinguished neither rotating the stage nor rotating independently the polarizers. Starting from the situation of Photo 1, turning the polarizers to extinguish U1 makes blue one side of the zigzag, a T1 state, and yellow the other side, a T2 state (Photo 5). when U2 is black T2 becomes blue and T1, yellow. The colors are the same as in the 0 – 1.5 μm and 1.5 – 3 μm regions. Some small T1 domains are on the same side of the zigzag as T2 and some small T2 domains on the same side of the zigzag as T1. The T1 and T2 domains which are on the same side of the zigzag are separated by a defect, L.

2.3.2. From 6 μm: Adiabatic propagation of a polarized vibration

There are some rare U1 and U2 domains pinned to the zigzag walls. A nearly good extinction can be reached by rotating independently the polarizer and the analyzer. Starting from the situation described in Fig 1, P_0 for the polarizer, A_0 for the analyzer – that is crossed polarizers -, the extinction is reached by rotating the polarizer anticlockwise by an angle of about 15°, and by rotating the analyzer clockwise by the same angle (Fig. 3). The new positions are P_1 and A_1, they make an angle of about (π/2–30°). No other rotation can give an extinction.

2.3.2.1. From 6 μm to about 14 μm

The field is more or less decorated by zigzags and essentially constituted by some uniform domains, U1 and U2 and by twisted domains, T1 and T2. In this thick part U1 and U2 are never side by side. U1 and T1, U2 and T2, T1 and T2 are separated by lines L (Photo 6). T1 and T2 can be extinguished, as written in the previous paragraph but not exactly with the same positions of the polarizers (Photo 7). When the uniform domains are extinguished, T1 and T2 are slightly different in color. If U1 is black, T1 is pale green and T2 pale pink (Photo 8a) and reversely when U2 is black, T1 is pale pink and T2 pale green (Photo 8b). These colors are very faint out and difficult to be distinguished. However by continuity with the thinner region it is possible to recognize T1 and T2 by the fact that U1 is never near T2 and U2 never near T1. Focusing at two different levels, it is possi-



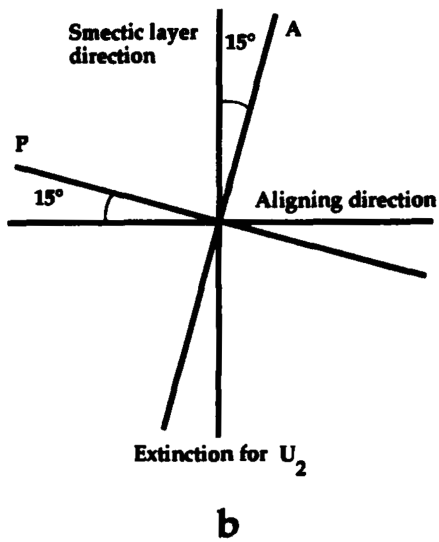


FIGURE 2 Relative positions of the polarizers, P and A, of the smectic layers and of the aligning direction, giving extinction in the uniform domains, domains U1 in 2a and domains U2 in 2b

ble to check that the defect between U1 and T1 is a line located on the upper surface and the defect between U2 and T2, a line located on the lower surface

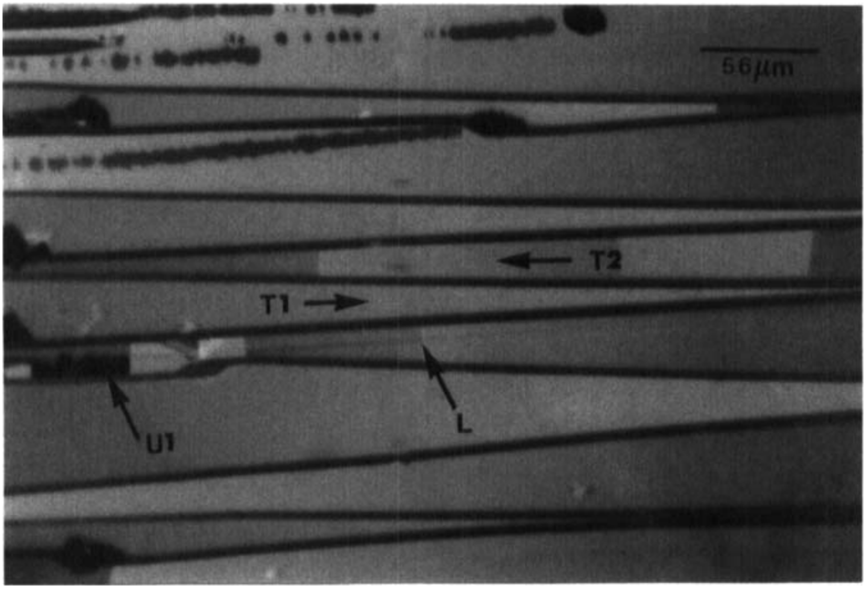


PHOTO 5 3 to 6 μm region. Same situation as in photo 3, but in the zigzag texture. Generally, T1 domains are on one side of the zigzag walls and T2 on the other side. However, some small domains of the other type can be on the same side of the wall. In this case T1 and T2 are neighbour and separated by a defect (L) (See Color Plate XIII at the back of this issue)

(Photos 8a –8b). T1 and T2 are separated by a broken line, which is located in the chevron plane, either running from the thin part of the cell to the thick one, or parallel to the edge (Photo 7).

In the same plane, small focal conics are in focus (Photo 9); they are made up of an ellipsis in the chevron plane and a short tip which is the projection in the plane of the hyperbola. On one side of the zigzag wall, the hyperbola goes towards the left and on the other side towards the right (Photo 6). Generally, T1 is predominating in the part where the hyperbolas are oriented towards the left and T2 in the part where there are oriented towards the right.

2.3.2.2. Thicker than 14 μm

The unwinding lines appear in this range of thickness. The lattice of lines is not regular and with a strong magnification it is possible to focus on different levels and to spot some pairs of lines in the upper part of the cell and some pairs in the lower one (Photos 10a, 10b, 10c). In the places where the lines appear, first only on one side of the chevron plane, they are in the lower part of the chevron in T2 and in the upper part in T1. Figure 4 gives a schematic representation of the rela-

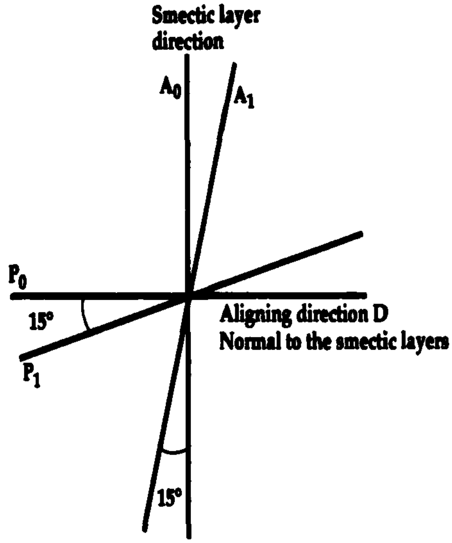


FIGURE 3 Relative positions of the polarizers, P_1 and A_1, of the smectic layers and of the aligning direction, giving extinction in the twisted domains T1 and T2. P_0 and A_0 are the polarizer directions in photo 1

tive positions of the defects. The lattice of unwinding lines becomes more and more regular when the thickness increases and several defects can be observed simultaneously (Photo 11):

- needles or zigzags (Photo 11, Arrow 1) and (Photo 12, Arrow 1)
- unwinding lines (Photo 11, Arrow 2 and Photo 12, Arrow 2)
- small equidistant loops decorating the zigzags (Photo 11, Arrow 3 and Photo 13)
- cofocal conics located in the plane of the chevron (Photo 11, Arrow 4 and Photo 12, Arrow 3), sometimes trapped in the middle, between two levels of pairs of unwinding lines (Photo 14)
- broken lines described as bounding T1 and T2 (Photo 11, Arrow 5)

2.4. Effect of a DC electric field

The observations performed without electric field cannot give any information about the direction of the local permanent polarization, P, at the liquid crystal – substrate interfaces. Using a method proposed by Glogarova[8] that we have also used in the past[9], we applied a DC electric field and observed the region where

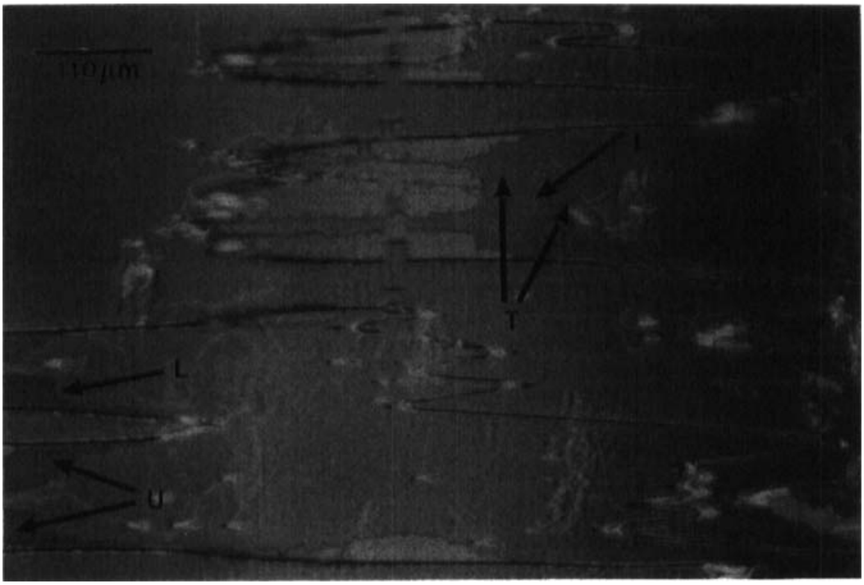


PHOTO 6 6 to 14 μm region. Zigzag texture similar to the texture seen in a thinner part in picture 1. U1 and U2 domains are no more side by side. T1 and T2 domains and U and T domains are separated by a defect (L) (See Color Plate XIV at the back of this issue)

the T1 and T2 twisted states are visible, for a thickness large enough (> 15 μm) to focus independently on the two surfaces. When the electric field is « up », from the bottom to the top, black domains appear, pinned to the upper glass plate, and are growing until they occupy the whole field when the electric field increases. After cancelling the electric field and reversing it, in the « down » direction, black domains grow from the lower surface. If, before applying any electric field, there are some U1 and U2 domains pinned to the zigzag walls, U1 domains are growing when the field is « up » and U2 when the field is « down ». We will see that the location of the growing domains connected to the extinction positions for the uniform and the twisted states makes possible to detect the sign of the polarization at the interfaces, connected to the distribution of the director.

3. INTERPRETATION

Most of the defects we have just described have been already interpreted from the topological point of view. The distribution of the director and the orientation

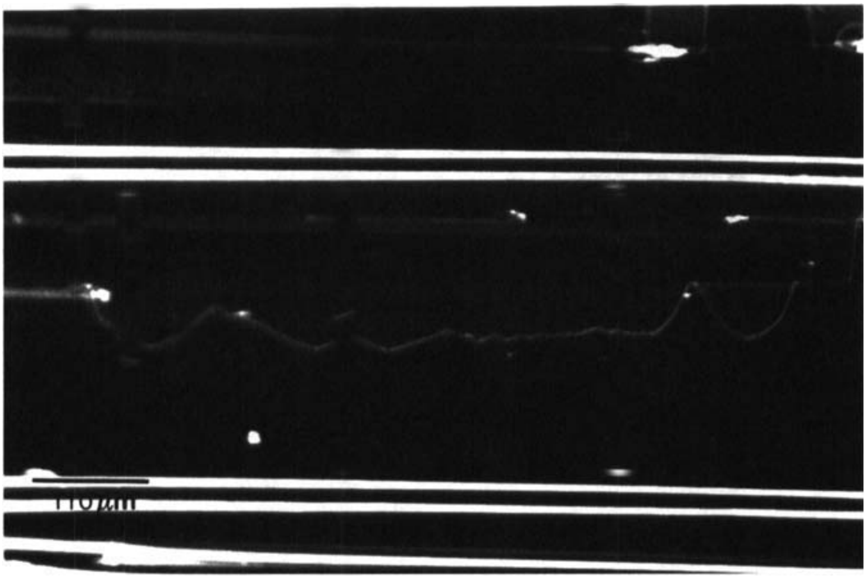


PHOTO 7 Same field of view as in photo 6. T1 and T2 can be extinguished almost at the same time by rotating independently the polarizer and the analyzer. They are separated by a broken line located in the chevron plane, the *inversion line* (See Color Plate XV at the back of this issue)

of the smectic layers they imply will help us to follow the evolution of the texture while the thickness increases. This evolution gives an overall information about the effect of the surface anchoring on the bulk organisation and an idea of the competition between the unwinding effect of the substrates and the helical structure due to the chirality.

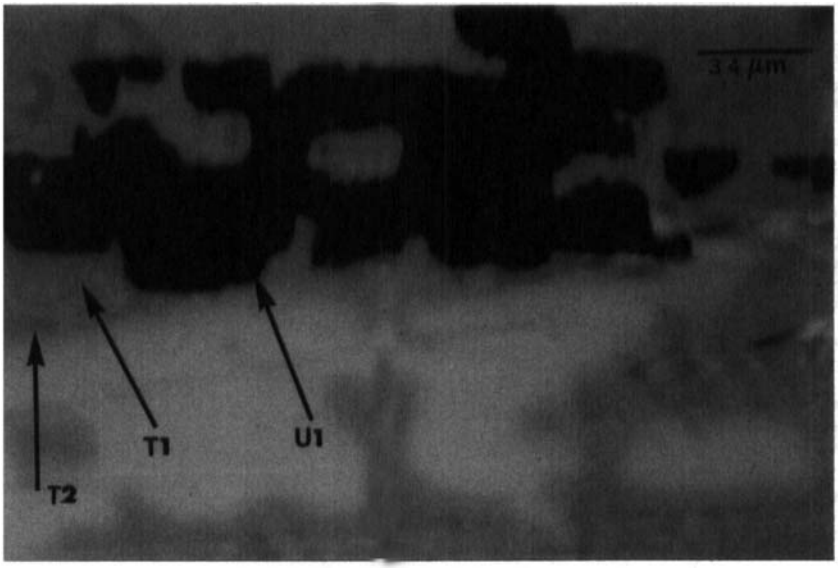
3.1. Interpretation of the textures and defects in relation with the local thickness

3.1.1. From 0 to 6 μm

Zigzags defects in the colored field underline the existence of the chevron texture, with two orientations of the chevron, as described in literature.

3.1.1.1. From about 0 to 1.5 μm

The very black extinction of U1 and U2 between crossed polarizers shows that the distribution of the director is uniform. Figures 5 gives the two possible situations for the director (5a, 5c and 5b, 5d) and in each of them the two possible directions for the polarization (« up » or « down »). The relative directions of the



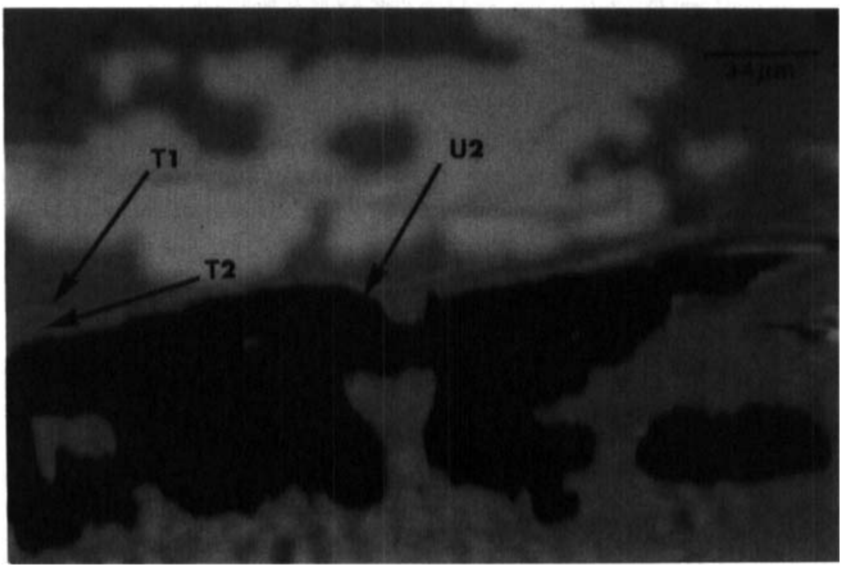


PHOTO 8A AND 8B Same field of view as in photo 6 and 7. In 8a, a U1 domain has been made black by a rotation of the polarizers and focused, while U2, which is whitish, is not focused. T1 is pale green and T2 pale pink. In 8b, a U2 domain has been made black by a rotation of the polarizers in the opposite direction and now focused, while U1, which is whitish, is not focused. T2 is pale green and T1 pale pink (See Color Plate XVI at the back of this issue)

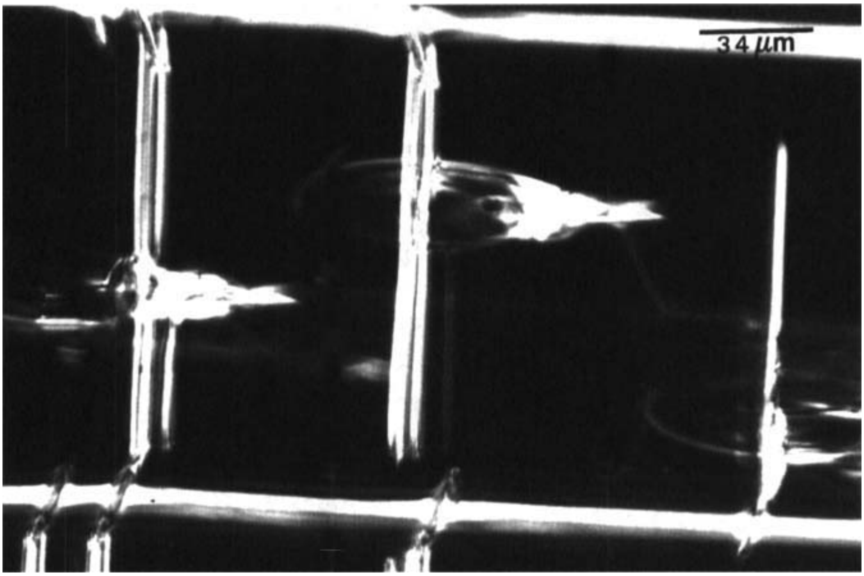


PHOTO 9 In the same region cofocal conics are in the black field, with the ellipsis in the chevron plane. A short tip, towards the right, is the projection in the plane of the hyberbola (See Color Plate XVII at the back of this issue)

privilaged vibrations and of the normal to the layers in the liquid crystal slab, giving the extinction between crossed polarizers, by clockwise or anticlocwise rotation of 15°, indicate that U1 is described by 5a or 5c and U2 by 5b or 5d. The effect of the DC electric field, inducing the growth of U1 when it is « up » and of U2 when it is « down », indicates that the topological situation is 5a for U1, « up » state, and 5b for U2, « down » state. A wall is necessary to connect a domain « up » to a domain « down », as shown in Fig 6. We call it a *up-down wall.* Because of the tilt of the smectic layers in the chevron texture, the permanent polarizations cannot be normal to the glass plates, and they are « nearly up » and « nearly down ».

The bluish or yellow domains, T1 and T2, can never be extinghished. This optical behaviour – a rotatory power – is due to a twist of the director between the bottom and the top of the cell, inducing a rotation of the incident linear vibration which is transformed and comes out as an elliptic vibration. There are two possible topological situations, schematized in Fig 7a and 7b. Configuration (c) in the bulk is equivalent to (a) and (b). In the thicker part of the cell T1 and T2 can be extinguished, about in the same conditions, by rotating independently the polarizer and the analyzer, because of the almost adiabatic propagation of the lin-

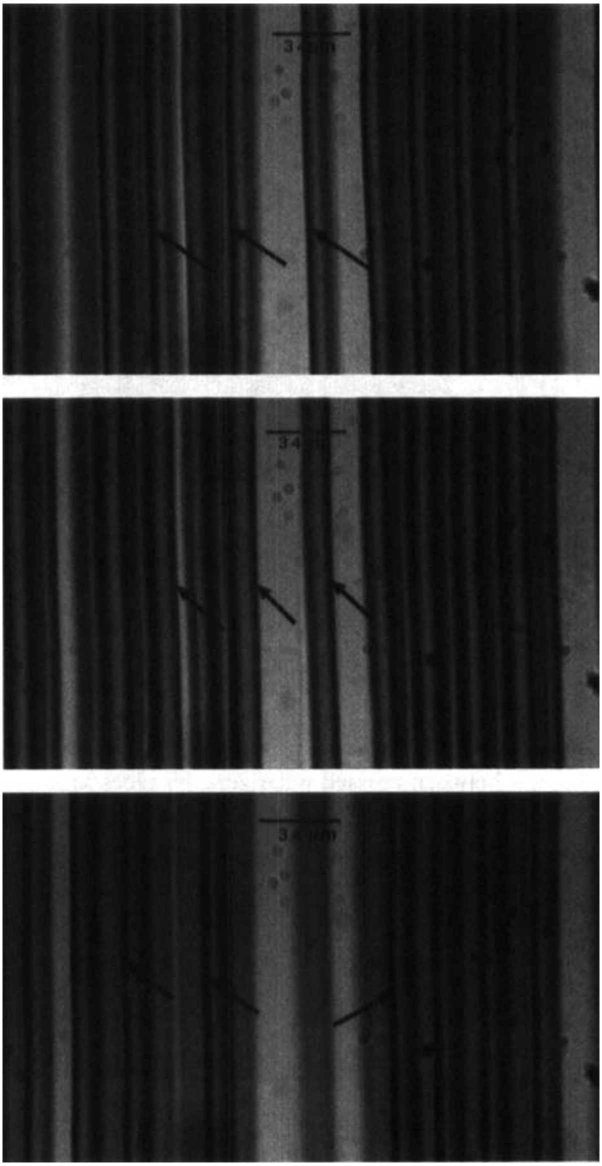


PHOTO 10A, 10B, 10C Region located in the part where the thickness is larger than 14 μm. A regular lattice of unwinding lines appears. There are two superimposed pairs of lines in the bulk of the cell, each one on one side of the chevron plane. It is possible to focus on three different levels: 10a, near the lower plate, with the lattice of unwinding lines of a pair, located very close to this surface; 10b, in the midlle of the sample, with the double lattice formed by the unwinding lines of the two pairs, located on both the sides of the chevron plane, very close to it; 10c, near the upper plate, with the lattice of unwinding lines of the second pair, located very close to the upper surface (See Color Plate XVIII at the back of this issue)

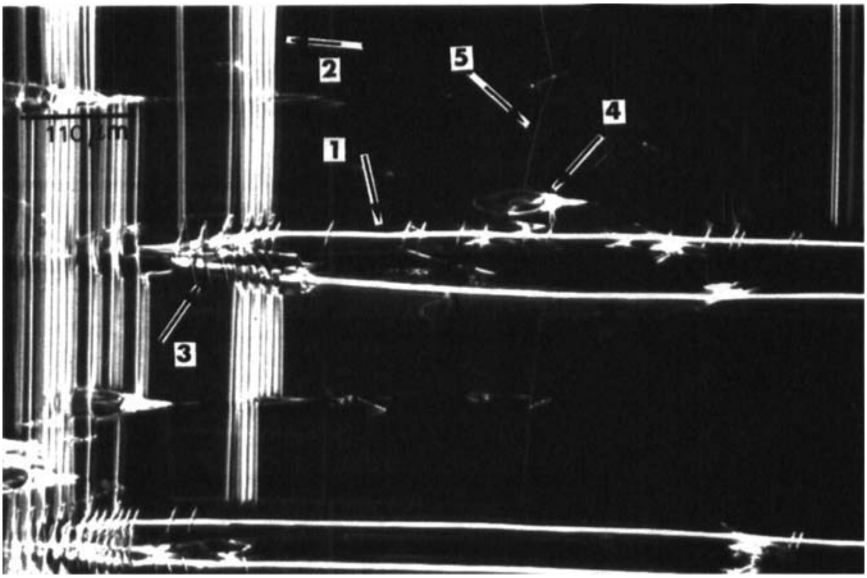


PHOTO 11 In the same region as in photo 10, several topological defects are observed: zigzag walls or needles (1), unwinding lines (2), a lattice of loops of unwinding lines decorating the zigzag walls (3), focal conics (4) and the *inversion line* (5) (See Color Plate XIX at the back of this issue)

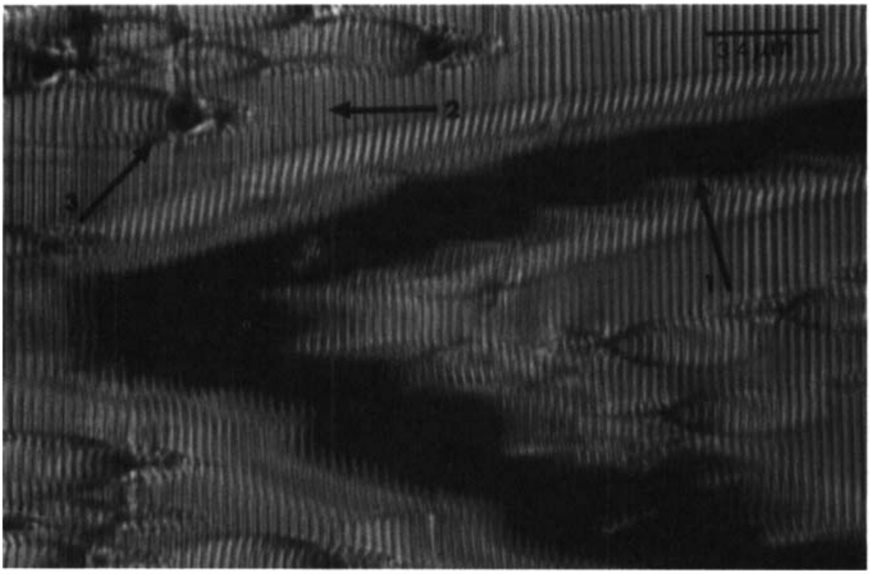


PHOTO 12 Almost in the same region as in photo 10, in a slightly thicker part, the zigzag wall (1) is very wide. The width is approximatively equal to the local thickness. The zigzag goes with unwinding lines (2) and focal conics oriented towards the left inside the zigzag and towards the right outside (See Color Plate XX at the back of this issue)

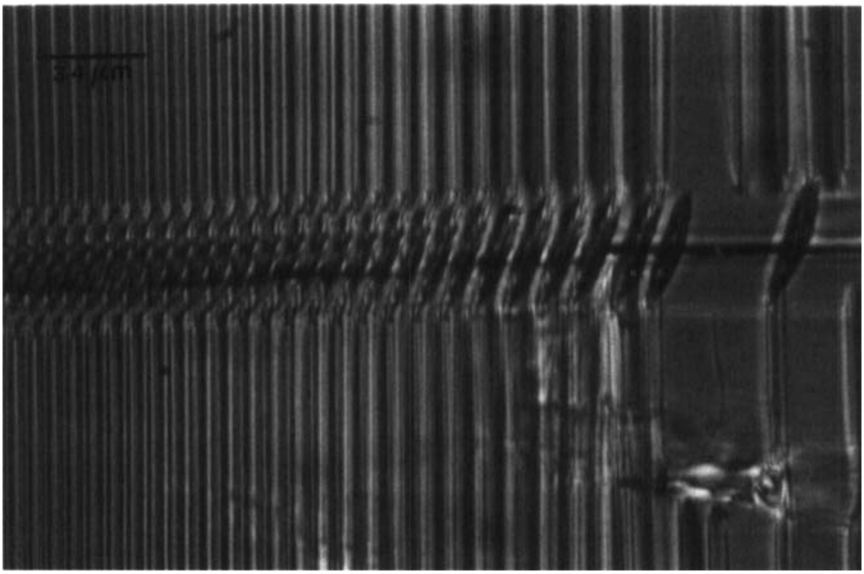


PHOTO 13 Lattices and loops of unwinding lines decorating the zigzag wall seen under a higher magnification (See Color Plate XXI at the back of this issue)

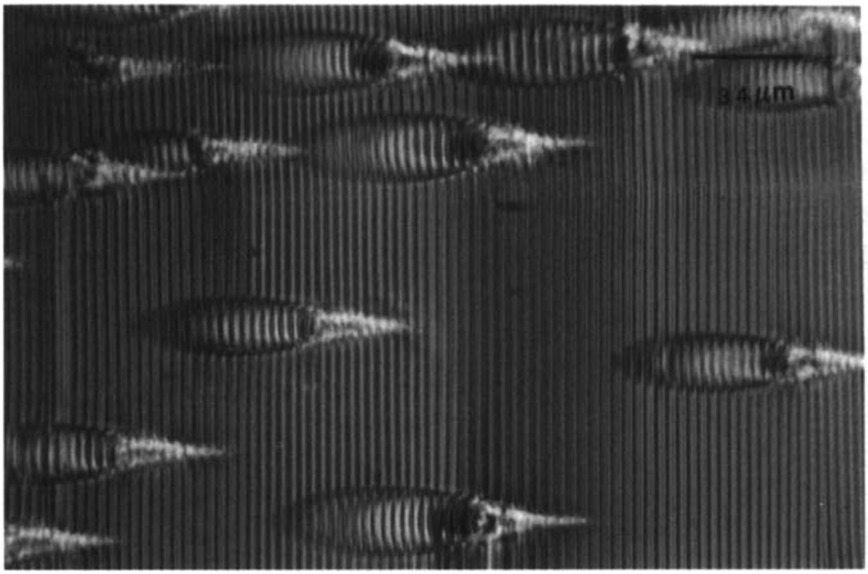


PHOTO 14 Regular lattice of unwinding lines and focal conics located in the chevron plane between the two pairs of lines (See Color Plate XXII at the back of this issue)

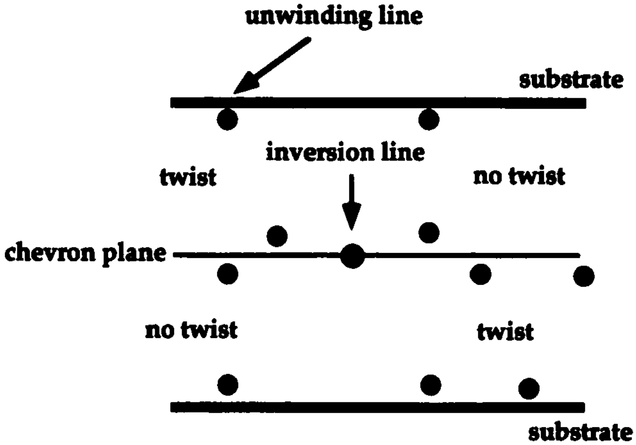


FIGURE 4 Relative position of the linear defects: unwinding lines near the surfaces of the glass plates and of the chevron plane and inversion line in the chevron plane separating the domain in which the twist is in the upper part from the domain in which the twist is in the lower part

ear vibration when the total rotation is small, compared to the total thickness. By continuity between the thin and the thick part, this optical behaviour gives the orientation of the director at the bottom and at the top of the cell, for T1 and T2, which is described by 7a. The director twist is connected to a splay for the polarization. It has been proved that the twist occurs on one side of the chevron plane either in the lower part or in the upper part, never on both sides[10]. Including the polarization directions there are four distributions for T1 and T2, shown in Fig 8a, b, c, d. As for U1 and U2, observations of the DC electric field effect indicate that the anchoring in T1 and T2 is polar, the polarizations at the surfaces being oriented towards the bulk of the cell, involving that configurations 8a and 8b are the only ones possible.

To join a uniform domain to a twisted one, several topological distributions can be imagined. Figures 9 a, b, c, d, e, f, g,h are schematic representations of these possible situations for one of the two possible tilting directions of the chevron. For the other one, the possible situations are quite similar. The observations reported in section 2.2. allow us to rule out some of these situations. The extinction positions of the « up » and « down » domains indicate that all the director distributions, described in Fig 9 for the uniform states, are possible. The situation in which a half-wall is necessary is less likely than a line, and we have noted that the boundaries between U1 and T1 domains are located on the upper surface and that the boundaries between U2 and T2 domains are located on the lower surface.

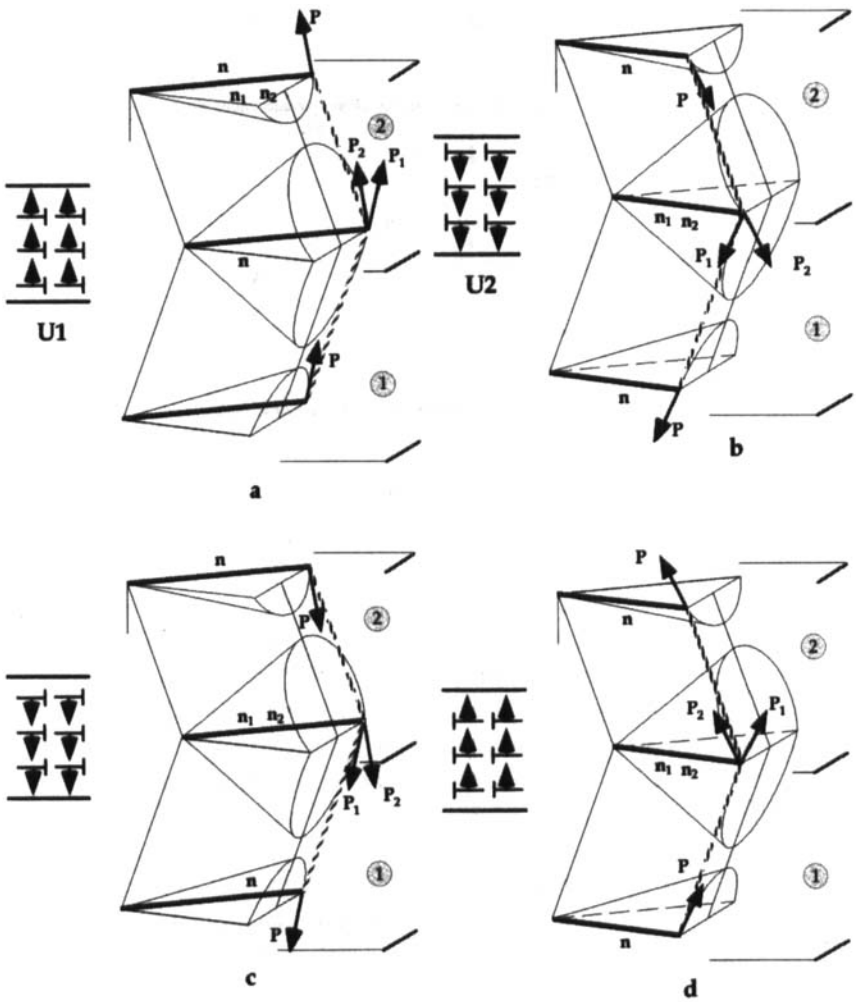


FIGURE 5 (a) or (c) and (b) or (d) give the two possible situations for the director in the uniform domains U1 and U2, (a) or (d) and (b) or (c) the two possible situations for the polarization. The electric field effect indicates that U1 chooses configuration (a) and U2 chooses (b)

This implies that the only possible configuration is 9h for U1/T1 and 9e for U2/T2 and consequently T1 corresponds to 8b and T2 to 8a. Finally, the proximity between uniform and twisted domains, and the behaviour with an electric field give, for the twisted part, a non ambiguous topology with two possible locations for the twist, visualized in Figure 10.

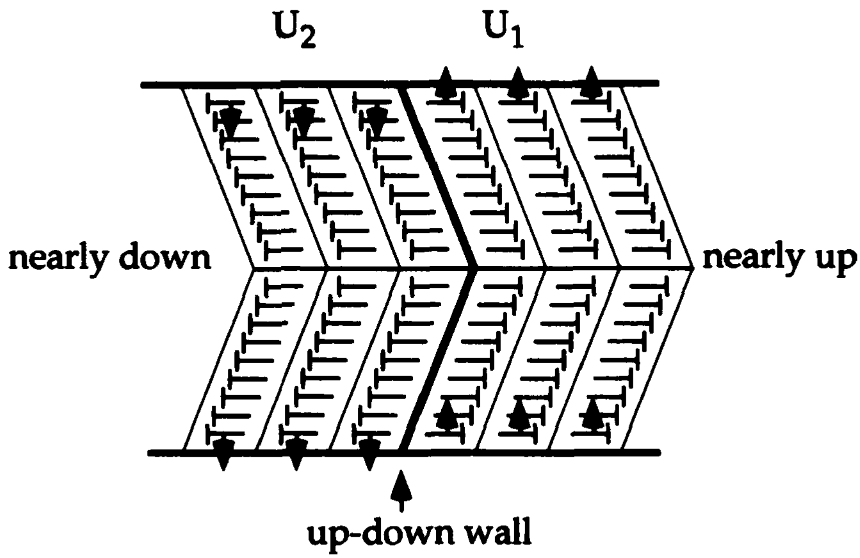


FIGURE 6 Topology of the boundary between a uniform domain U1 and a uniform domain U2. A defect wall, called *up-down wall*, is necessary between them. Due to the chevron, the polarization is not exactly « up » or « down » but « nearly up » or « nearly down »

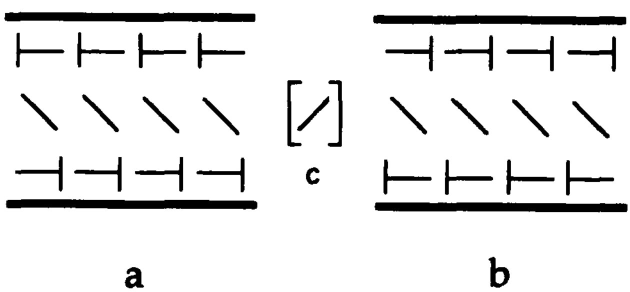


FIGURE 7 There are two possible configurations to form a twist from the bottom to the top of the cell, in relation with the starting situation. Rotating of half a turn on the cone clockwise or anticlockwise is equivalent

A defect line connects a domain T1, in which the twist is located in the upper side of the chevron, to a domain T2 in which the twist is located in the lower side (Fig. 10). The location of this line, called « *inversion line*» in ref 8, can be detected only in the thick part of the cell, by focusing on it, exactly in the plane of the chevron.

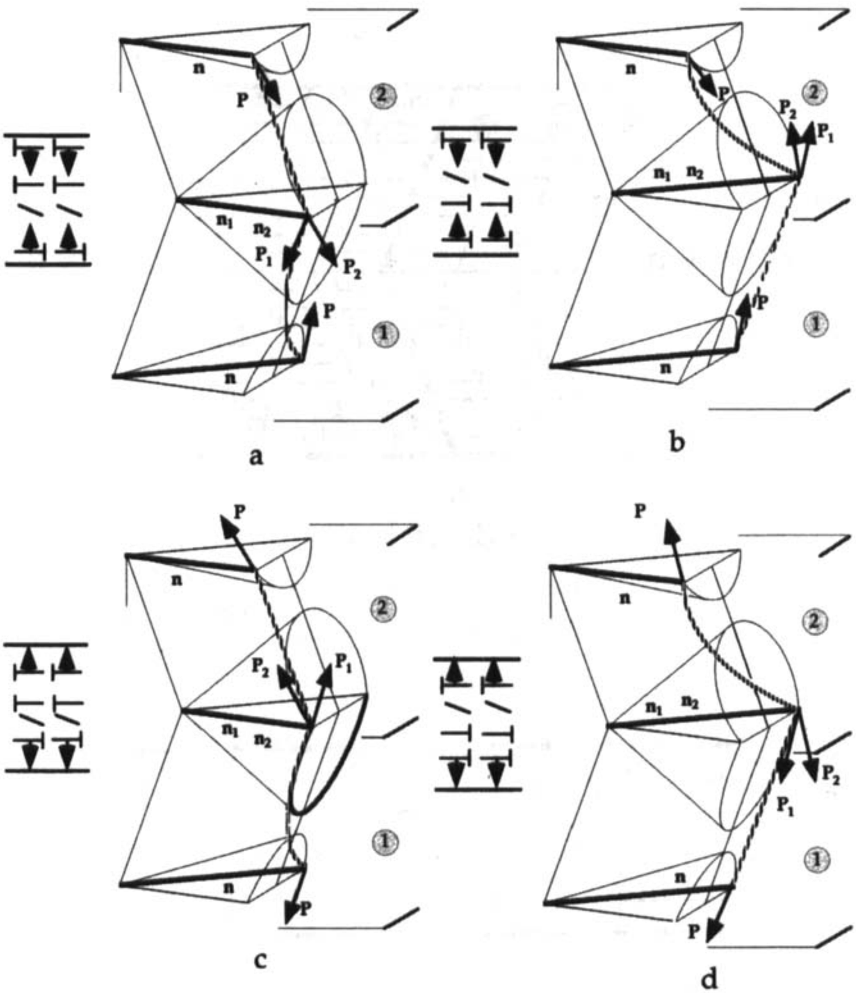


FIGURE 8 The only situation observed for the director on the surfaces in the twisted domains T1 and T2 is the one described in (a), (b), (c) and (d). In (a) or (c) the twist is in the lower part of the cell and in (b) or (d) the twist is in the upper part. In (a) or (b) the polarization goes towards the bulk and in (c) or (d) it goes towards the surfaces. The electric field effect proves that only (a) and (b) are possible

As a conclusion, in the thin part of the wedge-shaped cell there are different kinds of defects bounding the different domains, a wall between two uniform domains, surface lines between a uniform and a twisted domain and a line located in the chevron plane between two twisted domains.

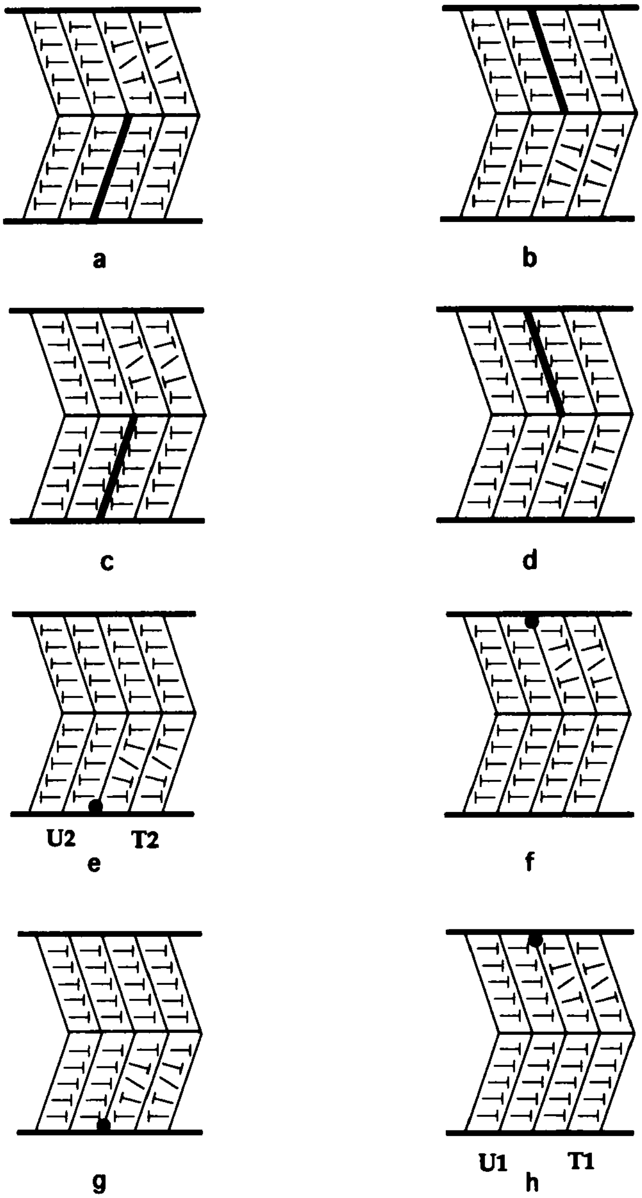


FIGURE 9 Possible configurations for the boundaries between a uniform and a twisted domains. The figure gives eight topological possibilities for the two different uniform domains U1 and U2 and the four possible distributions in T1 and T2. In the present experimental conditions, (b), (c), (f) and (g) are not observed for T1 and T2. (a) and (d) involve half a defect wall, less probable than a defect line. (e) gives the proposed configuration for U2/T2 and (h) for U1/T1

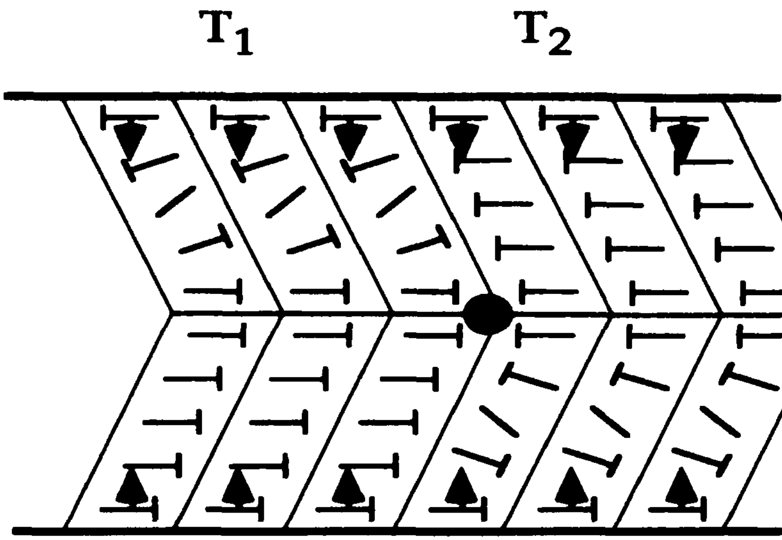


FIGURE 10 Topology of the boundary between two twisted domains, T1 and T2. A defect line, called *inversion line*, connects these domains in which the twist is not located on the same side of the chevron

3.1.1.2. From about 1.5 to 3 μm

Observations has shown that U1 and U2 are no more side by side in this region. A defect wall is expensive in energy, especially when the area it occupies is large: the proximity of U1 and U2 is avoided to minimize the energy.

The interaction between the surfaces and the liquid crystal is essentially polar as described in Figure 10, but a polar configuration needs for the director about a half-turn on the cone. In the very thin part of the wedge (0–1.5 μm) the rotation has to be done on a very short distance. To avoid the rotation, uniform domains can take place, in spite of the most favorable polar anchoring. When the thickness goes from 1.5 to 3 μm the situation begins to change and twisted domains occupy more and more the field because the polar anchoring predominates over the other effects. We observed that there are few zigzags. It can be explained by a tendency to prefer one of the two directions of the chevron; however it is not clear why this occurs. Note also that the T1 domains are more numerous than T2. It means that in this chevron, the twist is easier in the upper part (T1), probably because the plane of the chevron is not exactly in the middle, so the twist takes place in the widest part.

In this range of thickness, for this compound and this aligning layer, the most favorable situation is a twist of the director between the chevron plane and the upper surface and one tilting direction of the chevron.

3.1.1.3. From about 3 to 6 μm

The color observed in this part is due to the rotatory power as in the two previous regions. Generally, the resulting color depends on the specific rotation of the light which is proportional to the pitch, to the effective birefringence and to the thickness. Here, two parameters are changing from the left to the right, the total thickness but also the specific rotation, because the rotation of the director is constant while the thickness is growing, thus the pitch is also growing. The variation of the total rotation induces this continuous change of color in a domain T1 or T2. We observed that the color is not exactly the same inside and outside a zigzag and on both sides of the line between T1 and T2. The twist is either in the lower part of the chevron or in the upper part. The measured transmitted light is not the same in the « linrot » situation (linear then rotating) and in the « rotlin » one (rotating then linear), as developped by S. Quentel[11 12]. The colors also are different. The linear defects between U1 and T1 or U2 and T2 are surface lines as in the thin region (Fig. 9h and 9e). The linear defect between T1 and T2 has the same nature as in the thinner part of the sample, it is an « inversion line » (Fig. 10).

3.1.2. From 6 to about 14 μm

The defects are the same as in the domain 0 – 6 μm, excepted that the wall separating U1 and U2 does not exist. The fact that Ul is never close to U2 makes evident that this wall is avoided. Now the field can be extinguished turning separately the polarizer and the analyzer, because the propagation of the light is almost adiabatic: the linear vibration follows the rotation of the director. There is no more rotatory power in the sense used previously. A weak difference between the shades of T1 and T2 is due also to the propagations « linrot » in T1 and « rotlin » in T2.

3.1.3. Thicker than 14 μm

The field can be extinguished because the propagation of the linear vibration is adiabatic. Whatever the thickness, if it is larger than 6 μm, the distance over which the rotation of the director takes place is so large that a rotatory power is no more possible.

Concerning the numerous defects in this range of thickness, they are all similar to the ones described in the literature. Some of them are typical of the organisa-

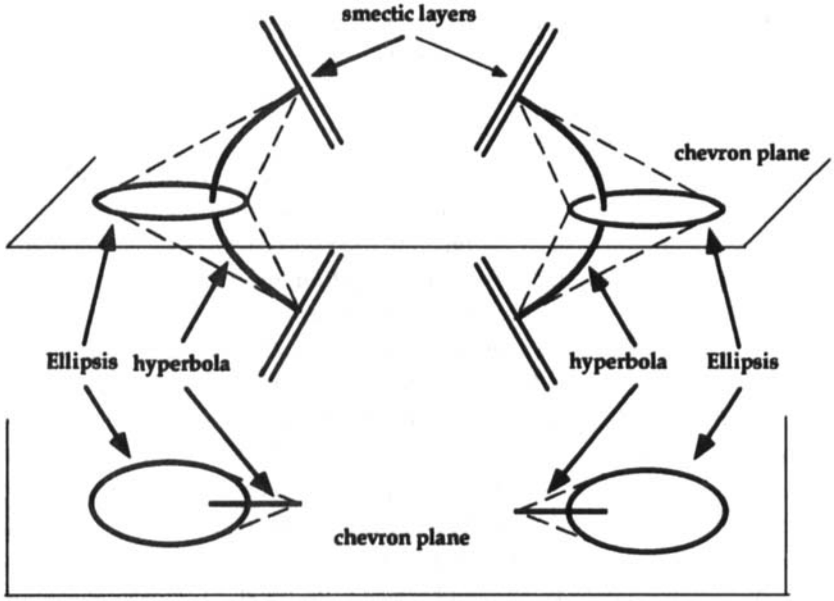


FIGURE 11 Organisation of the smectic layers associated to the focal conics observed in the chevron plane. These conics connect the smectic layers tilted in one direction near the lower plate to the ones which are tilted in the opposite direction near the upper plate. They allow a bend of the smectic layers in the middle of the cell, in spite of a discontinuity. The hyperbola goes to the left on one side of the zigzag wall and to the right on the other side

tion of the smectic layers, needles, zigzags and focal conics, others are due to the unwinding effect of the surfaces on the helical texture, unwinding lines and loops. The inversion line is due to the very particular distribution of the director in the chevron, connected to the polar anchoring on the surfaces.

- Needles and zigzags are of the same nature as in the thin part. But the largest the thickness, the widest the walls. The width of the zigzag wall was evaluated by N.A. Clark et al[13] to be almost equal to the thickness of the cell.
- Two pairs of unwinding lines take place when the thickness on each side of the chevron plane is more than the pitch of the chiral smectic C texture.
- The loops going with the zigzag walls are unwinding lines. In the wall there is no chevron, the smectic layers are perpendicular to the surfaces. This is why there is a line near the lower plate and another one near the upper plate. These two lines create a loop in place of two pairs.
- Cofocal conics take place when, instead of the chevron plane, there is a curvature of the smectic layers. It is well known that this defect allows a curvature without any change of the layer thickness. Figure 11 shows that the

directions of the hyperbola branches are perpendicular to the directions of the smectic layers far from the plane of the ellipsis.

- The inversion lines circulate between the other defects, always located in the chevron plane, separating « linrot » and « rotlin » domains.

3.2. An overview of the topology

We can now give a schematic representation of the topological situation of the chiral smectic C in a wedge-shaped confined geometry. Figure 12 describes the organisation of the smectic layers, the distribution of the director corresponding to the different domains we observed, and the location of the topological defects, wall and lines. On the left, in the thinner part are the uniform domains, U1 and U2 followed by the twisted domains, T2 and T1. The thickness in this region is too small to allow the helical structure. When the thickness is larger than the helical pitch the helix appears and, with it, the unwinding lines, located very close to the substrates and close to the chevron plane. Everywhere, except in the uniform part, the inversion lines, located in the chevron plane, separate domains in which the twist occurs on one side of this plane from the domains in which it occurs on the other side. Topology of the zigzags is not described on this picture. The region where are the superimposed pairs of unwinding lines and the focal conics is not represented.

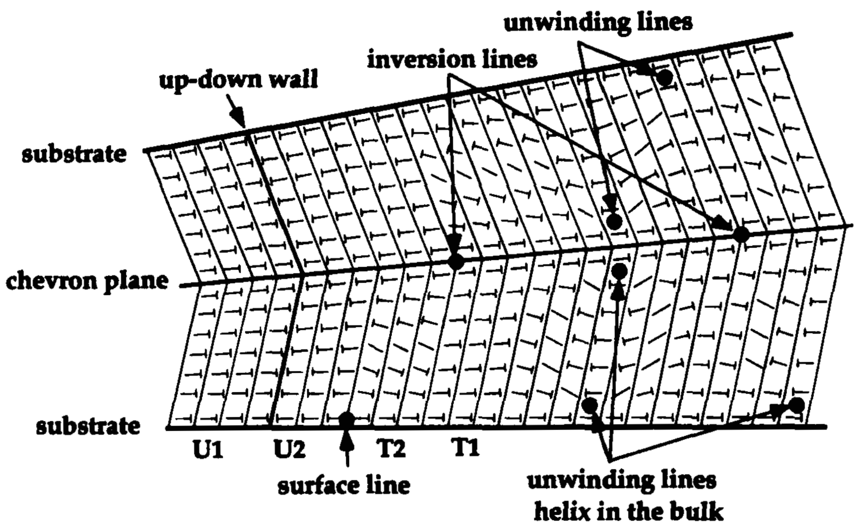


FIGURE 12 Organisation of the smectic layers, distribution of the director and location of the topological defects, corresponding to the texture observed in a wedge-shaped cell

4. CONCLUSION

The observation under a polarizing microscope of a chiral smectic C, confined in a wedge-shaped cell, with a planar anchoring, revealed a wide range of topological defects. Many of them had been already observed and interpreted, but often independently in thin and thick cells. The interest to see them together has been that one defect can help to understand the situation involved in another one. The continuity between the thin and thick parts, particularly concerning the extinctions and the colors displayed between crossed polarizers, allowed us to understand the nature of the defects, walls or lines, and the connecting role they play between different distributions of the liquid crystalline director.

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