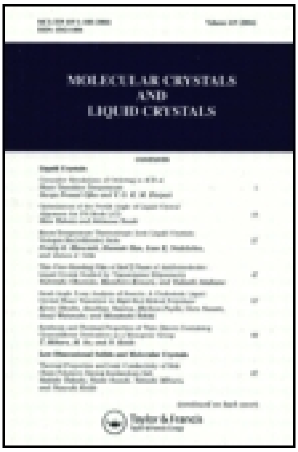

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A Discrete Change of the Rotation Angle in Twisted Structures

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A DISCRETE CHANGE OF THE ROTATION ANGLE IN TWISTED STRUCTURES

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Abstract

A forced relaxation of LC molecules placed in an usual twist cell was realised at relative low AC electric field frequencies in a nematic LC material, possesing an inversion of dielectric anisotropy sign upon frequency. Some changes of periodic structures were observed in range of critical frequencies. A discrete change of the rotation angle of the NLC structure was observed. The possibility of the practical use of this penomena is discussed.

Modulated structures have been studied at relatively high frequencies of the applied electric field in dielectric regime. When an electric field is applied perpendicular to a nematic layer, Williams domains appear at a well-defined instability threshold voltage [1]. It's known that these domains orient themselves perpendicular to the main direction of the director averaged over the thickness of the layer. Domain's directions make an angle ±π/4 with the rubbing directions. In usual twist- cells the Williams domains in the different regions usually are perpendicular to each other and make an angle π/4 with the rubbing directions [2]. Dichroic measurements of the cells may give information on the twist sign [3]. We operate with twist-angle ϕ in laboratory coordinate system

Here Φ - twist angle, $\vec{n}_a$ and $\vec{n}_b$ - director of nematic molecules at glass surfaces. The direction α of domains relatively $\vec{n}_a$ can by expressed as

$$\alpha = \frac{\Phi}{2} \pm \frac{\pi}{2} \qquad (1)$$

For example, twist angle $\Phi = \pm\pi$ for elongated domains in dielectric regime, when $\vec{n}_a \parallel \vec{n}_b$ (photo 1). For opposite twist case $\Phi = \pm\frac{\pi}{2}$ (photo 2).

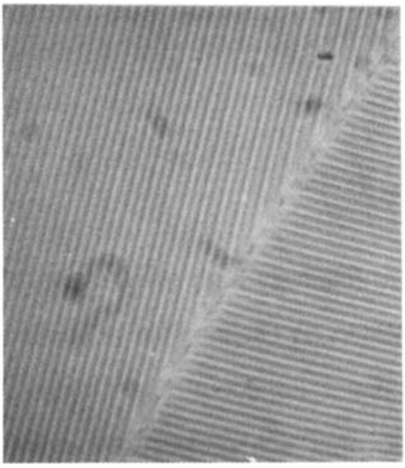

Photo 1.

Williams domains at $\Phi = 0°$ (right) and $\Phi = 180°$ (left)

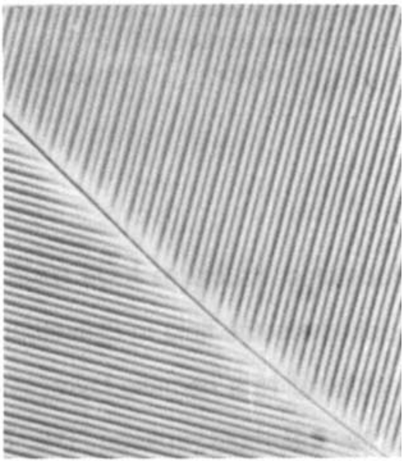

Photo 2.

Williams domains at $\Phi = \pi/2$(upper) and $\Phi = -\pi/2$(lower)

It's well known, that a twisted structure is stable, when $\Phi >> \pi$ and pretilt angle $\Theta >> 0°$. In our experiment pretilt angle Θ was varied. This led to drastical changes of the twist angles $\Phi_0 \leftrightarrow \Phi_\pi$ (when $\dot{n}_a \parallel \dot{n}_b$) and $\Phi_{\pm\frac{5}{2}\pi} \leftrightarrow \Phi_{\pm\frac{1}{2}\pi} \leftrightarrow \Phi_{\pm\frac{3}{2}\pi}$ (when $\dot{n}_a \perp \dot{n}_b$).

A behaviour of two tolane-based mixtures was studied by switching the frequency of the applied field from low to high (in materials showing a strong dispersion of $\varepsilon_{||}$) at room temperature. The cell was prepared by standard method. Two planar oriented glass electrodes were coated with polyimide and then rubbed to provide the preferred orientation on each plate. The thickness of the cell was 13.85 µm. The preferred orientation of two opposite plates was 0° or 90°. The electrooptical measurements were performed with He-Ne laser P=1mW in electric field of low and high frequency, using polarising microscope . A dependence of the threshold voltage (creation of Williams domains) upon frequency was measured by decreasing step by step frequency and amplitude. It's shown in fig.1 and in fig.2.

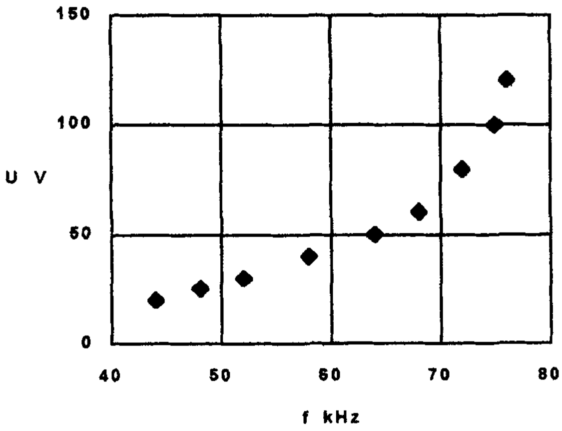

Fig.1.A dependence of a threshold voltage of Williams domains vs frequency for a case $\Phi = 0°$ (nematic LC No 2).

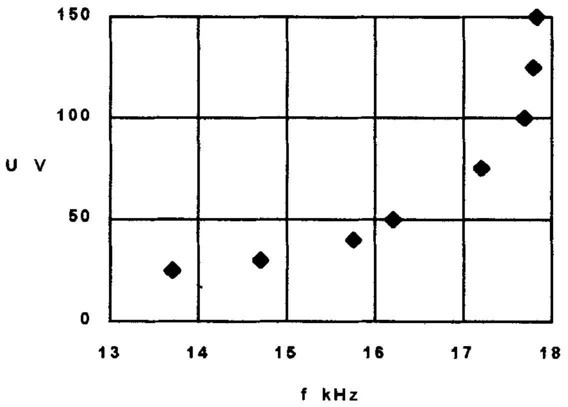

Fig.2 .A dependence of a threshold voltage of Williams domains vs frequency for a case Φ =90° (nematic LC No 1).

Fig.1 corresponds to a case, when the angles of cell orientation φ=0° , fig.2 - when φ=90°. This dependence is exponent - like. A stable domain structure was created, when the voltage was lower than the threshold value. In this case we have two critical frequencies - f_{c1} and f_{c2}, between which domain structure exists. At critical frequency f_{c2} threshold voltage $U_c \rightarrow$ infinity. When the temperature increases, the range f_{c1}-- f_{c2} collapses to frequency f_{c3}, over it the domain structure does not exist. A dependence of the domain period upon critical voltage U_c is represented in Fig.3.

When $U>U_c$, domain structure exist at lower frequencies ($f<f_{c1}$), just these domains occupy only part of area, separated by disclinations. In every area there are zones of opposite pretilt angle of molecules (photo 3).

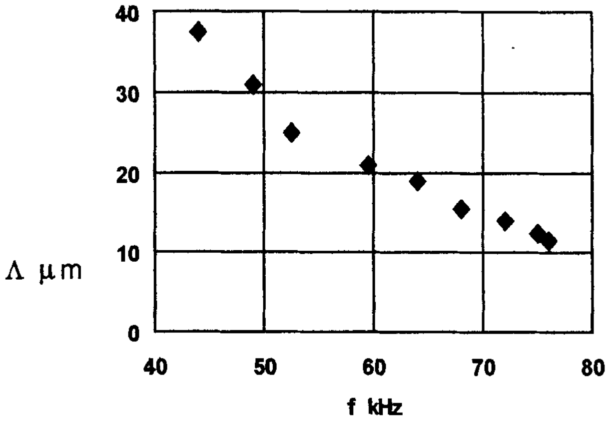

Fig.3. A dependence of Williams domains period upon field frequency at a voltage close to the threshold (nematic LC No 2).

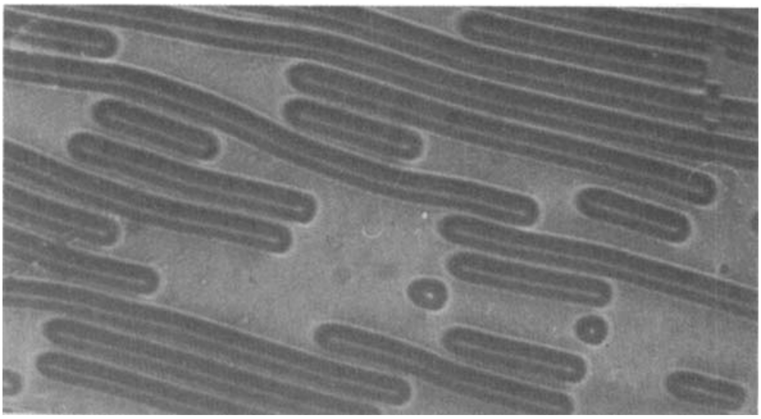

Photo 3. A transition of domains to zones (separated by disclination lines) of anti-parallel orientation of the LC molecules,.

When AC electric field is switched off, disclinations disappear. If the amplitude of AC electric field is increased after domain structure formation, this domain structure is not stable.

When the voltage is increased further, a hexagonal structure is formed, where separated directions are 0°, $\Phi/2$ and Φ. At the highest voltages the structure comes to a turbulent motion.

After turbulence state it's possible to observe different phenomena depending upon applied frequency. There exists a critical frequency f_{CC} , over which all the reorientation phenomena are possible. When $f<f_{CC}$ an increase of voltage leads to a homeotropic orientation. At $f\approx f_{CC}$ turbulence motion was observed till 250 V. Critical frequency f_{CC} is very sensitive to temperature and at high temperatures it shifts to high values of frequency. When frequency just a little exceeded f_{CC}, turbulence motion disappeared and periodic structure was formed again, similarly to preceding turbulence state. The only difference- $\Phi/2$ direction disappears and the only domains with 0° and Φ directions remain. After electric field is switched off, an optical active state remains, with twisting angle $\Phi = -3/2\pi$, or $\Phi = 3/2\pi$ .This angle depends on the value of the voltage, which was applied to cell prior to switching off The spontaneous motion to the states $\Phi = \pm\pi/2$ starts from surface defects in states $\Phi = \pm 3/2\pi$. Williams domains were formed in this situation near threshold regime (photo 4).

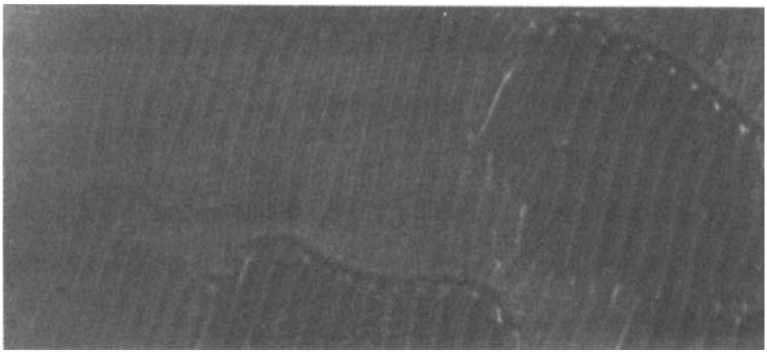

Photo 4. William s domains in the regions with $\Phi = \pi/2$ and $\Phi = 3\pi/2$.

When an applied voltage was raised further, a twisted structure with $\Phi = \pm 5/2\pi$ was created in small areas.

Here described method for creation twisted structures with $\Phi > \pi/2$ is not unique. The discrete change of the rotation angle $\Phi > \pi/2$ in twisted structures was studied in a special regime with dual frequency driving. When voltage (U=10V, f=50kHz) was applied to the cell to cause a forced relaxation, rotation moment of molecules was created and stable, supertwisted $\Phi = 3/2\pi$ structure realised with discrete optical transmission 17.3% and contrast K=5.7. This state was quasi stable, i.e., after few minutes it returned to the initial state independently from an applied voltage and its frequency. We determined that this quasi stability depended upon local surface defects, which served as centers of the NLC molecules spontaneous reorientation. When the quantity of surface defects was decreased (especially when electrodes were coated by a SiO film) supertwisted $\Phi = 3/2\pi$ structure was stable during 30 min. at U=10÷20V, when $f_1 << f_C$ and $f_2 > 3f_C$. At lower voltages and frequencies (U<10V $f_2 < 2f_C$) we had well-known dual frequencies drive twist effect. At higher voltage (U>20V) in local region (not in all cell) a structure was created with $\Phi = 5/2\pi$, transmittance 30%. Switching time in the NLC layer (d=13.85μm) was measured by an application of meander form signal (U=10V). In normal twist effect case with a free relaxation, switching time "on" and "off" was 25 ms and 100 ms, accordingly. In a forced relaxation case, when super twisted structure ($\Phi = 3/2\pi$) was created, switching time was 3÷4 ms in all the cell. In dynamic regime a modulation was realised with a period 4 ms. Switching time was 3÷5 times shorter as compared with that in case of an usual dual frequency twist effect.

From these data we may see that it's possible to realise a super twisted

(Φ =3/2 π) LCD structure in a usual twist cell, at much simpler technological requirements as to compare with other methods.

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