INFLUENCE OF THE SURFACE STATE TO THE THRESHOLD AND TIME PROPERTIES OF THE FERROELECTRIC LIQUID CRYSTAL

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In this work the influence of the polar and dispersive parts of the anchoring energy of the liquid crystal molecules with surfaces on the threshold voltage and the switching time of the "up-down" and "twist-down" transitions were studied by computer modeling of the ferroelectric liquid crystal electrooptic properties.

The electrooptic properties of the surface stabilized ferroelectric liquid crystal (SSFLC) depend both on the material parameters and external parameters [1-3]. The electrooptic switching with high speed and low threshold voltage occurs in this materials and widely use in the display technique.

The threshold and time characteristics of this effect strongly depend on the surface state treatment.

In the given work the influence of the polar and dispersive parts of the anchoring energy on the threshold voltage and the switching time of the electrooptic effects were studied by computer modelling of the ferroelectric liquid crystal electrooptic properties.

The considered geometry of the electrooptic cell is shown in fig.1. The director of the SSFLC, the applied electric field and the spontaneous polarization has the following component, consequently:

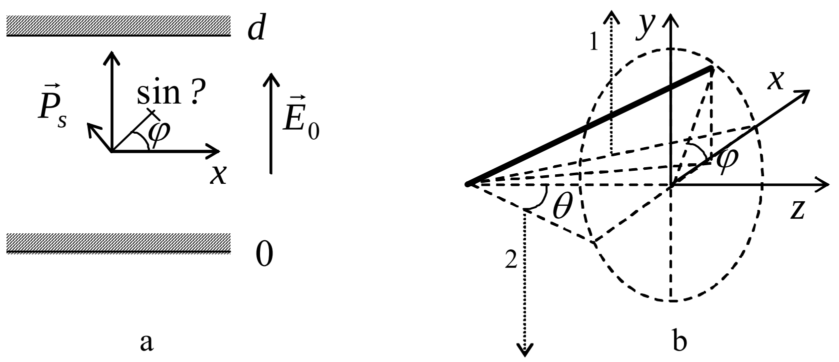

Fig.1 The cell geometry

$$\vec{n}(\sin\theta\cos\phi,\ \sin\theta\sin\phi,\ \cos\theta),\quad \vec{E}(0,\ E_0,0),\quad P_s(P_s\sin\phi,\ P_s\cos\phi,0) \qquad (1)$$

were θ and Φ are tilt angle and azimuthally angle, respectively.

For considered geometry the free energy per unit area of the cell has the form:

$$F = \frac{1}{2}\int_0^d B\theta^2\left(\frac{d\phi}{dy}\right)^2 dy - \frac{1}{2}\int_0^d \varepsilon_0\Delta\varepsilon(\vec{n}\vec{E})^2 dy - \frac{1}{2}\int_0^d \vec{P}_0\vec{E}dy \mp$$

$$\mp W_1^{0,d}\cos\phi_s - W_2^{0,d}\cos^2\phi_s \qquad (2)$$

where the first term is the elastic energy density (B is corresponding elastic constant), the second term relates to the electric field interaction with the dielectric anisotropy of the medium ($\Delta\varepsilon = \varepsilon_{\parallel} - \varepsilon_{\perp}$ is the anisotropy of the dielectric permittivity, ε_0 is the electric constant) and the third term describes the electric field interaction with the spontaneous polarization. The term $W_1^{0,d}\cos\phi_s$ describes the polar interaction of FLC molecules with the surface: this term takes the minimum on the lower surface if $\phi_s = 0$ and on the upper surface if $\phi_s = \pi$. The term $W_2^{0,d}\cos^2\phi_s$ describes the dispersive interaction with the surface and takes the minimum if on the both surfaces $\phi_s = 0$ or $\phi_s = \pi$.

The minimization of the free energy density (2) gives us the dynamic Euler-Lagrange equation:

$$\theta^2 \gamma \frac{d\phi}{dt} = B\theta^2 \frac{d^2\phi}{dy^2} + \frac{\varepsilon_0 \Delta\varepsilon \theta^2 E^2}{2} \sin 2\phi - P_s E_0 \sin \phi \qquad (3)$$

with the boundary conditions:

$$B\theta^2 \frac{d\phi}{dy}\bigg|_{0,d} = W_1^{0,d} \sin \phi_s \mp W_2^{0,d} \sin 2\phi_s \qquad (4)$$

where γ - is the rotational viscosity.

For numerical solving this problem has been used MathCad-2001 program [4] and the Johns retardation matrix method was applied for determining of the light transmittance of the FLC cell [5].

It was analyzed the dependences of the threshold voltages and the switching times of $Up(\varphi_0 = \varphi_d = \pi) - Down(\varphi_0 = \varphi_d = 0)$ and $Twist(\varphi_0 = 0,\ \varphi_d = \pi) - Down(\varphi_0 = \varphi_d = 0)$ transitions on the polar (at $y = 0$ $W_1^0 = W_{11}$, $y = d$ $W_1^d = W_{12}$) and the dispersive parts (at $y = 0$ $W_2^0 = W_{21}$, $y = d$ $W_2^d = W_{22}$) of the anchoring energy. The threshold voltage was determined from the voltage dependence of the cell transmittance.

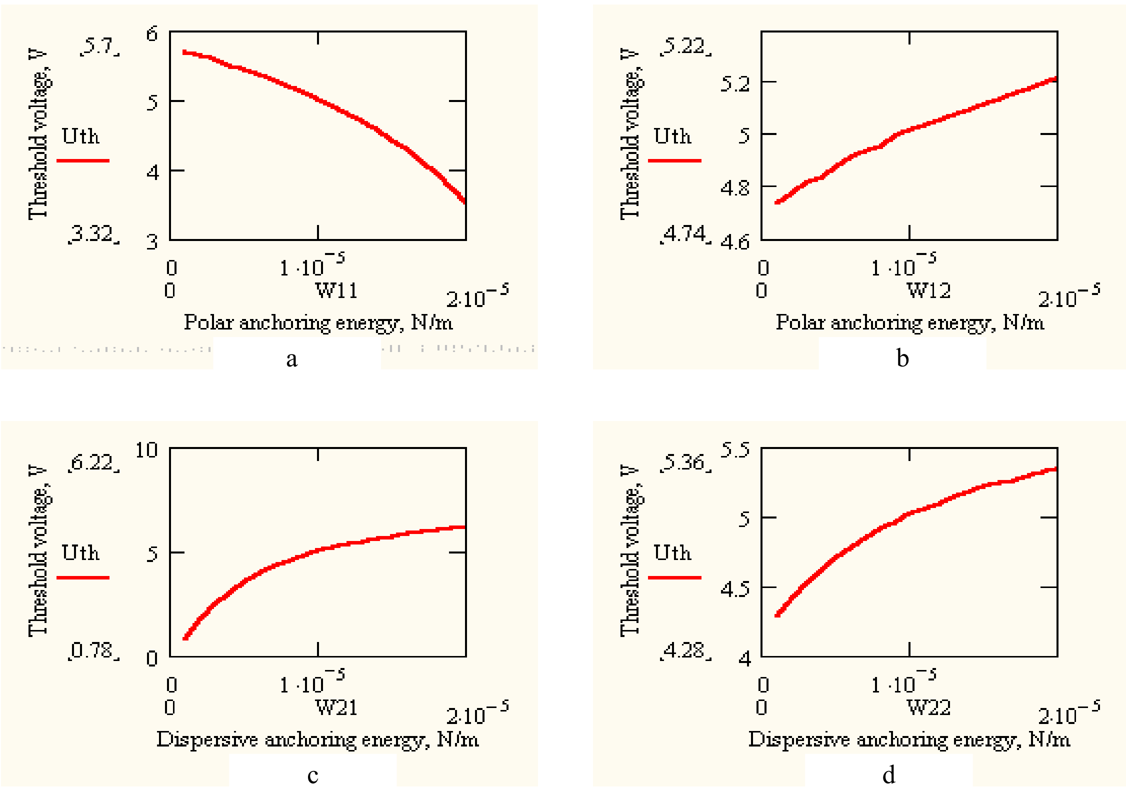

Fig.2. Dependences of the threshold voltage on the anchoring energy at lower (a, c) and upper surfaces (b, d) for the “up-down” transition.

The threshold voltage and the corresponding switching time of the “up-down” transition decrease by increasing of the polar part of the anchoring energy at the lower surface W_{11} (fig.2a, 3a) that was expected, because the rise of the polar anchoring with lower surface stimulates the “up-down” transition.

By increasing of the polar anchoring with upper surface the threshold voltage (fig.2b) and the corresponding switching time (fig.3b) of the “up-down” transition increase, because with the increasing of the polar anchoring at the upper surface the initial “up” state becomes more stable and the occurring “up-down” transition becomes more difficult.

The rising of the dispersive part of the anchoring energy both at upper and lower surfaces leads to the increasing of U_{th} and τ_{sw} (fig. 2c, 2d, 3c, 3d).

The dispersive interaction with surface is same for both surfaces and the increasing one of these leads to the rising another.

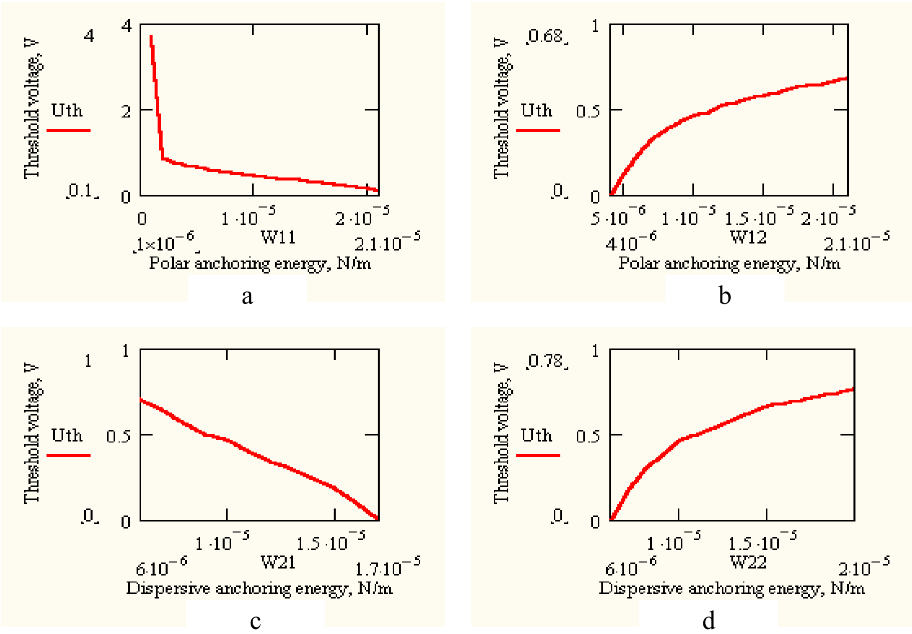

Fig.3 Dependences of the switching time on the anchoring energy at lower (a, c) and upper surfaces (b, d) for the "up-down" transition.

Some of the electro optic characteristics of the "twist-down" transition are analogously to the "up-down" transition. U_{th} decrease by increasing of the polar anchoring at the lower surface (fig.4a) and U_{th} increase too by increasing of the polar anchoring at the upper surface (fig.4b).

Note, that the rising of the dispersive anchoring at the lower surface stimulates the "twist-down" transition (fig.4c) and the increasing of the dispersive anchoring at upper surface, in contrary, resist to occurring this transition (fig.4d).

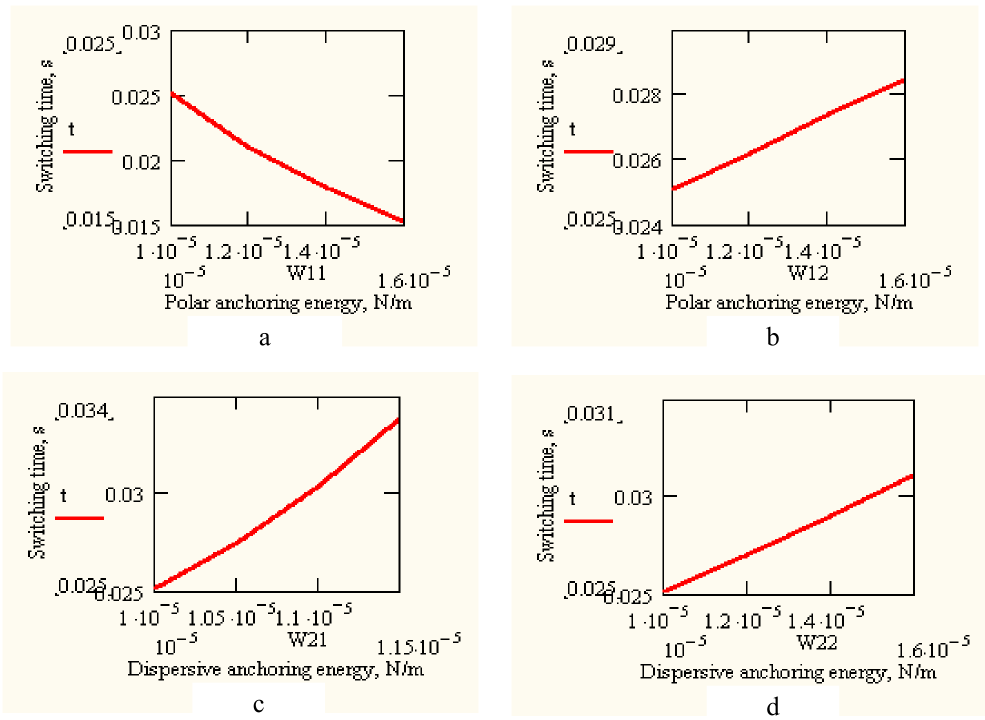

Fig.4. Dependences of the threshold voltage on the anchoring energy at lower (a, c) and upper surfaces (b, d) for the "twist-down" transition.

Therefore, for switching time and threshold voltage decreasing it is necessary to increase the polar interaction at lower surface in the "up-down" transition case and it is necessary to rise the polar and dispersive anchoring at lower surface and to decrease them at upper surface in the "twist-down" transition case.

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SEQNETOELEKTRİK MAYE KRİSTALIN ASTANA VƏ ZAMAN XASSƏLƏRİNƏ SƏTH ŞƏRAİTİNİN TƏSİRİ

Bu işdə seqnetoelektrik maye kristalın elektrooptik xassələrinin kompüter modelləşdirilməsi yolu ilə maye kristal molekullarının səthlə ilişmə enercisinin polyar və dispersiv hissələrinin «up-down» və «twist- down» keçidlərinin astana gərginliyinə və keçid müddətinə təsiri öyrənilmişdir.

Х.Ф. Аббасов

ВЛИЯНИЕ СОСТОЯНИЯ ПОВЕРХНОСТИ НА ПОРОГОВЫЕ И ВРЕМЕННЫЕ ХАРАКТЕРИСТИКИ СЕГНЕТОЭЛЕКТРИЧЕСКОГО ЖИДКОГО КРИСТАЛЛА

В данной работе было изучено влияние полярной и дисперсионной частей энергии сцепления молекул с поверхностью на пороговые напряжения и времени включения переходов «up-down» и «twist-down» компьютерным моделированием электрооптических свойств сегнетоэлектрического жидкого кристалла.

Received: 02.07.04