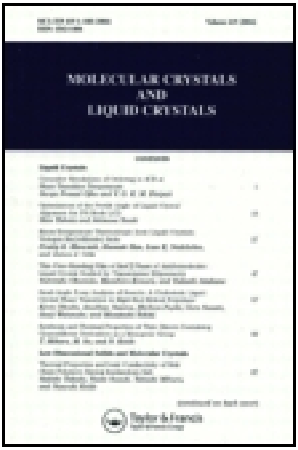

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Switching Behaviour of a Thermochromic Ferroelectric Liquid Crystal with High Spontaneous Polarization

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Switching Behaviour of a Thermochromic Ferroelectric Liquid Crystal with High Spontaneous Polarization

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The switching processes of a planar aligned thermochromic $S_c{}^*$ liquid crystal sample were investigated. Depending on the applied voltages, between the rest unwound states, the following structures can be distinguished. At low voltages—the director field is continuously deformed; at a threshold voltage U_i—an irregular stripe system appeared; at a higher threshold voltage U_{II} (and only if $f > 70\text{Hz}$)—a regular stripe system existed. The detailed experimental results regarding these structures, and a phenomenological explanation are presented here.

Keywords: Liquid Crystals (6130), Ferroelectricity (7780), Optics (9200), Instabilities (4630L), Electrical Properties (7390)

INTRODUCTION

The research of chiral smectic C ($S_c{}^*$) ferroelectric liquid crystals is a very intensively studied field of the liquid crystal research because of the possibility to prepare from them fast switching display devices. The largest attention was paid to those materials which have large helical pitch relative to the usual sample thickness (some microns). This geometry makes possible to prepare bistable switching display elements with switching time being in the order of microseconds.[1]

Less attention was paid to the thick samples (where the sample thickness is larger than the pitch) because it is not possible to make bistable displays from them.

This disadvantage is really essential until the pitch p is larger than the visible light wavelengths. However if the pitch is in the visible light wavelength regime

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this disadvantage may be over compensated by other favourable properties. Due to the selective Bragg reflections these materials have a colour even looking them without crossed polarizers. Their colours depend on temperature (thermochromic materials).

Furthermore, as it was reported recently[2,3] they show a switching even in very small electric fields (theoretically without lower threshold) with fairly small switching times, large contrast and viewing angle.

This new switching behaviour is the direct consequence of the small pitch. The visible light cannot resolve the helix, thus the material behaves as an uniaxial system. The uniaxis is the average value of the directors (the long axis of the average refractive index). Without electric field it is parallel to the helical axis, however under the influence of small electric fields it deforms continuously (hereafter we refer to this continuously deforming director state as CDD state) yielding that the uniaxis turns away to the direction of the electric field. This continuous deformation of the director field results in a colour change placing the planar aligned material between crossed polarisers.

This behaviour holds however only in case of small electric fields. Increasing the electric field we reach an intermediate regime (the applied voltage is still smaller than the unwinding critical voltage) where the continuous director deformations are substituted by the appearence of some instabilities.

In this paper we report on our investigations regarding this intermediate switching regime.

We used a liquid crystal mixture which contains materials showing nonchiral smectic C phase with doping chiral component[2] thus having $S_c{}^*$ phase from 8°C up to 56°C. The material has a large spontaneous polarization ($P_o = 7\cdot10^{-4}$Q/m^2 at room temperature) and small pitch $P_o \sim 0.3\mu$m.

We describe our experimental results and suggest an explanation of the results.

EXPERIMENTAL

We used $d = 15 \pm 2\mu$m thick homogeneously planar aligned samples. The alignment was obtained by shearing at the S_A-$S_c{}^*$ phase transition temperature[4] without any surface treatments.

We applied three methods for our investigations.

1. Investigation of the diffraction pattern of the sample illuminated by a He-Ne laser ($\lambda = 6326$A) while driving the sample by various electric fields.
2. Visual observation of the sample texture in a polarizing microscope while applying various electric fields to the sample.
3. Observation of the time dependence of the transmitted direct beam intensity of a laser light (He-Ne, $\lambda = 6326$A) detected by a photodiode and screened on a digital oscilloscope.

All the experiments were done at room temperature ($T = 23 \pm 0.5$°C).

EXPERIMENTAL RESULTS

1. Diffraction measurement

Our planar S_c* sample can be regarded as a diffraction grating with the size of the grating being equal to the pitch p. For the diffraction condition we obtain that diffraction occurs only if $p > \lambda$. (λ = 6326A is the wavelength of the incoming light beam.) Because in our material $p \sim 0.3$ μm we could not see any diffraction when the material was in rest (only the direct trace was seen). Applying small voltages $U < 5$V no diffraction was found. Increasing the electric voltage up to a threshold value U_I a diffraction stripe appeared. The stripe was parallel to the helical axis and ended at a more intense spot indicating a maximal scattering vector q_I (this means a minimal wavelength λ_I of the appeared structure).

The geometry sketched on Figure 1 allowed for us to determine λ_I by measuring

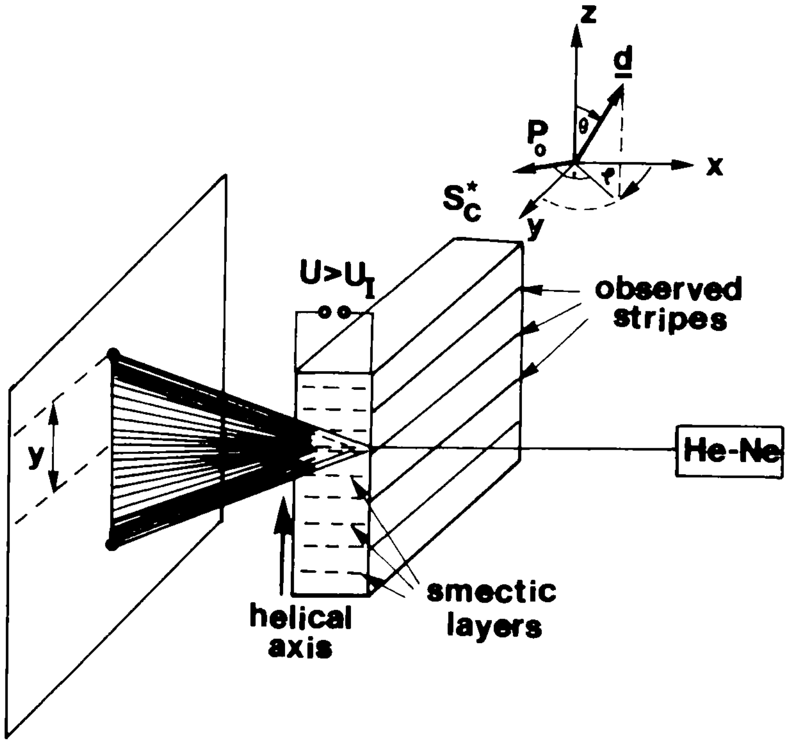

FIGURE 1 Sketch of the diffraction set up. The planar oriented thermochromic S_c* sample is illuminated by a He-Ne laser, while applying various electric voltages to the electrically conductive bounding plates. The diffraction pattern is seen on a screen placed at a distance of d from the liquid crystal film. At the top part of the figure the S_c* director coordinate system is seen. The director d makes an angle θ with the smectic layer normal being in the z direction; its projection to the smectic layer (XY plane) makes an azimuthal angle φ with the applied electric field direction (x axis). The resulting permanent polarization P_o is in the smectic layer and perpendicular to the director.

the distance y between the laser trace and the observation point (the end spot of the stripe) on the scattering pattern by the relationship:

$$\lambda/\lambda_I = y/(y^2 + d^2)^{1/2} \tag{1}$$

Writing this formula we supposed that the scattering was caused by disclination lines which are from each other by the distance λ_I. (d is the distance of the observation screen from the sample).

This type of light scattering could be observed until $f \lesssim$ 70–100Hz. Increasing the frequency the scattered spot intensity decreased. Within our measuring error we found that λ_I did not depend on the applied frequency. However there was a frequency dependence of the threshold voltage U_I as it can be seen on Figure 2 (open circles).

Further increasing the applied voltage *at low frequencies ($f <$ 70Hz)* no significant

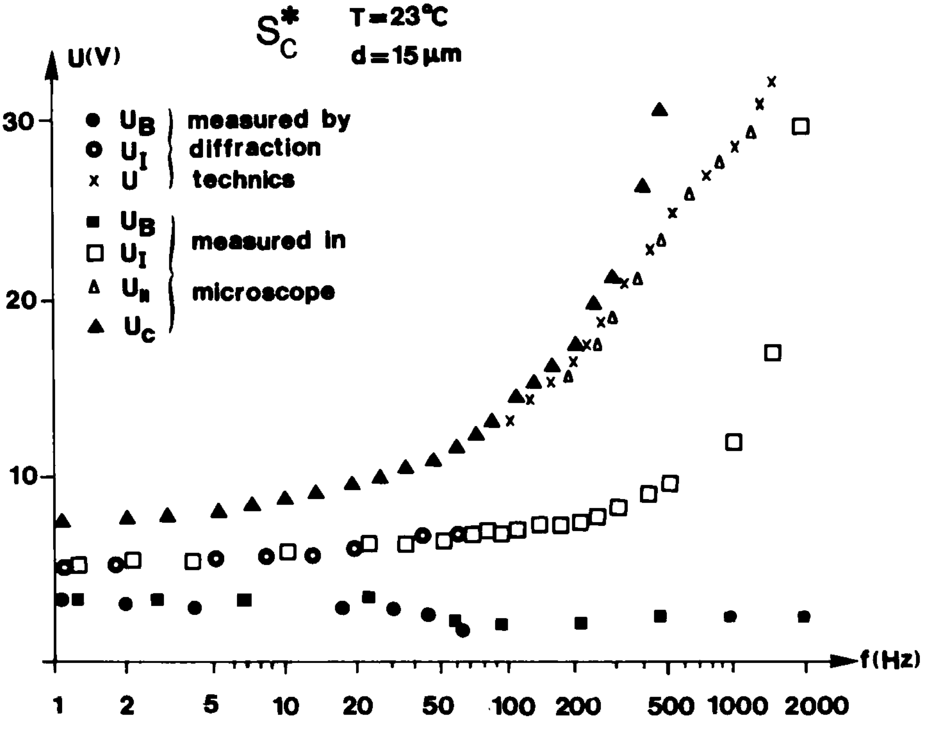

FIGURE 2 The frequency dependences of the threshold voltages observed visually by diffraction method and in the microscope. The threshold voltages U_I (where the irregular stripe system occurred) are denoted by open circles and open squares observed by diffraction and in microscope respectively. The full triangules represent the unwinding critical voltages at different frequencies. Both the $U_I(f)$ and the $U_c(f)$ functions show a large increase at high frequencies, however these frequencies are different: $U_c(f)$ has a large increase at $f \sim$ 500Hz, but $U_I(f)$ has at $f \sim$ 2KHz. At frequencies $f >$ 70Hz another stripe system appears at U_{II}. The measured U_{II} values are denoted by crosses (determined by diffraction technics), and by open triangulars (observed in microscope). Decreasing the applied voltages starting from the unwound state, a hysteresis can be seen: the irregular strip system disappear only at U_b ($U_b(f) < U_I(f)$).

change was found in the scattering pattern until the unwinding critical voltage U_c, where the diffraction pattern disappeared again. (For the unwinding critical voltage $U_c = 8V$ was found at static case. This value slightly increased with the frequency and reached $U_c = 10V$ at $f = 70Hz$.) Lowering the electric voltage from $U > U_c$ to U_c, the diffraction pattern appeared again without any hysteresis, but the intensity of the scattering stripe decreased relative to the intensity of the end-spot (which corresponds to λ_I). Also did not change the value of λ_I. Further decreasing the electric voltage we observed that the diffraction pattern did not demolish at U_I, but existed further until a significantly smaller value U_b. The frequency dependence of U_b is plotted on Figure 2 and indicated by full circles.

At higher frequencies ($f > 70Hz$) a different behaviour was found. Until $U < U_{II}$ no diffraction spot was seen. At U_{II} sharp diffraction spots appeared. Calculating from Equation 1 we obtained for its wavelength λ_{II} that it was larger than λ_I and slightly depended on the frequency. This dependence is shown on Figure 3, and the frequency dependence of U_{II} is plotted on Figure 2 (the measured values denoted by crosses). Increasing further the electric voltage the diffraction pattern vanished at U_c. Decreasing the electric voltage from $U > U_c$ the diffraction spots reappeared than disappeared without any hysteresis (i.e. at the same voltages when in case of increasing voltages).

2. Direct microscopical observations

Placing the sample between crossed polarizers the following main structures were observed in a microscope.

At zero electric voltage the texture (disregarding the impurities) was homogeneous (the light could not resolve the helical structure) (see Figure 4a). Observing the sample in incident transmitted light by eye without polarizers (as the consequence of the selective Bragg reflection) the sample was found to be violet-blue.

At low frequencies ($f < 70Hz$) increasing the applied voltage the colour changed continuously (e.g. from green to pink placing the sample between crossed polar-

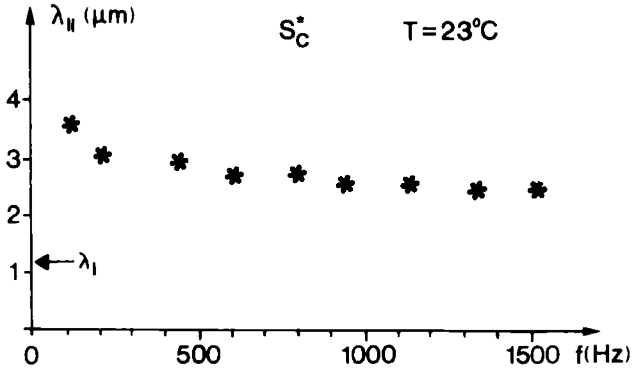

FIGURE 3 Frequency dependence of the wavelength λ_{II} characterising the pitch of the regular stripe system appeared at U_{II}.

izers). However at the threshold voltage U_I (in accordance with the threshold value observed by diffraction) irregular stripe system (hereafter we call it "IS" state) appeared parallel to the helical axis. Wide and fine lines coexisted as it is seen on Figures 4b and 4c.

This structure is similar to the one observed and reported by Y. Ouchy *et al.*[5] (They measured a 3.5 μm thick sample owing a pitch $p = 0.6\mu m$.)

Increasing the applied voltage the continuous lines teared up and dotted stripes could be observed (see Figure 4d).

Finally, reaching the unwinding critical voltage U_c, an unwound sample created as it can be seen on Figure 4e. (We need to note that the textures of the unwound and the rest states are slightly different: the focal conics which can be seen in Figure 4a are missing in the unwound state.

At high frequencies ($f > 70Hz$) we have found a different sequence of texture changes. When $U < U_I$ (see Figure 5a at $f = 400Hz$) a continuous change of the colour could be observed if the sample was placed between crossed polarizers.

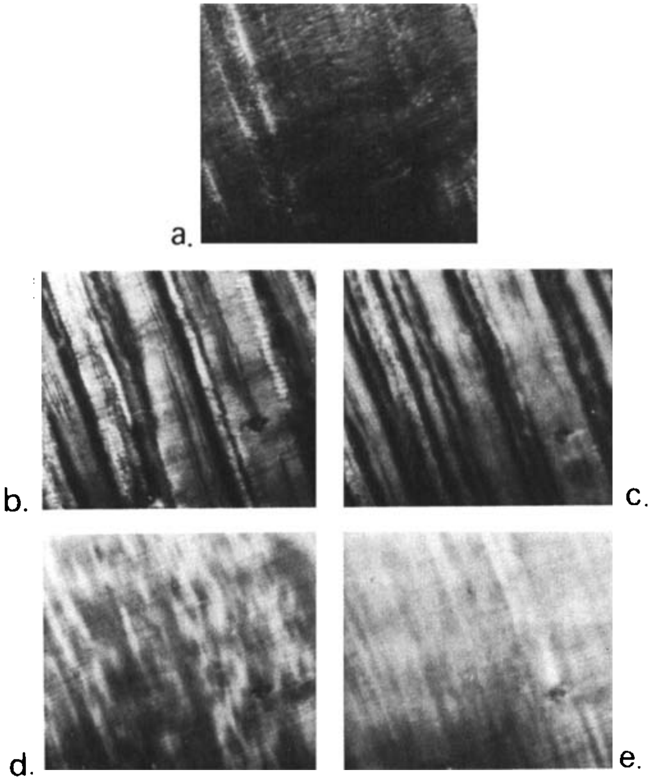

FIGURE 4 The main structures appeared in the planar oriented S_c^* thermochromic liquid crystal by applying different voltages with the frequency $f = 30$ Hz on the electrodes at $T = 23°C$; observed in polarizing microscope: (a) The texture is in rest ($U = 0V$). Because the pitch is smaller than the visible light wavelengths the helical structure looks to be homogeneous; (b) and (c) $U = 8V$ and $U = 9V$ respectively applied on the electrodes. The pictures show an irregular stripe system; (d) Dotted stripes at $U = 9.5V$; (e) $U = 11V$. Homogeneous unwound texture.

At U_I the "IS" state was observed similarly to the lower frequency case, but the contrast was smaller (Figure 5b at $f = 400\mathrm{Hz}$).

Further increasing the applied voltage we reached a region $U > U_\mathrm{II}$ where more or less regular stripes appeared with the distance between the stripes being constant. Hereafter we call this state to "RS" state (at $U = 21\mathrm{V}, f = 400\mathrm{Hz}$ it is shown on Figure 5c).

Finally at U_c the sample has got unwound (at $f = 400\mathrm{Hz}$, $U = 30\mathrm{V}$ this state is seen on Figure 5d).

Decreasing the applied voltage from $U > U_c$ we have not found any hysteresis at U_c and at U_II but found at U_I. The observed threshold functions—together with the values measured with the diffraction method—are plotted on Figure 2 (open squares for $U_\mathrm{I}(f)$; open triangulars for $U_\mathrm{II}(f)$; full triangulars for U_c; and full squares for U_B). Comparing these functions with data observed in our diffraction measurement we could see a correspondence between the "IS" state seen on microscope and the diffraction stripe characterised with the minimal wavelength λ_I. Also can be seen a correspondence between the "RS" state and the observed diffraction spot characterised by the wavelength λ_II.

3. Switching characteristics observed by photodiode

We analyzed the time dependence of the transmitted light intensity while applying sinusoidal and square shape AC voltages without and with different bias voltages on the planar oriented sample (Figures 6, 7, 8).

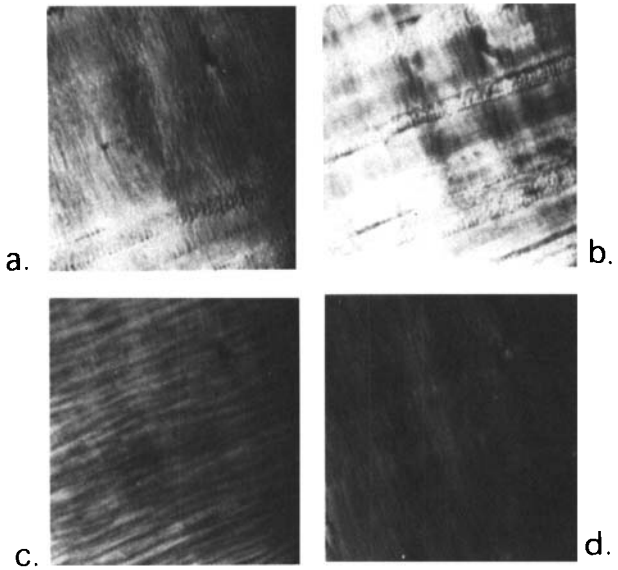

FIGURE 5 The main visible textures when we apply different voltages with the frequency $f = 400$ Hz on planar S_c^* thermochromic liquid crystal at room temperature ($T = 23°\mathrm{C}$): (a) $U = 0\mathrm{V}$. Helical structure with $p \sim 0.3\mu\mathrm{m}$; (b) $U = 8.4\mathrm{V}$. Irregular stripe system; (c) $U = 18\mathrm{V}$. Regular stripe system. The distance between the stripes is about $3\mu\mathrm{m}$; (d) $U = 21\mathrm{V}$. Unwound texture.

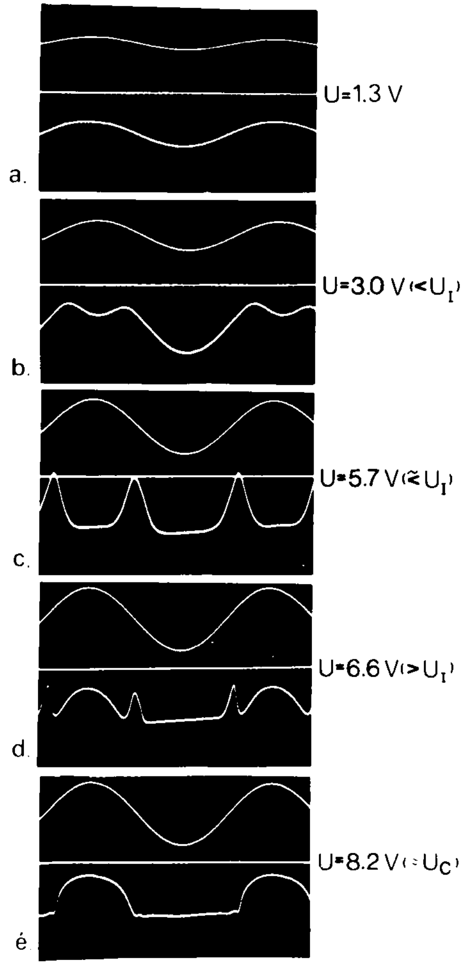

FIGURE 6 Oscillograms representing the electrooptical responses of a S_c^* thermochromic liquid crystal at room temperature ($T = 23°C$) by applying different sinusoidal voltages with $f = 30Hz$ on the electrodes. The upper parts show the time dependences of the applied voltages, the lower parts represent the time dependences of the negative of the transmitted light intensities measured by a photodetector: (a) $U = 1.3V$; (b) $U = 3.0V$ ($U < U_\mathrm{I}$); (c) $U = 5.7V$ ($U \sim U_\mathrm{I}$); (d) $U = 6.6V$ ($U > U_\mathrm{I}$); (e) $U = 8.2V$ ($U \sim U_c$).

On the upper parts of the photos the applied voltage signals, and the lower parts the negative of the transmitted light intensity can be seen (where the oscilloscope trace is maximal the transmitted light intensity is minimal). During the observation the sample was placed between crossed nicols, so that the optical axis of the sample made 8° with the axis of one of the polarizers. The frequency of the applied voltages is 30Hz.

In case of symmetrical AC voltages depending on $U_c(f)$ 5 different types of responses could be distinguished (Figure 6a–e).

Until a certain voltage (at $f = 30Hz$ until $U = 1.5V$) the optical response was

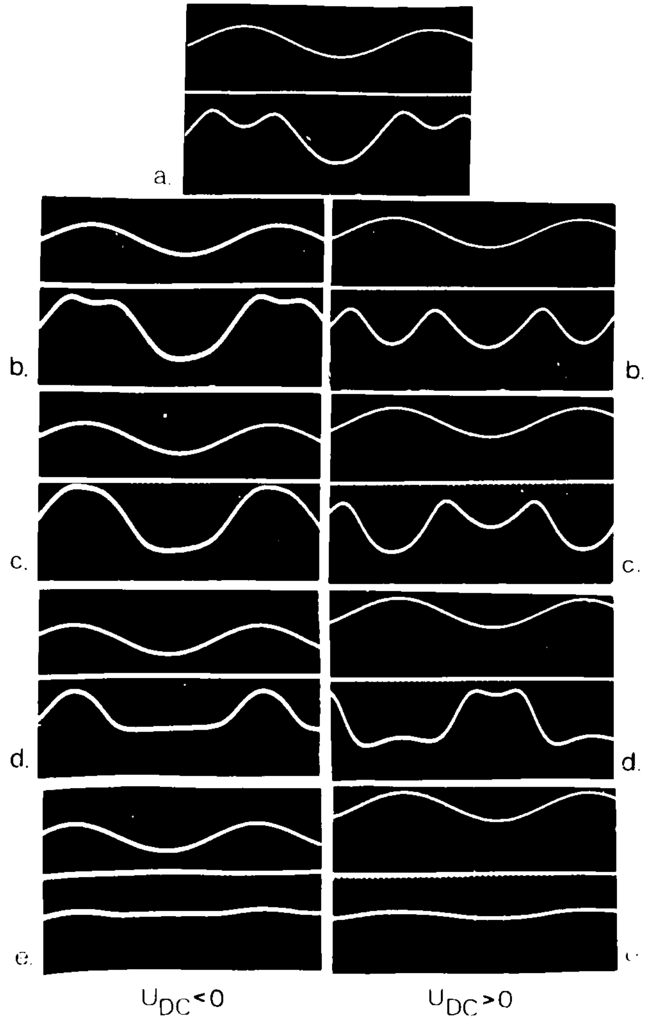

FIGURE 7 The effect of different bias voltages superponed to an alternating sinusoidal one (f = 30 Hz, U_{AC} = 3V) applied at room temperature (T = 23°C) on a planar S_c^* thermochromic liquid crystal. The oscillograms show the electroptical responses. On the upper parts, the applied sinusoidal voltages; on the lower parts, the time dependences of the negative of the transmitted light intensities measured by a photodetector can be seen. In pictures on left side the applied bias voltages were negative, while pictures on right side pictures represent the responses when $U_{DC} > 0$: (a) U_{DC} = OV; (b) $|U_{DC}|$ = 1.0V; (c) $|U_{DC}|$ = 1.5V; (d) $|U_{DC}|$ = 2.8V; (e) $|U_{DC}|$ = 3.6V.

found to be linear: applying sinusoidal voltage function the transmitted light intensity function was also sinusoidal as it is seen on Figure 6a at U = 1.3V. It indicates that the sample is in the continuously deforming director (CDD) state. At higher voltages than +1.5V the transmitted light intensity increased (the amplitude at the maximum of the lower oscilloscope trace decreased) while at negative applied voltages the linear response still remained. In case of U = 3.0V the response function can be seen on Figure 6b. This asymmetric response

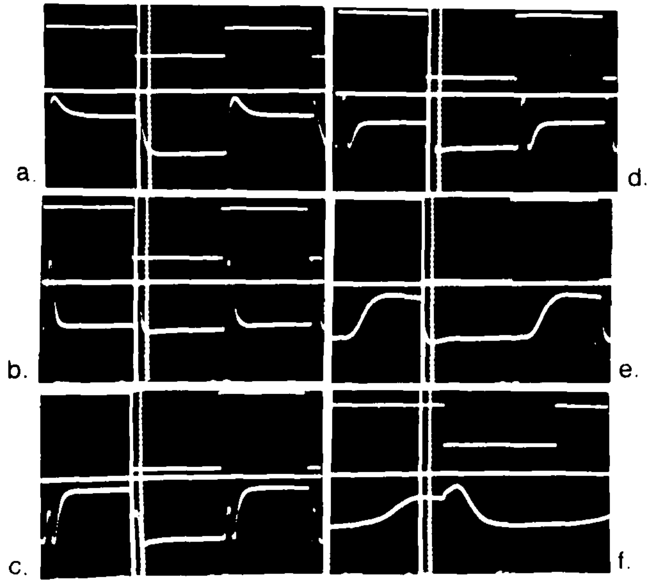

FIGURE 8 Oscillograms representing the switching behaviours of a planar S_c* thermochromic liquid crystal. On the upper parts the applied square shaped voltages, on the lower parts the time dependences of the negative of the transmitted laser light intensities (measured by a photodetector) can be seen. The sample was at room temperature (T = 23°C). The frequency of the applied voltages in each case was f = 300Hz: (a) U = 4.7V τ = 200μs; (b) U = 8.2V τ = 200μs; (c) U = 10.4V τ = 200μs; (d) U = 13V τ = 170μs; (e) U = 15 V τ = 170μs; (f) U = 18.5V τ = 1.3ms.

can easily be explained on the basis of the earlier results regarding the temperature dependence of the tilt angle and the applied voltage dependence of the direction of the effective optical axis.[3] At f = 30Hz and U = 1.5V the optical axis turns away by 8° so that at U = 1.5V the effective optical axis points to the direction of the polarizer (the light intensity is minimal, i.e. the oscillogram trace is maximal). However at $U = -1.5$V the effective optical axis makes 16° with the same polarizer, thus the transmitted light intensity is not maximal yet. Consequently, increasing slightly the applied voltage amplitude the material is still in the CDD state, but the oscilloscope trace of the response function has a local minimum minimum at positive voltages. At U = 3.0V this situation is seen in Figure 6b.

At U = 5.7V the transmitted light intensities decreased both at +5.7V and −5.7V. On the basis of our microscopical and diffraction findings it is due to the appearance of the irregular stripes (IS state). In this "IS" state the responses can be seen on Figures 6c and 6d (f = 30Hz; U = 5.7V and U = 6.6V respectively).

Reaching the unwinding critical field U_c (at f = 30Hz U_c = 8.2V) the response of the system resembles us to the behaviour of a comparator: the response for the sinusoidal applied voltage is practically square shaped. (Figure 6e). At $U \leq U_c$ the material is in the unwound stable state which does not vary when even further increasing the applied voltage. On Figure 6e we can see that the material shows a hysteresis: decreasing the applied voltage below U_c the structure does not change until the polarity of applied voltage is reversed. It shows that to demolish the unwound state a rather long time or a driving force of the reversed electric field is needed.

The effect of the bias voltages mixed with the alternating sinusoidal one is represented on Figure 7 (f = 30Hz, U_{AC} = 3V). The textures in case of $U_{DC} > 0$ can be seen on the right hand side, and in case of $U_{DC} < 0$ on the left hand side.

The oscilloscope traces can be explained similarly as it was done in case of Figure 6a–e. Figure 7a is identical to Figure 6b. In Figure 7b $|U_{DC}|$ = 1V bias voltage was applied together with U_{AC} = 3.0V. The effect of 1V bias voltage is to get turn away the effective optical axis by 6°. In case of $U_{DC} = -1$V and $U_{DC} = +1$V the angle between one of the polarizer and the effective optical axis is $\langle\theta\rangle = 14°$ and $\langle\vartheta\rangle = 2°$ respectively. Due to the effect of U_{AC} = 3.0V at f = 30Hz the effective optical axis oscillates around its static position by the angle 15°. It means that at positive voltages still there is a little minimum in the oscilloscope trace.

In Figure 7c $|U_{DC}|$ = 1.5V. It makes the effective optical axis to turn away by 9°. In case of U_{DC} = 1.5V the effective optical axis makes 17° with the polarizer, thus due to the influence of U_{AC} the effective optical axis oscillates between 2° and 32° consequently, the response of the sample is linear now.

The photos d. represent the responses when $|U_{DC}| + U_{AC} > U_I$ was, thus the "IS" state existed.

In photos e. practically no intensity change can be seen. Here $|U_{DC}| - U_{AC} > 0$ ($|U_{DC}|$ = 3.6V) thus there is no polarity change. We observed that the response decreased to zero just when $|U_{DC}| = U_{AC}$ showing that there is no lower threshold for the "CDD" mode.

In Figure 8 we represent the electrooptical responses applying symmetrical square wave voltages on the sample. Photos a. and b. show the responses at the "CDD"; photos c. and d. represent the response in the "IS" state; photo e. was taken when dotted lines were seen in the microscope and finally, photo f. was taken when regular stripes (the "RS" state) existed.

The advantage of the square wave driving arises from the fact that it makes possible to determine the switching times. In accordance to References 2, 3 we obtained that in the "CDD" state the switching time τ is τ = 200μs (the switching time was determined by the rising time from 10% of transmittance up to 90% of transmittance).

In the "IS" state the determination of switching time has become ambiguous because of the complicated response form. However we can see on Figures 8c–e that the switching times in the "IS" state are comparable to that in "CDD" state.

The switching time abruptly increased however, as the applied voltage reached U_{II}. At U_{II} the switching time is $\tau \sim 4$ ms which decreases nearly linearly with increasing voltages (at $U = U_c$ $\tau \sim 1.3$ ms was found).

DISCUSSION

By three experimental methods we proved that as an influence of electric voltages the following four structures exist depending on the electric voltage $U(f)$.

A. If $U(f) < U_I(f)$ ($f \geq 0$Hz) the original helix structure continuously deformes while remaining the original periodicity $p \sim 0.3\mu m$. We called it continuously deforming director ("CDD") state.

In the microscope a homogeneous structure could be visible with its colour depending on the electric voltage. Applying square wave voltages with $U(f) < U_I(f)$ one can switch between two colours even at very low electric fields.

In this state one can describe the switching process easily as follows. The equation for the helix unwinding in an alternating electric field $E = E_o \exp(i\omega t)$ reads:

$$K\theta(\delta^2\varphi/\delta z^2) - \gamma\theta(\delta\varphi/\delta t) + P_oE\sin\varphi = 0 \tag{2}$$

Here we chose the coordinate system so that z let be in the direction of the helical axis, thus the azimuthal angle φ reads in rest: $\varphi = q_oz$, where q_o is the wave number of the helix ($q_o = 2\pi/p_o$, $p_o \sim 0.3\ \mu m$). Furthermore, we used the following notation:

—P_o is the absolute value of spontaneous polarization,
—γ is the rotational (around the azimuthal angle) viscosity of the substance,
—θ is the tilt angle depending only on the temperature, and
—K is the Frank's elastic constant describing the director twist.

At "CDD" we can describe the variation of azimuthal angle φ as:

$$\varphi = q_oz + \Delta - \exp i(\omega t + \delta) - \sin q_oz \tag{3}$$

If we use the $\sin\varphi \sim \sin q_oz$ approximation, Equation (2) can be solved analytically and one obtains that:

$$\Delta = P_oE_o/(2Kq_o^2\theta - (1 + \tau_o^2\omega^2)) \tag{4}$$

where $\tau_o = \gamma/(Kq_o^2)$ describes the relaxation time of the director. This is proportional to the switching time of the sample τ, thus the above calculation showed explicitly that τ does not depend on the electric voltage in this approximation. Our experimental observations show that this approximation holds only until $E < U_I/d$ ($\sim 3 - 10^5$V/m at low frequencies).

B. The above mentioned calculation does not hold if approximation $\sin\varphi \sim \sin q_oz$ is not valid (at high voltages). In this case higher order terms of z appear in Equation (2). In addition taking into consideration the boundary conditions Equation (2) cannot be solved simply analytically. However experimentally we studied the influence of electric voltages $U > U_I$ and found that an irregular parallel stripe system existed ("IS" state). For the minimal wavelength $\lambda_I \sim 1.15\mu m$ was found.

On Figure 4 one can be see that in "IS" the boundaries of stripes are rather rough.

This fact, and the hysteresis which we observed creating and demolishing the "IS" state (see the difference between $U_I(f)$ and $U_b(f)$ on Figure 2) suggest that these stripes are the consequence of surface disclinations.[6] The rough lines reflect the nonuniformity of the surfaces.

We think that this nonuniformity is responsible even for the observed value of the minimal wavelength of the stripes.

Explaining this statement we start from the model regarding to the structure of a planar S_c* (introduced by Glogarova *et al.*[7]) and follow the considerations of Y. Ouchy *et al.*[5] (which they made explaining the electrooptic switching mechanism they observed on a 3.5μm thick sample filled with S_c* material with helicoidal pitch 0.6μm).

As in static electric fields we obtained that the threshold voltage amplitude U_I was independent of the applied voltage polarity, we can conclude that—within the measuring error of U_I—the director field of our material was symmetric with respect to the boundary plates. (Figure 9a)

In various electric fields this structure changes as follows. Applying electric fields in "CDD" state) the internal disclination lines shift toward one of the bounding plates (determined by the electric field polarity), and increasing U one part of the disclination lines reach the bounding plates (Figure 9b). Because of the nonuniformity of the bounding plates (consequently of the sample thickness d, which variation can reach even 10–20%) the lines touch the plates at different applied voltages. Where the lines reached the plates the internal disclination lines become surface disclination lines, which—as increasing the electric field—bifurcate and move in opposite directions along the surface plates (see Figure 9c and 9d). This sidewise movement results in domaines with different orientations at the surfaces. Due to the nonuniform shape of the surfaces the sizes of these domaines are random. This causes the irregular stripe system found in microscope, and consequently the continuous stripe observed in the diffraction measurement. According to this model the wavelength of the shortest detectable periodicity must be equal to the original pitch multiplied by integer numbers.

Our measurement made us possible to measure only four or larger number times of the pitch. (The diffraction condition was satisfied also in case of three times of pitch, however it should have appeared at very large diffraction angles which was not possible to detect in our set up.)

Thus we conclude that the λ_I which we observed must be equal to $4 \cdot p$. From our data it means that $p \sim 0.29 \pm 0.01\mu m$ at $T = 23°C$.

C. Only in alternating electric fields, if $f > 70Hz$, at voltages $U_c > U > U_{II}$ ($U_{II} > U_I$) we observed another stripe state. Here the stripes were found in equal distances from each other, therefore we named it regular stripe system ("RS" state).

The existence of the "RS" state must be in connection with internal disclinations because the lines were not rough but fairly straights.

The fact that "RS" existed only at high frequencies ($f > 70Hz$), indicates that it is due to dynamical processes.

For its theoretical explanation we should consider the director equation Equation (2) with taking into consideration also the influence of the dielectric coupling. The resulting equation is a double sine-Gordon equation. The analysis of its solutions in case of our experimental circumstances would be a very difficult task and needs further examinations. This is not the subject of this paper.

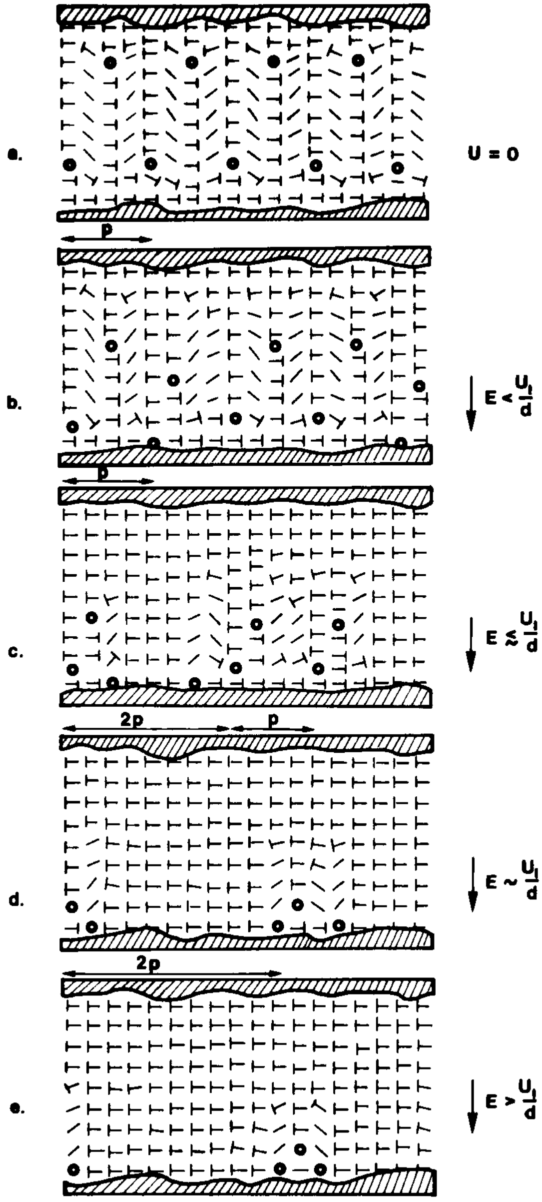

FIGURE 9 Model for describing the structural changes of planar S_c* samples due to applied electric voltages. The model based on the model of Glogarova *et al.*[7] and Ouchy *et al.*[5] with taking into consideration the influence of the nonuniform bounding plates. The nails represent the directors. (The head of the nail indicates the end of the ditector which are turned toward the observer.) The open circles represent the dechiralization lines ($\pm 2\pi$ disclination lines). p is the helical pitch. (a) U = OV. The sample is in rest. (b) O < $U \sim U_\mathrm{l}$. The dechiralization lines shift to the direction of the applied electric field E. (c) $U \sim U_\mathrm{l}$. Where the sample thickness is smaller than the mean value the dechiralization lines touch the bounding plates. (d) $U = U_\mathrm{l}$ One part of the internal disclination lines became surface disclinations which bifurcate and move in opposite direction along the bounding plates. (e) $U > U_\mathrm{l}$ At some places uniform structure exist, while in other places the sample is still chiral. This results in the observed irregular stripe system.

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