

INFLUENCE OF A SURFACE CONDITION ON THRESHOLD CHARACTERISTICS OF FERROELECTRIC LIQUID CRYSTALS

A.R. IMAMALIYEV, S.Z. TEMIRNIYAZOVA

Baku State University
Baku 370148, Z.Khalilov str.23

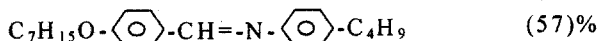
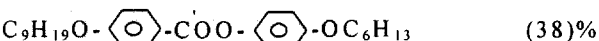
In this paper the dependence of ferroelectric liquid crystal threshold voltage on surface treatment (orientant covering and rubbing) has been experimentally studied and the simple theoretical model explaining this results has been proposed.

1. INTRODUCTION

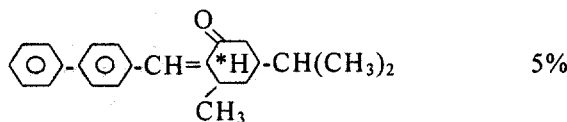
Ferroelectric liquid crystals (FLC) attract the attention of researchers because of their high sensitivity to external electric field. As a result of strong interaction of spontaneous polarization with electric field the submicrosecond electrooptic effect occurs in thin planar sample of FLC [1]. In practice the threshold voltage of this effect that depends on material parameters of FLC and surface conditions [2] plays an important role. In this paper the dependence of threshold voltage on surface treatment (orientant covering and rubbing) has been experimentally studied and the simple theoretical model explaining this results has been proposed.

2. EXPERIMENT

An object of investigation was the induced ferroelectric liquid crystal that was obtained by doping of smectic C matrix



with polar chiral dopant



The spontaneous polarization per unit tilt angle for this FLC is equal to $16\text{nC}\cdot\text{cm}^{-2}\text{deg}^{-1}$.

The FLC-cell consist of thin film (about $5\mu\text{m}$) of FLC between two plane-parallel glass plates separated by thin teflon spacer. The internal surfaces of plates are covered by thin transparent film of In_2O_3 and undergo further treatment. The later includes the covering by polyimide lacquer in order to obtain a planar orientation and the rubbing to achieve the monodomination of the sample.

The measurement was carried out in the device on the basis of polarizing microscope. The threshold voltage was obtained from transmittance-voltage dependence, when applying triangular wave to the cell. As a threshold voltage we take a value of voltage for which a transition to final uniform state starts.

The results of the measurement are presented in the following table.

Table

№№	Surface conditions		Cell thickness $d, \mu\text{m}$	Tilt angle θ, deg	Threshold voltage U_{th}, V	$\frac{U_{th}}{d\theta}$
	Presence of orientant	rubbing				
1	-	-	6	8	1,7	0,16
2	-	+	6	11,5	2,3	0,13
3	+	-	5,6	7	1,8	0,25
4	+	+	6	11	2,5	0,18

3. DISCUSSION

We propose a simple model qualitatively explaining these experimental data. The surface free energy density for ($\theta \ll 1$) can be presented in the form [4].

$$F = \int_{-d/2}^{d/2} \left[\frac{1}{2} G_\phi \theta^2 \left(\frac{\partial \phi}{\partial x} \right)^2 - P_s E \sin \phi \right] dx + (\mp W_1 \theta^2 \sin \phi + W_2 \theta \cos^2 \phi + W_3 \theta^2 \sin^2 \phi) \quad (1)$$

The first term in the integrand is the elastic energy, G_ϕ is the elastic constant corresponding to azimuthal angle change along the cell thickness, i.e. X axis (fig.1). The second term is interaction energy of the spontaneous polarization P_s and external electric field \vec{E} .

The first term in the surface energy is its polar part. Depending on the orientant nature the spontaneous polarization is directed towards the surface or from it: for

instance, the condition $\left(\phi \left(\frac{d}{2} \right) = -\phi \left(-\frac{d}{2} \right) = \frac{\pi}{2} \right)$ corresponds

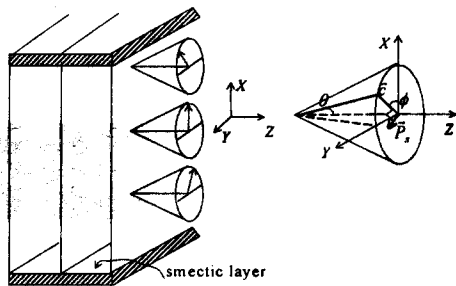
to the minimum of polar part of the surface energy. The second contribution is the surface energy due to dispersion interaction of liquid crystal molecules with surface, which tends constrain molecules parallel to surface

$\phi \left(\frac{d}{2} \right) = \phi \left(-\frac{d}{2} \right) = \pm \frac{\pi}{2}$. The surface profiling (rubbing) that is

necessary to obtain the monodomain sample generates an opposite effect: it tends to align molecules parallel to Z axis

$\left(\phi \left(\frac{d}{2} \right) = \phi \left(-\frac{d}{2} \right) = 0 \text{ or } \pi \right)$ which was taken into account by

the third part of the surface energy. Coefficients W_1, W_2 and W_3 are corresponding coupling energies.



The minimization of the free energy (1) with respect to azimuthal angle leads to balance torque equation

$$G_\phi \theta^2 \frac{\partial^2 \phi}{\partial x^2} + P_s E \cos \phi = 0 \quad (2)$$

with boundary conditions

$$F' = \frac{1}{2} G_\phi \theta^2 \left(\frac{\partial \phi}{\partial x} \right)^2 \Big|_{-d/2}^{\xi} + W \sin \phi \left(-\frac{d}{2} \right) - (W_2 - W_3) \cos^2 \phi \left(-\frac{d}{2} \right) \quad (4)$$

The first integral of equation (2) gives

$$\left(\frac{d\phi}{dx} \right)^2 = \frac{2}{\xi^2} (1 - \sin \phi)$$

After a substitution of this expression into the equation (4) it is not difficult too see that the value $\phi(-d/2) = -\pi/2$

$$U_{th} = \frac{[W_1 + 2(W_2 - W_3)]^2 \theta^2 d}{G_\phi P_s} \approx \frac{(W_1^2 + 4\Delta W) \theta^2 d}{G_\phi P_s} \quad (5)$$

Since $P_s \sim \theta$, the ratio $U_{th}/\theta d$ does not depend on a tilt angle for given substance and depends only on surface conditions.

The formula (5) allows us to interpret the obtained data. The greater values of $U_{th}/\theta d$ for last two cases show that the covering of substrates by orientant (polymid) strongly

$$G_\phi \frac{d\phi}{dx} \Big|_{\pm d/2} = [W_1 \cos \phi \pm (W_2 - W_3) \sin 2\phi] \Big|_{\pm d/2} \quad (3)$$

in order to define the equilibrium director distribution.

In all considered cases in the absence of electric field the equilibrium configuration corresponds to the twist state

$$(\phi(x) = -\frac{\pi}{2} + \frac{x}{d} \cdot \pi), \text{ that takes place for strong polar cohesive}$$

$$W_1 \geq \frac{G}{d} \text{ and } W_1 \gg \Delta W. \text{ Then we appl a weak electric field,}$$

the azimuthal angle ϕ takes a value $\frac{\pi}{2}$ everywhere, except of

$$\text{the range of size } \xi = \sqrt{\frac{G_\phi \theta^2}{P_s E}}. \text{ Then the azimuthal angle}$$

dependent part of the free energy takes the form

corresponds to the minimum of energy (4) for small fields.

When the condition $P_s E \xi \geq [W + 2(W_2 - W_3)] \theta^2$ takes place this minimum loses its stability. From the later inequality we obtain an expression for threshold voltage

increases the value of the polar part of cohesive energy. This fact has been confirmed by independent experiments: in the case of polymide covering the stability of twist states increases essentially in comparison with a non-covered substrate.

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A.R. İmaməliyev, S.Z. Temirniyazova

SƏTH ŞƏRAİTİNİN SEQNETOELEKTRİK MAYE KRİSTALIN ASTANA XARAKTERİSTİKALARINA TƏSİRİ

İşdə səthin işlənməsinin (oriyentant çəkilməsi və silinmə) seqnetoelektrik maye kristalın astana xarakteristikalarına təsiri təcrübi öyrənilmiş və təcrübi verilənləri izah edən sadə nəzəri model təklif edilmişdir.

A.P. Имамалиев, С.З. Темирниязова

ВЛИЯНИЕ ПОВЕРХНОСТНЫХ УСЛОВИЙ НА ПОРОГОВЫЕ ХАРАКТЕРИСТИКИ СЕГНЕТОЭЛЕКТРИЧЕСКОГО ЖИДКОГО КРИСТАЛЛА

В работе экспериментально изучено влияние поверхностной обработки (нанесение ориентанта и натирание) на значение порогового напряжения сегнетоэлектрического жидкого кристалла и приведена простая модель, объясняющая эти данные.

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